20th International Conference on
Nuclear Tracks in Solids

Book of Abstracts

Portorož, Slovenia
August 28 - September 1, 2000
For the symbol of this meeting we have chosen the drawing of the old sailing ship. It is symbolizing the venue at the sea side and also quite sophisticated technology of old days. With our research and developments, also in the area covered at this meeting, we are permanently trying to improve it.
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International
Nuclear Track Society

Institute "Jožef Stefan"

Nuclear Society of Slovenia

ORGANISER ADDRESS

Nuclear Society of Slovenia – 20ICNTS
Jamova 39, SI-1000 Ljubljana, Slovenia
E-mail: 20icnts@ijs.si,
Tel.: + 386 1 588 5247, + 386 1 588 5363
Fax: + 386 1 561 22 76

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- 3rd International Colloquium on Corpuscular Photography, Moscow, USSR, 1960
- 4th International Colloquium on Corpuscular Photography, Munich, Germany, 1962
- 5th International Conference on Nuclear Photography, Geneva, Switzerland, 1964
- 6th International Conference on Nuclear Photography, Florence, Italy, 1966
- 7th International Colloquium on Corpuscular Photography and Visual Solid Detectors, Barcelona, Spain, 1970
- 8th International Conference on Nuclear Photography and Solid State Detectors, Bucharest, Romania, 1972
- 9th International Conference on Solid State Nuclear Track Detectors, Munich, Germany, 1976
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- 15th International Conference on Particle Tracks in Solids, Marburg, Germany, 1990
- 16th International Conference on Nuclear Tracks in Solids, Beijing, China, 1992
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<td><strong>11</strong>: Invited Lecture: PHYSICAL SCIENCES</td>
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<td>9:00</td>
<td>OPENING OF THE CONFERENCE</td>
<td><strong>12</strong>: High Energy Interactions &amp; Cosmic Rays 4</td>
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<td>9:30</td>
<td><strong>1</strong>: Invited Lecture: INTRODUCTORY</td>
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<tr>
<td>10:00</td>
<td>Coffee break</td>
<td>Coffee break</td>
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<tr>
<td>10:30</td>
<td><strong>2</strong>: Invited Lecture: BASIC PROCESSES</td>
<td><strong>13</strong>: Instrumentation, Methods, Software 1</td>
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<tr>
<td>11:15</td>
<td><strong>3</strong>: Poster session 1</td>
<td><strong>14</strong>: Poster session 2</td>
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<tr>
<td>12:00</td>
<td>Parallel A</td>
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<td>Parallel B</td>
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<td>12:00</td>
<td>Plenary; <strong>4</strong>: Nuclear Track Physics &amp; Chemistry 1</td>
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<tr>
<td>12:45</td>
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<tr>
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<td><strong>6</strong>: Nuclear Track Physics &amp; Chemistry 3</td>
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<tr>
<td>15:15</td>
<td>Coffee break &amp; Poster session 1 continued</td>
<td>Coffee break &amp; Poster session 2 continued</td>
</tr>
<tr>
<td>15:45</td>
<td>Parallel A</td>
<td><strong>17</strong>: Instrumentation, Methods, Software 4</td>
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<td><strong>9</strong>: High Energy Interactions &amp; Cosmic Rays 2</td>
<td><strong>21</strong>: Earth &amp; Planetary Sciences, Dating 1</td>
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## Preliminary Program

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<td>24: Nuclear Physics &amp; Chemistry 2</td>
<td>28: Environmental Science, Radiometry 1</td>
<td>9:30 Coffee break</td>
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<tr>
<td>9:45 Coffee break</td>
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<td></td>
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<tr>
<td>11:15 Break</td>
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<td></td>
<td>11:15 Break</td>
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<tr>
<td>12:00</td>
<td>26: Radiation Protection, Dosimetry 1</td>
<td>30: Poster session 3</td>
<td>12:00 Parallel B</td>
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<td>31: Radiation Protection, Dosimetry 2</td>
<td>41: Instrumentation, Methods, Software 6</td>
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<tr>
<td>12:00</td>
<td>11:30</td>
<td>35: Environmental Science, Radiometry 2</td>
<td>31: Radiation Protection, Dosimetry 2</td>
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<tr>
<td>12:00</td>
<td>12:15 Lunch break</td>
<td>32: Radiation Protection, Dosimetry 3</td>
<td>42: Nuclear Track Physics &amp; Chemistry 5</td>
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<td>36: Environmental Science, Radiometry 3</td>
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<td>15:45</td>
<td>34: Radiation Protection, Dosimetry 5</td>
<td>38: Earth &amp; Planetary Sciences, Dating 5</td>
<td>13:30 – 14:00 Concluding Remarks</td>
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<tr>
<td>17:00</td>
<td>39: Nuclear Technology 1</td>
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<td>17:00</td>
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Plenary session

Session 1
9:30 Invited Lecture: INTRODUCTORY
Chairperson: Radomir Ilic, Slovenia
143 Saeed A. Durrani
Nuclear Tracks - a Success Story of the 20th Century

10:00-10:30 coffee break

Session 2
10:30 Invited Lecture: BASIC PROCESSES
Chairperson: Wolfgang Enge, Germany
144 Annie Dunlop, G. Jaskiewicz, M. Kopcewicz
Nanometric Crystallisation of an Amorphous Alloy Along the Path of GeV Monoatomic Projectiles

Session 3
11:15 Poster session 1
Chairperson: Jozsef Pálfalvi, Hungary
Nuclear Track Physics & Chemistry
Modifications Induced by Proton Irradiation in Polyallyl Diglycol Carbonate
112 Birgit Dörschel, Dietrich Hermsdorf, Uwe Reichelt
Experimental determination of the critical angle for particle registration and comparison with model predictions
120 Hardev S. Virk, Ajeet Srivastava
Modification of optical, chemical & structural response of CR-39 polymer by 50 MeV lithium ion irradiation
121 F. Malik, Ehsan-Ullah Khan, S.N. Husaini, S. Karim, M. Sajid, Imtinan Qureshi
Effect of Swelling on the Determination of Bulk Etch Rate in Various SSNTDs
122 Tam Nguyen, László Lakosi
Optimizing Etching Conditions for CR-39 Detectors Irradiated by Spent Reactor Fuel
123 Tomoya Yamauchi, Shuji Takada, Hirotaka Ichijo, Keiji Oda
Raman and Near-IR Study on Proton Irradiated CR-39 Detector and the Effect of Air-Leak on the Damage Formation
Investigation of heavy ions tracks in polymers by methods of high effective chromatography and atomic force microscopy
125 M. Siems, K. Freyer, H.C. Treutler, Gilbert Jönsson, Wolfgang Enge
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<td>Modifications in Etching Characteristics and Surface Topography of some Electron Irradiated Polymers</td>
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**Instrumentation, Methods, Software**

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<td>Using a Confocal Microscope for the Extraction of Track Parameters in CR-39 SSNTDs</td>
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Session 4

12:00 Nuclear Track Physics & Chemistry 1
Chairperson: Masami Fujii, Japan

12:00 145 Mehdi Sohrabi, S. Hosseini Toudashki, M. Taheri
A New Method to Measure the Range and to Study the Structure of ECE Tracks in Poly carbonate Detectors

12:15 107 Tomoya Yamauchi, Hirotaka Ichijo, Keiji Oda, Birgit Dörschel, Dietrich Hermbsdorf, Karin Kadner, François Vaginay, Michel Fromm, Alain Chambaudet
Inter-comparison of geometrical track parameters and depth dependent track etch rates measured for Li-7 ions in two types of CR-39

12:30 103 Thomas Turowski, Wolfgang Enge
A Track Formation Model: Ionising Particles May Create Shockwaves
12:45-14:15 lunch break

Parallel session: A

Session 5
14:15 Nuclear Track Physics & Chemistry 2
Chairperson: Ilona Hunyadi, Hungary

14:15 141 Kazuie Kimura, Samit Sharma, Anatolijs Popovs
Novel Ultra-fast Luminescence from Incipient Ion Tracks of Insulator Crystals

14:30 105 B. Ravat, Manuel Grivet, Y. Grohens, Alain Chambaudet
Electron irradiation of polyurethane: Study of chemical and structural modifications using FTIR, UV spectroscopy and GPC

14:45 102 Valery Ditlov
Track Theory Evolution During International Solid State Detector Conferences

15:15-15:45 coffee break + POSTER SESSION 1 continued

Session 6
15:45 Nuclear Track Physics & Chemistry 3
Chairperson: Alain Chambaudet, France

15:45 108 Nakahiro Yasuda, Kuniaki Amemiya, Kazuyuki Uchikawa, Nanae Watanabe, Hiroyuki Takahashi, Masahuru Nakazawa, Mikio Yamamoto, Koichi Ogura
Estimation of the latent track size of CR-39 using atomic force microscope

16:00 109 Zohra Lounis-Mokrani, Michel Fromm, Rémi Barillon, Robert Katz, Alain Chambaudet, K. Morsli, M. Allab
FTIR Study of Light, Ion-Irradiated CR-39 Detector: Correlation with the Ion Track Formation Mechanism in the Vicinity of the Bragg-Peak

16:15 110 Birgit Dörschel, Dietrich Hermbsdorf, Karin Kadner
Studies of Experimentally Determined Etch Rate Ratios in CR-39 for Ions of Different Kind and Energy

16:30 111 A. F. Saad, S. T. Atwa, Masami Fujii
Study on the Structure of Latent Tracks in CR-39 And SR-90 Track Detectors by FT-IR Spectroscopy

16:45-17:00 break

Session 7
17:00 Nuclear Track Physics & Chemistry 4
Chairperson: Bojana Grabež, Yugoslavia

17:00 146 Dipak Sinha, T. Phukan, S.P. Tripathy, R. Mishra, Kamal K. Dwivedi
Optical and Electrical properties of gamma irradiated PADC detector

17:15 113 Abdul Malek, C.S. Chong
Generation of CO2 in Gamma Ray Irradiated CR-39 Plastic
MONDAY

Program of the Conference

17:30  114  Gurpartap Randhawa, Hardev S. Virk
Submicroscopic Investigations of Heavy Ion Latent Tracks in Some Track Recorders

17:45  115  G. Giacomelli, Miriam Giorgini, Laura Patrizii, V. Popa, Paola Serra

Parallel session: B

Session 8

14:15  High Energy Interactions & Cosmic Rays 1
Chairperson: Denis F. O’Sullivan, Ireland

14:15  301  Yury Batusov, F. Balestra, M. P. Bussa, G. Piragino, G. B. Pontecorvo
Escape of Charged Particles at Stopping Annihilation of Antiprotons in the Heavy
Nuclei of Nuclear Emulsion

14:30  323  Galina I. Orlova
The Particularity of the Pseudorapidity Distributions in Proton and Heavy Ion
Collisions in Nuclear Track Emulsion at Energies from 4.5 To 200 A GeV

14:45  303  Živojin Todorovic, Svetislav Savovic, Stevan Jokic
Fission of Pb in the 4He Induced Reactions at 0.65 - 12.7 GeV

15:00  304  Frank Flesch, G. Iancu, Wolfgang Heinrich
Projectile Fragmentation of Silicon Ions at 490 A MeV

15:15-15:45  coffee break + POSTER SESSION 1 continued

Session 9

15:45  High Energy Interactions & Cosmic Rays 2
Chairperson: Kamal K. Dwivedi, India

15:45  305  Svetlana P. Tretyakova, R. Bonetti, Alexander Golovchenko, A. Guglielmetti, Radomir Ilic,
Ch. Mazzocchi, V. L. Mikheev, A. A. Ogloblin, Jure Skvarc, A. Shigin
Study of Cluster Decay of 242Cm Using SSNTD

16:00  306  Werner Günter, Wolfgang Heinrich, Frank Flesch, Günther Reitz
Energy Spectrum of Stopping HZE-Particles Inside the International Space Station

16:15  307  Shahid Manzoor, Imitan Qureshi, Mukhtar Rana, Muhammad Shahzad, G. Sher, M. Sajid,
Hameed Khan, G. Giacomelli, Miriam Giorgini, G. Mandrioli, Laura Patrizii, V. Popa, Paola
Serra, V. Togo
Total Fragmention Cross Sections of 158 A GeV Lead Ions in Copper and CR-39

16:30  308  Imitan Qureshi, Ashiq Dogar, Amjad Farooq, Muhammad Shahzad, Shahid Manzoor,
Hameed Khan
The Fission Systematics of (15.9 MeV/u) Au Ions in Polymer CR-39

16:45-17:00  break

xxvi  20th International Conference on Nuclear Tracks in Solids: Book of Abstracts
Session 10

17:00 High Energy Interactions & Cosmic Rays 3
Chairperson: Shi-Lun Guo, China

17:00 332 D.T. Khathing, S.P. Tripathy, R. Mishra, B.K. Verma, Kamal K. Dwivedi
Range and Energy Loss Rate of 118 MeV 28Si in some Polymers Using PADC as Detector

Determination of Z/ß for Strange Quark Matter Candidates with CR-39 Track Detector

17:30 311 Laura Patrizzi
Search for massive rare particles with the MACRO track-eth detector at Gran Sasso

17:45 312 Carlos Domingo, J. Font, C. Baixeras, Lluis Font, Francisco Fernandez
Identification of Ultra–Heavy Cosmic Ray Ions Recorded in Polycarbonate Detectors Using a Corrected Bethe–Bloch Formula

19:30 COCKTAIL RECEPTION
Tuesday, 29. 8. 2000

Plenary session

Session  11
8:30 Invited Lecture: PHYSICAL SCIENCES
Chairperson: Lewis Chadderton, Australia
313 Reinhard Brandt
Some Contributions from SSNTD towards nuclear science: From
multifragmentation to the Rubbiatron

Session  12
9:00 High Energy Interactions & Cosmic Rays 4
Chairperson: Reza Hashemi-Nezhad, Australia
9:00 333 Vitaly D. Rusov, Tatyana N. Zelentsova, S.I. Kosenko, M.M. Ovsyanko, I.V. Sharf
Detection of Phase Transition Signal “Hadrons - ???” in Inelastic pp-Collisions in
Track UA5 and CDF Experiments
9:15 315 Bojana Grabež
Multifragmentation induced by GeV 4 He beams
9:30 331 Igor V. Zhuk, M. K. Kievet, Elena M. Lomonosova, Sergei Boulyga, I. L. Rakhno, Boris
Kulakov, Reinhard Brandt, J. - S. Wan
Spatial and Spectral Characteristics of Neutron Field Formed by Relativistic
Protons with Energy from 0.5 to 7.4 Gev on Lead and Uranium Targets
9:45 316 Shi-Lun Guo, Li Li, Tadayoshi Doke, J. Kikuchi, Atsushi Kyan, Eiichi Yoshihira, T. Kato, T.
Murakami
Characteristics of Heavy Ion Tracks in Bubble Detectors

10:00-10:30 coffee break

Session  13
10:30 Instrumentation, Methods, Software 1
Chairperson: Laszlo Sajo Bohus, Italy
10:30 201 Jure Skvarc, Alexander Golovchenko
The method of trajectory tracing of Z < 20 ions in the energy region below 300 MeV/u
10:45 202 Daniel Palacios Fernandez, Francisco Palacios Fernandez, Laszlo Sajo Bohus, Jozsef Pülfalvi
A New Method to Measure Track Density and to Diferenciate Nuclear Tracks in
CR-39 and LR-115 SSNT Detectors
11:00 203 François Vaginay, Michel Fromm, Geert Meesen, Alain Chambaudet, André Poffijn
3-D Confocal Microscopy Track Analysis: A Promising Tool for the Determination
of CR-39 Response Functions
Session 14
11:15 Poster Session 2
Chairperson: Michel Fromm, France

High Energy Interactions & Cosmic Rays
302 Ehsan-Ullah Khan, Imtinan Qureshi, J.J. Baluch, Muhammad Shahzad, S. Karim, M. Sajid, F. Malik, S.N. Husaini
Heavy Ion Interaction of (14.0 MeV/u) Pb + U

SSNTD Studies of Lead Nuclei Fission Induced by 0.5 and 1.0 GeV Protons Inside Massive Hg, Pb and U Targets

321 Imtinan Qureshi, Muhammad Shahzad, G. Sher, Shahid Manzoor, Mukhtar Rana, Hameed Khan, R. J. Peterson
Fission of Copper Induced by (1068 MeV)\(\pi\) Using CR-39 Detector

322 Leonid Kashkarov, G.V. Kalinina
Track Density Gradient in the Meteorite Silicate Crystals: Modified Measuring Technique to Obtain Energy Spectrum of the Cosmic Ray VH-NUCLEI

324 M.A. Kondratyeva, Charmen A. Tretyakova, Svetlana P. Tretyakova, D.A. Zhuravlev
About Imitation of Anomalous Cosmic Ray Carbon’s Tracks in CN-Kodak

325 Bojana Grabež, G. Wirth
Fragmentation of Ag and Pb targets induced by 0.5A GeV and 1A GeV Au projectiles

326 Gurpartap Randhawa, Hardev S. Virk
Range of Heavy Ions in Different Track Recording Dielectrics: Measurements and an Analysis

328 Muhammad Shahzad, Imtinan Qureshi, Shahid Manzoor, Ehsan-Ullah Khan, Hameed Khan
Study of the Reaction Step Preceding Sequential Fission in the Reaction (16.7 MeV/u)\(^{238}\)U + nat.Au Using MICA Track Detector

Nuclear Physics & Chemistry
408 Mohammed Al-Jarallah, A.A. Naqvi, Falah Abu-Jarad, Fazal-Ur-Rehman, S.M. Ayub, R. Nassar, S. Kidwai
Response of Nuclear Track Detectors to 1-3 MeV 3He and 4He ions

409 Elzbieta Skladnik-Sadowska, Jaroslaw Baranowski, Marek Sadowski
Low-Energy Ion Measurements by Means of CR-39 Nuclear Track Detectors

410 Fermin Castillo-Mejia, J. Rangel, Guillermo Espinosa, J.J. Golzarri, Carlos Amero, J.J.E. Herrera
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411 Carlos Amero, J.J. Golzarri, Guillermo Espinosa
148\(^{Gd}\), 235\(^{U}\), 239\(^{Pu}\) and 244\(^{Cm}\) Alpha Particle Energy Analysis Using Tracks in Solids
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507 Mahmoud K. Kullab, Barakat A. Al-Bataina, A.M. Ismail, Khalid Abumurad
Seasonal Variation of Radon-222 Concentrations in Specific Locations in Jordan

512 Észter Baradacs, Ilona Hunyadi, Zoltan Dezso, Istvan Csige, Pavel Szerbin
226Ra in Geothermal and Bottled Mineral Waters of Hungary

521 Khatam Murtazaev, Michel M. Monnin, Vladimir P. Perelygin, A. Murtazaev
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522 Raphael Tisserand, Claude Dubois, Michel Rebetez, Manuel Grivet, Fabian A. Villa
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523 Mohyi El-Din Kenawy, Abdel-Fattah Hafez, A.F. Said
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524 Bao-Liu Chen, Li Li, Li Guo, Yanchou Lu, Gongming Yin, Shi-Lun Guo
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525 Tatyana Tsvetkova, Igor Nevinsky, Michel M. Monnin, Viktor Panyushkin, Vladimir P. Perelygin
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526 Mohyi El-Din Kenawy, T.A. Sayyah, A. Morsy, T.D. Hegazy, A.F. Said
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527 N. U. Khattak, Aziz Qureshi, M. Akram, K. Mehmood, T. Iqbal
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529 Bikram Bajwa, Hardev S. Virk
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532 Leonid Kashkarov, A.I. Ivliev, S.S. Assonov, A.S. Semenova
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534 V.A. Alekseev, A. Malgin, M. Hernandez-Pajares, V. Oraevsky, Yu. Ruzhin, O. Ryazhskaya, I. Shagimuratov
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535 Michelle Derbyshire, Christopher Ingelbrecht, Frans de Corte, Peter Van den Haute, Jan Van Ham
Preparation and Certification of Two Uranium Glass Reference Materials for Fission-Track Dating of Geological Samples

536 Khalid Abumurad, Mahmoud Al-Tamimi
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Mohamed Mansy, A. Hussein, Hussein M. El Samman, M. El-Hawary, A.R. El-Sersy, Mohammed El-Fiki
Study of Radioactive Materials Content in Some Egyptian Rocks

Surinder Singh, Rajeev Malhotra, Jatinder Kumar
Uranium analysis and Radon Exhalatron Studies in Geological Samples from Kulu Area, Himachal, Pradesh, India

Nuria Segovia, P. Pena, E. Tamez, M. Mená, C. Valdés
Soil Radon Response Around an Active Volcano

Asem Abdel-Naby
Determination of Effective Radium Content in Makkah Soil by CR-39 Nuclear Track Detectors

Sandor Csegzi, Istvan Csige
Representative Indoor Radon Survey in Gyergyőremete, Romania

C. Baixeras, B. Erlandsson, Lluis Font, Gilbert Jönsson
Radon Exhalation From Samples

Maria Laura Balesstrieri, Giulio Bigazzi
A First Record of the Transantarctic Mountains Late Cretaceous Uplift-Denudation Phase in the Admiralty Block, Northern Victoria Land (NVL), Antarctica

Sergey Zhmodik, Anatolyi G. Mironov, V.A. Bobrov
Distribution of Uranium High Concentrations in Lake Baikal Sediments Using SSNTD-Method

Satoshi Koshimizu, Kenji Tomura, Genju Yamamoto
Fission Track Dating of Some Obsidians from Japan

D. Sengupta, Rajeev Kumar, A.K. Singh, Rajendra Prasad
Radon Exhalation and Radiometric Prospecting of Rocks Associated with CU-U Mineralisations

Radiation Protection, Dosimetry

Aziz Boukhair, Céline Heilmann, A. Pape, Guy Portal
Fast neutron and gamma-ray dosimetry with imaging plates

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12:00 Instrumentation, Methods, Software 2
Chairperson: Falah Abu-Jarad, Jordan

12:00 204 Khalid Jamil, Ashiq Dogar, Safdar Ali
Parametric Studies of Different Shapes of Radon Dosimeters Using Monte Carlo Simulation Technique

12:15 205 Rakesh Kumar Jain, A. V. Prokofiev, Andrei N. Smirnov, Luigi Tommasino
Measurements of High Energy Neutrons by Fission-Induced Reactions

12:30 206 Vera Bradnova, Boris Kulakov
Scanning Film Pictures to Determine a Nuclear Beam Profile
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<td>238 Mohamed Mansy, Hussein M. El Samman, M. Hassan, E. Mahfouz, Hoda Eissa, Mohammed El-Fiki</td>
<td>Calibration of Radon Monitors and its Associated Uncertainties in NIS Egypt Radon Calibration Chamber</td>
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<td>208 Bassam Aharmim, A. Sabir</td>
<td>Theoretical estimation of sensitivity for the cup type SSNTD radon measurements</td>
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<td>209 E.G. Boulyga, Sergei Boulyga</td>
<td>Software Development for Physical and Chemical Applications</td>
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<td>210 Eudice Vilela, R.A. Lima, M.S. Nogueira, A.L. Ferreira Filho, W.A. Castro</td>
<td>Type tests of an extremity ring dosimeter provided by a Brazilian dosimetry service</td>
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<td>211 Khalil Amgarou, Lluis Font, Carlos Domingo, Francisco Fernandez, C. Baixeras</td>
<td>Simultaneous Measurement of Radon, Radon Progeny and Thoron Concentrations Using Makrofol-DE Detectors</td>
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<td>212 Rodrigo Neman, I.D. Schmitman, Julio Cesar Hadler Neto, P.J. Iunes, S.R. Paulo, Sandro Guedes Oliveira</td>
<td>Measurement of Indoor $^{222}$Rn Using CR-39 under a Thin Film Geometry</td>
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<td>233 Vadim A. Nikolaev, I.B. Vorobjev</td>
<td>Track Detection System for Neutron Dosimetry</td>
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<td>234 Ana Danis, M. Oncescu, Mariana Ciubotariu</td>
<td>System for Calibration of Track Detectors Used in Gaseous and Solid Alpha Radionuclide Monitoring</td>
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### 17:45 218 Keiji Oda, Hirotaka Ichijo, Nobumasa Miyawaki, Tomoya Yamauchi
Improvement of Neutron Detection Efficiency with High-Sensitive CR-39 Track Detector

### Parallel session: B

### Session 19

**12:00 High Energy Interactions & Cosmic Rays 5**

**Chairperson:** Karl - Ontjes Groeneveld, Germany

**12:00** 317 Justin Donnelly, Denis F. O’Sullivan, Alexander Thompson, L.O’C Drury, K.-P. Wenzel
The Relative Abundance of Actinides in the Cosmic Radiation

**12:15** 318 Denis F. O’Sullivan, D. Zhou
Investigation of Cosmic Rays and Their Secondaries at Aircraft Altitudes

**12:30** 319 Matthias M. Meier
Determination of Charge States of Single Swift Heavy Projectiles by High-Energy Deltaelectrons

**12:45-14:15 lunch break + Meeting of INTS**

### Session 20

**14:15 Nuclear Physics & Chemistry 1**

**Chairperson:** Hameed Khan, Pakistan

**14:15** 401 Bassam Aharmim, H. Marah, A. Sabir
Intrinsic efficiency for alpha particles detection in LR-115 simulations and experiments

A Particle Track Detector $?_p$ Measurement Without Neutron Irradiation

**14:45** 403 Elzbieta Skladnik-Sadowska, Jaroslav Baranowski, M. Milanese, R. Moroso, J. Pouzo, Marek Sadowski, J. Zehrowski
Spatial Structure and Energy Spectrum of Ion Beams Studied with CN-Detectors within a Small PF-Device

**15:00** 404 J. Rickards, V. Romo, J.I. Golzarri, Guillermo Espinosa
Nuclear Tracks in CR-39 Produced by Carbon, Oxygen, Aluminum and Titanium Ions

**15:15-15:45 coffee break + POSTER SESSION 2 continued**

### Session 21

**15:45 Earth & Planetary Sciences, Dating 1**

**Chairperson:** Guillermo Espinosa, Mexico

**15:45** 501 M. Akram, N. U. Khattak, Aziz Qureshi, K. Mehmood, Imtinan Qureshi, Hameed Khan
Boron Determination in Tourmaline by Neutron induced Alpha Autoradiography for Use in the Interpretation of Geological History

**16:00** 502 Igor Nevinsky, Victor Nevinsky, Viktor Panyushkin, Vasiliy Ferronsky, Tatyana Tsvetkova
Attempt to Determine Tritium, Na-22, Cl-36 And Radon on the Territory of Mud Volcanos in Taman
16:15  503  Tatsuo Suzuki  
\textit{B}_0 \text{ value of dosimeter glasses for fission-track dating}

16:30  504  Mohyi El-Din Kenawy, A. Morsy, T.D. Hegazy  
Plastic Track Detector for Estimation of Alpha-Activity in Plack Sand

\textbf{16:45-17:00} \hspace{1cm} \textbf{break}

\textbf{Session 22}

\textbf{17:00}  \textbf{Earth \& Planetary Sciences, Dating 2}  
\textit{Chairperson:}  Hardev S. Virk, India

17:00  505  Ammeer Azam, Manoj Gupta, A.H. Naqui, D.S. Srivastava  
"Measurement of Effective Radium and Radon Exhalation Rate in Soil Samples Using LR-115 Type II Plastic Track detectors"

17:15  506  Hameed Khan, Aziz Qureshi, N. U. Khattak, M. Sardar, Mohamed Tufail, M. Akram, K. Mehmood  
Determination of Uranium Contents In Rock Samples From Kakul Phosphate Deposit, Abbotabad (Pakistan) Using Fission Track Technique

17:30  547  Mahmoud K. Kullab, A.M. Ismail, Y. Abu-Rukah  
A Rapid Analysis of Radioisotope Concentrations in Sediments using gamma-ray Spectrometry

17:45  508  Ali Khayrat, M. Oliver, Saeed A. Durrani  
The Effect of Soil Grain Size on Soil Radon Concentration

\textbf{19:30}  \textbf{GENERAL ASSEMBLY INTS}
Wednesday, 30. 8. 2000

Plenary session

Session  23
8:30  Invited Lecture:  BIOMEDICAL SCIENCES
Chairperson:  Koichi Ogura, Japan
601 Luigi Tommasino
Personal Dosimetry and Area Monitoring for Neutrons, Radon, and Cosmic Rays

Session  24
9:00  Nuclear Physics & Chemistry 2
Chairperson:  Vladimir P. Perelygin, Russia
9:00  405 Jean-Emmanuel Groetz, Bernard Tournier, Alain Chambaudet, Nicolas Raimondi
Evaluation and Performance of the CR-39 (Tastrak) in Neutron Dosimetry Around
Bremsstrahlung Accelerator and Nuclear Fissile Materials
9:15  406 Reza Hashemi-Nezhad, Reinhard Brandt, J. - S. Wan, Peter Vater
Determination of Slow Neutron Flux and Spatial Distribution Using LR-115 2B
Detectors and Comparison of the Results With Monte Carlo Simulations
9:30  407 Adam Szydlowski, Marek Sadowski, M. Jaskola, T. Czyzewski, A. Korman, I. Fijal, A.
Advantage of PM-355 Nuclear Track Detectors in Light-Ion Registration and High-
Temperature Plasma Diagnostics

9:45-10:15  coffee break

Session  25
10:15  Earth & Planetary Sciences, Dating 3
Chairperson:  Ana Danis, Romania
10:15  509 Ruben Badalian, Giulio Bigazzi, Marie-Claire Cauvin, Christine Chataigner, Ruben
Jrbashyan, Serguei Karapetian, Massimo Oddone, Jean-Louis Poidevin
An International Research Project on Armenian Archaeological Sites:
Fission-Track Dating of Obsidians
10:30  510 Hardev S. Virk, Vivek Walia
Helium/ Radon Precursory Anomalies of Chamoli Earthquake, Garhwal Himalaya
10:45  511 Raphael Tisserand, Michel Rebetez, Manuel Grivet, Christine Trautmann, Frank Palmino
AFM investigations for a better understanding of the etching track process in apatite
11:00  528 Gilbert Jönsson
Soil Radon Depth Dependence

11:15-11:30  break
Session 26
11:30 Radiation Protection, Dosimetry 1
Chairperson: Birgit Dörschel, Germany

11:30 602 Anaida Akopova, Jean-Noel Capdevielle, Anahit Melkonian, Stepan Tatikyan
Cosmic radiation doses on board of Concorde and Armenian airlines

11:45 604 Rick Tanner, David Bartlett, L.G. Hager
Recent Enhancements to the Understanding of the Response of the NRPB Neutron
Personal Dosemeter

12:00 605 Alexander Dyakov, T.N. Perekhozheva, E. I. Zlokazova
Methods of High-Sensitive Analysis of Actinides in Liquid Radioactive Waste

12:15 lunch break

14:30-18:30 Excursion to the Postojna Cave

19:30 CONFERENCE BANQUET
Thursday, 31. 8. 2000

**Plenary session**

**Session 27**

8:30 **Invited Lecture 5**

*Chairperson:* Elena Flitsiyan, USA

- 901 Pavel Apel
  Track-Etch Technique in Membrane Technology

**Session 28**

9:00 **Environmental Science, Radiometry 1**

*Chairperson:* Jure Skvarc, Slovenia

- 9:00 701 Sergei Boulyga, J.S. Becker, H.-J. Dietze
  Determination of Uranium Isotopic Composition in Soil Hot Particles from the Chernobyl Vicinity

- 9:15 702 S.R. Paulo, Rodrigo Neman, P.J. Iunes, Julio Cesar Hadler Neto
  Simulating Radon Daughters Diffusion Through the Air and Their Depletion on Material Surfaces

- 9:30 718 D. Selmeczi, B. Szabo, Laszlo Sajo Bohus, Noemi Rozlosnik
  Morphological Changes in Living Cell Cultures on Exposition by Alpha-Particles Studied by Optical and Atomic Force Microscopy

- 9:45 703 Julia Bondar
  A Non-Destructive Method of Pu Determination in Specimens

**10:00-10:30 coffee break**

**Session 29**

10:30 **Material Science, Radiography 1**

*Chairperson:* Peter Vater, Germany

- 10:30 808 Igor Lengar, Jure Skvarc, Radomir Ilic
  Deposition of Radon Decay Products on Metals in Contact

- 10:45 802 Dmitri Zagorski, V.A. Skuratov, A.E. Efimov, V.A. Kluev, Yu.P. Toporov, V.V. Roddatis, B.V. Mchedlishvili
  Swift heavy ion irradiation effect on the surface of Al₂O₃ single crystals

- 11:00 803 Elena Flitsiyan
  Radiography Techniques for Studying Elemental Distributions
### Session 30

**11:15 Poster Session 3**  
Chairperson: Rick Tanner, United Kingdom

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<td><strong>A Development of Plastic Track Detector Method to Solve Safety Problems of Nuclear Reactors</strong></td>
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<td><strong>Indoor Radon Level in Dwellings of Rajshahi City in Bangladesh Using Passive Solid State Nuclear Track Detector Technique</strong></td>
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<td><strong>Radon levels in dwellings in Tomsk and correlation with influence factors</strong></td>
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<td><strong>Radon and Its Progeny Concentrations in Dwellings: Influences of Geological and Housing Factors</strong></td>
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<td><strong>An Indoor Radon Survey for Lung Diseases Epidemiology</strong></td>
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<td><strong>Transport of the U-Oxides Through the Ground</strong></td>
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721 A.A. Abdel-Monem, Hoda Eissa, A.I. Abdel-Hafez, S.A. El-Fiki, Y.A. Abdul-Razek, Anas El-Naggar
Effect of the Environmental Conditions on Radon Gas and Progeny Concentrations in the Granitic U-Exploration Galleries, Eastern Desert, Egypt

722 Hoda Eissa, A.A. Abdel-Monem, A.I. Abdel-Hafez, F.H. Abdel-Kader, S.F. Hassn, Anas El-Naggar
Ambient and Seasonal Effects on the Radiation Protection Measurements in U-Exploratory Tunnels Using SSNTDs at Al-Allouga Mine, Sinai, Egypt

723 Y.S. Chung, Zinaida En, S.Y. Cho
Determination of Boron Concentration in Korean Total Diet by (n, a) Radiography

724 Bassam Aharmim, H. Marah, A. Sabir
Radon Measurements In Moroccan Waters by Etched Track Detectors

725 H.I. Farag, F. Ahmad, Mohammed El-Fiki, S.A. Gaafer, Noha-Emad, Hoda Eissa
In Vivo and In Vitro Radiation Dose Measurements in RadioIodine Therapy of Thyroid Cancer

Material Science, Radiography

801 Antoni Kalicki, Ewa Panczyk, Łużia Rowinska, Bozena Sartowska, Lech Walis, Krzysztof Pytel, Beatrycze Pytel, Alina Koziel, Ludwik Dabkowski, Małgorzata Wierzchnicka, Leonard Strzałkowski, Tadeusz Ostrowski, Maria Ligeza
Neutron Autoradiography – Working-out Method and Application in Investigations of Paintings

809 Bozena Sartowska, Jerzy Kunicki-Goldfinger
Determination of Chemical Homogeneity of Historical Glassware Using Autoradiography of Potassium Natural Radioactivity

810 József Pálfalvi, Márton Balaskó
Neutron Field Mapping by CR-39 for Radiography and Other Applications

811 Radovan Antanasijević, Dušan Joksimovic, Jovan Vukovic
Radiography by Soft X-Rays from Plasma Focus Device

Nuclear Technology

906 Svetlana P. Tretyakova, Alexander Golovchenko, Marlies Luszk-Bhadra, Mehran Katouzi, Radomir Ilic, Jure Skvarc, G. Zorin
Response of Fast Neutron Dosimeter Based on 12C(N, 3a) Reaction and Cr-39

914 S.N. Husaini, Ekhsan-Ullah Khan, F. Malik, Imtinan Qureshi, M. Sajid, S. Karim
Separation of Emulsions Using MICA Filters

915 Marek Buczkowski, Bozena Sartowska, Danuta Wawszczak, Wojciech Starosta
Radiation Resistance of Track Etched Membranes

916 V. Perez-Medina, Miguel Balcázar, A. Tejeda, M.E. Camacho, Letitia Tavera
Neutron Measurements for a Polyhedral Room

917 Tam Nguyen, László Lakosi
Monitoring fast neutron flux inside spent reactor fuel by CR-39 detector

918 Yong-Qian Shi, Yi-Guo Li
Measurement of Fast Neutron Fission Factor for Heavy Water Zero Power Reactor by Solid State Nuclear Track Detector

919 Shiv Chakarvarti
Telescopic Metallic Microstructure Synthesis Using Piled Nuclear Track Filters
920 Farhood Ziaie, Hossein Afarideh, S. M. Hadji-Saeid
Investigation of Beam Uniformity in Industrial Electron Accelerator

921 Radovan Antanasijevic, Radomir Banjanac, Aleksandar Dragic, Zvonko Maric, Jovica Stanojevic, Vladimir Udotivic
Beam Acceleration in Plasma Focus Device

923 Igor V. Zhuk
Sensitivity Coefficient of the System "Metal Uranium Thick Foil - SSNTD" for Neutron Registration

924 Arturo Lopez, F. Aguilar, Miguel Balcázar, J. Sole
Neutron Irradiation Calibration for FTD by Fission Products from U₃O₈ Powder

925 Karel Turek, Gábor Dajkó
Comparison of experimental and calculated response of CR-39 to neutron spectra of Am-Be and ²³²Th source

926 Mehdi Sohrabi, M. Taheri
Alpha Responses of Polycarbonate, LR-115 and CR-39 Detectors for Measuring ²²⁶Ra in Microprecipitate Filters for Large-Scale Environmental Monitoring

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Parallel session: A

**Session 31**

12:00 **Radiation Protection, Dosimetry 2**
Chairperson: Radovan Antanasijevic, Yugoslavia

12:00 606 Ammar A. Al-Sa’ad
Optimization of BN1 Screen thickness for Thermal Neutrons Detection

12:15 607 Filip Vanhavere, M. Coeck
The BDT Bubble Neutron Detector For Personal Dosimetry

12:30 608 Oleg A. Bondarenko, Yu.N. Onishchuk, V.M. Petryshyn, A.V. Dmitrienko
Methods for Monitoring of Neutron Fields Inside the Object Shelter Using SSNTD

12:45-14:15 lunch break

**Session 32**

14:15 **Radiation Protection, Dosimetry 3**
Chairperson: Nuria Segovia, Mexico

14:15 609 Hiroko Tawara, Tadayoshi Doke, Takayoshi Hayashi, Atsushi Kyan, Shunji Nagaoka, Toru Nakano, Shinpei Takahashi, Kazuhiro Terazawa, Eiichi Yoshihira
LET Distributions Obtained by CR-39 Plates Onboard the Space Shuttle Missions STS-84, 89 and 91 and the Dose Equivalent Estimation by a Combination of their Distributions and TLD-data

14:30 610 Ana Danis, Mariana Cibuotariu, Ildiko Mocsy, Vlad Tomulescu
The Diffusion and Deposition of the Gaseous and Solid Alpha Radionuclides Genetically Related in Air

14:45 611 Baldev Singh, Surinder Singh
A Comparison of Indoor Radon at the Centre and the Walls of Some Dwellings Using Passive Track Etch Technique

15:00 612 Abdurashid Yafasov
Program of the Conference

National Program for Radon Exposure Protection in Uzbekistan

15:15-15:45    coffee break + POSTER SESSION 3 continued

Session  33

15:45 Radiaton Protection, Dosimetry 4  
Chairperson: Imtinan Qureshi, Pakistan

15:45 613 R. C. Ramola, M.S. Negi, V.M. Choubey, T. V. Ramachandran  
Simultaneous Measurement of Equilibrium Factor F Between Radon and its  
Progeny and Thoron and its Progeny in Indoor Atmosphere using Solid State  
Nuclear Track Detector

16:00 614 Ilona Hunyadi, Istvan Csige, Zoltan Dezso, Zoltan Papp, Thomas Streil  
Spatial Distribution of Radon and Thoron in a Stone-House in the Zemplén  
Mountain, Hungary

16:15 615 Navjeet Sharma, Hardev S. Virk  
Exhalation rate study of radon/thoron in some building materials

16:30 616 Jozsef Pálfalvi, Laszlo Sajo Bohus  
Four Year Experiences with a Sandwich Track Etch Detector System Used for  
Reactor Beam- and Personnel Dosimetry

16:45-17:00    break

Session  34

17:00 Radiation Protection, Dosimetry 5  
Chairperson: Albert M. Marenny, Russia

17:00 617 Janja Vaupotic, Ilona Hunyadi, Eszter Baradacs  
Through Investigation of Radon in a School With Elevated Levels

17:15 618 Wei Lu, Yunjiang Yao, Fang Zhang, Baoxiang Yang, Bo Zhang, Xixin Ja  
Use of SSNTD in study of relation of indoor radon and building fabric

17:30 619 Riad Shweikani, Ghassan Raja, M. Takeyedin  
The Effect of High Voltage Power Lines on Radon Concentration in Soil

17:45 620 A. Canoba, F.O. Lopez, M.I. Arnaud, A.A. Oliveira, A.M. Osorio, R. Aparecido, C. Rodriguez,  
Guillermo Espinosa, J.I. Golzarri, T. Martinez, M. Navarrete, L. Cabrera, Nuria Segovia, P. Pena, E. Tamez, Patrizia Pereyra, Maria Elena Lopez Herrera, Laszlo Sajo Bohus  
Indoor Radon Measurements and Methodologies in Latin American Countries

Parallel session: B

Session  35

12:00 Environmental Science, Radiometry 2  
Chairperson: Michel M. Monnin, France

12:00 704 O.A. Alekseeva, S.F. Gundorina, M.V. Frontasjeva, M.V. Gustova, A.G. Belov, Vladimir P.  
Perelygin, O.S. Zaveriokhia  
Neutron, Gamma and Roentgen Fluorescent Activation Analysis of Hair of  
Children, Suffering from Bronchial Asthma
12:15  705 Y.S. Chung, Zinaida En, S.Y. Cho
Determination of Uranium Concentration in Human Hair by (n, f) Radiography

12:30  706 František Spurný, Valeriy Babmlevski, Alexander Molokanov, B. Vlček
Dosimetric and Microdosimetric Characteristics of High Energy Proton Beams

12:45-14:15 lunch break

Session  36
14:15  Environmental Science, Radiometry 3
Chairperson:  František Spurný, Czech Republic

14:15  707 Mariana Ciubotariu
On the TH Internal Contamination by Ingestion Using the Fission Track Method

14:30  708 H.I. Farag, F. Ahmad, A.A. Hamed, S.A. Gaaafar, H. Salwa, Hoda Eissa, Mohammed El-Fiki
Photon and Neutron Dose Distribution for Head and Neck Cancer Treatment Using
TLD Dosimetry

14:45  709 Khalid Abumurad
Chances of Lung Cancer Due to Radon Exposure in al-Mazar Area, Jordan

15:00  719 Letitia Tavera, M. Brenna, M. Perez, J. Serment, Miguel Balcázar
Alpha Damage and Repair in a Biological Monitor

15:15-15:45 coffee break + POSTER SESSION 3 continued

Session  37
15:45  Earth & Planetary Sciences, Dating 4
Chairperson:  Miguel Balcázar, Mexico

15:45  513 Jumanazar Ishankuliev, Svetlana P. Treyakova, B. A. Muradov, Gulbahar Annakova
Investigation of Radon Dynamics in the Seismic Active Structures of Kopetdag

16:00  514 V.A. Akimov, Abdurashid Yafasov, A.A. Yafasov
Influence of Geotectonic Structure on Radon Behavior in the Environment

The Large Detector as an indicator of radon field variations before the earthquakes
in Central Italy, Greece, Turkey, Aegean and Mediterranean Seas

16:30  516 Khatam Murtazaev, Michel M. Monnin, Vladimir P. Perelygin, A. Murtazaev
Measurement of Alpha-Particles with CR-39 Film in the Units of Northern Tajikistan

16:45-17:00 break
Session 38

17:00 Earth & Planetary Sciences, Dating 5
Chairperson: Giulio Bigazzi, Italy

17:00 517 Julia Bondar, Vladimir P. Perelygin
Evolution of the Bragin pallasite: evidence from the fission-track analyses

17:15 518 Oleg Povetko, Kathryn Higley
Study of Particles of Actinides in Soil Samples Using Nuclear Track Detectors

17:30 519 Leonid Kashkarov, G.V. Kalinina, K.A. Lorentc, M.A. Nazarov
Fission-Track Dating of Impact Craters Using Glass Track Detector: Some Methodological Aspects

17:45 520 Mahmoud Al-Tamimi, Khalid Abumurad
Radon Anomalies on Five Faults in Southwest of Irbid City North of Jordan
Friday, 1. 9. 2000

Plenary session

Session 39
8:30 Nuclear Technology 1
Chairperson: Mohammed El-Fiki, Egypt

8:30 902 Serguei N. Dmitriev, Lyubov Kravets, V. V. Sleptsov, V. M. Elinson
A high-frequency plasma discharge effect on track membranes

8:45 903 Masaru Yoshida, Yasunari Maekawa, Ryoichi Katakai, Reimar Spohr, Pavel Apel
Synthesis of temperature- and pH-sensitive gels and its application to ion-track filters

9:00 904 Shiv Chakarvarti
Improved Design of Electrolysis Cell for Galvanic Replication and Synthesis of Nano/Microstructures and Devices

9:15 905 Etienne Ferain, Roger Legras
Pore Shape Control in Nanoporous Particle Track Etched Membrane Production

9:30-10:00 coffee break

Session 40
10:00 Nuclear Technology 2
Chairperson: Marlies Luszik-Bhadra, Germany

10:00 922 Fazal-Ur-Rehman, Falah Abu-Jarad, Mohammed Al-Jarallah
Comparison and Limitations of Three Different Bulk Etch Rate Measurement Methods as a Function of High Gamma Absorbed Doses in Nuclear Track Detectors

10:15 907 Maria Zamani-Valasiadou, Reinhard Brandt, Monique Debeauvais, J.-C. Adloff, Boris Kulakov, Misha I. Krivopustov
Spallation Neutron Production from Heavy Targets by Proton Irradiation

10:30 908 Yong-Qian Shi, Yi-Guo Li
Reactor Fission Rate Measurement for Miniature Neutron Source Reactor (MNSR) by Solid State Nuclear Track Detector

10:45 909 Shiv Chakarvarti, Vijay Kumar
Synthesis of Tapered Micro-Tipped Metallic Field Emission Electrodes

11:00-11:15 break

Parallel session: A

Session 41
11:15 Instrumentation, Methods, Software 6
Chairperson: Vitaly D. Rusov, Ukraine

11:15 219 Vera Shirkova, Svetlana P. Tretyakova
New Detectors of the Basis of Copolymer of Tetrafluoroethylene with Ethylene (PTFE-E)

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Program of the Conference

FRIDAY

11:30 220 Ammar A. Al-Sa’ad
A Theoretical Design of an Excluded Radon Daughters Plate-out Container

11:45 221 Farhood Ziaie, A. Karimi, Hossein Afarideh, S. M. Hadji-Saeid
Manufacturing of the Graphite Calorimeter at Yazd Radiation processing & Research Center

12:00 222 Octavian Sima
Monte Carlo simulation of radon SSNTD detectors

12:15-12:30 break

Session 42

12:30 Nuclear Track Physics & Chemistry 5
Chairperson: Svetlana P. Tretyakova, Russia

12:30 116 V. K. Lyapidevsky, Albert M. Marenny
Universal Mechanism for Displacement of Atoms in a Charged-Particle Track

12:45 117 Dragoslav Nikezie
Three Dimensional Analytical Determination of the Track Parameters-Part II

13:00 118 Feng Liu, Yagang Wang, Jianming Xue, Sixue Wang, Guanghua Du, Sha Yan, Weijing Zhao, Shimin Hou, Shouguang Zhao
New application of STM observation of individual ion damage on HOPG

13:15 119 Vera Shirkova, I.P. Chihacheva, A.M Evtushenko, S. Budris
Graft-Polymerization into Some Fluoropolymers Irradiated by Accelerated Heavy Ions

Parallel session: B

Session 43

11:15 Nuclear Technology 3
Chairperson: Valery Ditlov, Russia

Modification of Polymer Track Membranes by Radiation-Induced Graft Polymerization

11:30 911 S. Amrita Kaur, Gurpartap Randhawa, Hardev S. Virk
Ion Track Filters: Some Applications in Science and Technology

11:45 912 Youssef Abdulla, D. A. Bradley, Y.M. Amin, B. H. Khoo
The Effects of Energy & Dose Rate on the Tl Response of a GE - Doped Optical Fibre

12:00 913 Pavel Apel, V.V. Berezkin, A.N. Nechaev, Dmitri Zagorski, T.V. Tsiganova, N.V. Mitrofanova, B.V. Meredishvili
The Track Membranes Porous Structure and Selective Properties Investigation

12:15-12:30 break
Session 44

12:30 Material Science, Radiography 2
Chairperson: Curt T. Reimann, Sweden

12:30 804 Anatolijs Popovs, E. Balanzat
In-situ Studies of Point Defect Creation CsI Scintillators Under 8.63 MeV/amu
86Kr Ion Irradiation at 15-300 K

12:45 805 Delara S. Gafitullina
Digital Autoradiography: Possibilities and Applications

13:00 806 Makhtuba Kadirova, N. Jumaev, Yu. E. Simakhin, M.M. Usmanova
Determination of Boron Distribution in Semiconductors, Alloys and Plants Using SSNTD

13:15 807 Elena Flitsiyan, Karl-Heinz Hellmuth
The Radiography System Models for Evaluation the Radionuclides Transport in Rocks

13:30-14:00 Concluding Remarks

14:00 lunch
Invited Lectures

Nuclear Tracks - a Success Story of the 20th Century
Saeed A. Durrani
School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, UK
s.a.durrani@bham.ac.uk

Starting with the observation of a few feeble trails of damage in a sheet of mica exposed to fission fragments some forty years ago, the discipline based on their correct interpretation has emblazoned a resounding success story in the second half of the 20th century. The spectrum of information revealed by the technique extends from delineating the history of the cosmos over some billions of years all the way to observing exotic decays lasting a minute fraction of a second. More directly useful researches have included medical and biological uses as well as industrial applications. A topic of great current interest is the study of the environmental and health effects of the naturally occurring radon gas. These and other highlights of the track work over the past forty-odd years of the 20th century - possibly with some glimpses of things to come in the 21st - will be presented and examined in this review paper.

Nanometric Crystallisation of an Amorphous Alloy Along the Path of GeV Monoatomic Projectiles
Annie Dunlop1, G. Jaskierovicz1, M. Kopcewicz2
1Laboratoire des Solides Irradiés, Commissariat à l’Energie Atomique/Ecole Polytechnique, 91128 Palaiseau, France
2Institute of Electronic Materials Technology, Wolczynska 133, 01-919 Warszawa, Poland
annie.dunlop@polytechnique.fr

The slowing-down of very energetic heavy projectiles mainly leads to electronic excitation and ionisation of the target atoms along the path of the projectiles. The characteristics of the resulting damage mainly depend on the nature of the target and on the amount of energy deposited in electronic processes. In quite a large number of amorphous alloys, it has been shown that if the rate of energy deposition in electronic processes is sufficient, above a critical irradiation fluence, very strong macroscopic deformations, named «anisotropic growth», occur in all the alloys that were previously studied.

We present here the first transmission electron microscopy studies a particular amorphous alloy, in which it is seen that under strong energy deposition in electronic processes, nanocrystallisation occurs along the path of each projectile. This crystallisation is evidenced at very low fluences in individual «tracks», as well as at high fluences when a strong spatial overlap of the damaged regions occurs.
Some Contributions from SSNTD Towards Nuclear Science: From Multifragmentation to the Rubbiatron

Reinhard Brandt
Kernchemie, FB 15, Philipps University, Marburg, Germany
brandtr@mail.uni-marburg.de

In this short contribution one must concentrate as follows:

1. **MULTIFRAGMENTATION** in heavy ion and relativistic interactions: Starting from the very early days in 1960 until presently, many SSNTD groups from the Eurasian continents played a prominent role in finding and interpreting multifragmentation, beginning with 3-pronged events and coming up to 6-7 pronged events. One highlight was the interpretation using the “Gottschalk-method” for a quantitative interpretation.

2. **ANOMALONS** have been discovered and observed since nearly 50 years with various SSNTD’s. Consequently, it would be redundant to repeat all the positive evidences. However, the important work of the Siegen group on non-confirming the anomalon hypothesis shall be critically reviewed.

3. **RUBBIATRONS** are the most advanced form of generating - in principio - nuclear energy in a safe way, simultaneously destroying all the bad plutonium on Earth. Some technical and social aspects will be reviewed. This research requires extensive use of SSNTD’s and radiochemistry in the two major research centers to study this technology in depth, i.e. in CERN, Geneva and the JINR, Dubna. A few results and their interpretation will be presented and compared: Sometimes the results are comparable. However, one aspect is divergent: CERN claims, that proton energies below 1 GeV are LESS efficient than above 1 GeV for "energy amplification". Experiments at the JINR do not confirm this. Details will be presented, including important results using SSNTD’s.

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Personal Dosimetry and Area Monitoring for Neutrons, Radon, and Cosmic Rays

Luigi Tommasino
Italian National Agency for Environmental Protection-ANPA, Via V. Brancati 48, 00123 Rome, Italy
tommasin@anpa.it

The first successful applications of damage track detectors in radiation protection have been made in the early 1970s in personal dosimetry of neutrons, radon and its progenies. Most of the scientists actively engaged in the solution of the complex problem of personal neutron dosimetry by damage track detectors--SSNTD, have attempted to develop individual radon monitoring for exposure in mines by using the same SSNTDs. In late 1970s and the early 1980s, new radon monitoring devices based on SSNTDs have been developed to measure radon in soil, mainly for applications in earth science. Most of the radon monitors, developed since then for completely different applications in mind, have been used later for large scale survey of indoor radon.

Following the recommendations of the International Commission of Radiation Protection ICRP 60 (1991), new surveys of the radiation environment produced by cosmic rays at aviation altitudes have been undertaken. The solution of the complex problem of assessing the aircrew exposures have been facilitated through multinational research co-operations, promoted by the European Union. In this way, it possible to exploit the expertise on damage track detectors in the field of space research and neutron dosimetry, available in different European laboratories.

With the current implementation within Europe of the European Union Directive 96/29, applications of damage track detectors will increase drastically, specially for the assessment of the exposure of the workers to natural sources of radiations. In this case, the early work on personal neutron/radon dosimeter beams, is highly valuable to tackle these new problems of individual monitoring.
Track-Etch Technique in Membrane Technology

Pavel Apel

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, 141980 Dubna, Russia
apel@nrsun.jinr.ru

The use of nuclear tracks for the production of porous membranes was proposed almost immediately after the discovery of particle track etching in thin sheets of materials. Two basic steps of the track membrane (TM) production process are radiation treatment (tracking) and subsequent chemical treatment. Historically, the tracking process was first carried out at nuclear reactors. In the nineties, heavy ion accelerators became a much more popular source of ionizing particles for TM technology. Track-etch membranes offer distinct advantages over conventional membranes due to a precisely determined structure. Their pore size, shape and density can be varied in a controllable manner so that a membrane with the required transport characteristics can be produced.

So far, the track formation and etching process is studied in much detail for several polymeric materials. Today we understand determining factors and have numerous empirical data enabling us to manufacture any particular product based on PET or PC films. Pore shape can be made cylindrical, conical, funnel-like, or cigar-like at will. The development of TMs using other polymers is still limited. Difficulties in the etching procedure, poor reproducibility of raw material properties or high production cost impede the large-scale manufacture of TMs from new polymers.

Applications of “conventional” track membranes can be categorized into three groups: process filtration, cell culture, and laboratory filtration. The use in biology stands out among other areas. A number of modification methods are developed for creating TMs with special properties and functions. A most prominent example is stimulus-responsive membranes obtained by grafting hydrogels onto a matrix having track pores. Track membranes seem to be the best porous material for providing the controllable transport of solutes or particulates. Nuclear track pores find diverse applications as model systems and as templates for the synthesis of micro- and nanostructures.
Modifications Induced by Proton Irradiation in Polyallyl Diglycol Carbonate

S.P. Tripathy\(^1\), R. Mishra\(^1\), Kamal K. Dwivedi\(^{2,3}\), D.T. Khathing\(^1\), S. Ghosh\(^2\), Dietmar Fink\(^2\)

\(^1\)Department of Physics, North-Eastern Hill University, Shillong-793 022, India.
\(^2\)Hahn-Meitner Institute, Glienicker Strasse 100, D-14109 Berlin, Germany.
\(^3\)Arunachal University, Rono Hills, Itanagar-791 111, India.

kkdwivedi@yahoo.com; kkdau@hotmail.com

Swift heavy ions interact predominantly through inelastic scattering while traversing through any polymeric medium producing excited/ionised atoms. Beyond a certain threshold, they affect the lattice structure leading to remarkable flexibility in engineering many physical and mechanical properties of the polymer. Polyallyl diglycol carbonate (PADC) is a class of polymeric detectors which finds its application in various fields. In this work, PADC detectors were exposed to four different doses (viz. 1 Mrad, 3 Mrad, 6 Mrad and 8 Mrad) of 62 MeV protons from heavy ion accelerator (ISL) at HMI, Berlin. The dose dependent modifications in the irradiated polymers have been studied and characterised through different techniques like Fourier Transform IR, UV-Vis, Electron Spin Resonance (ESR), Thermogravimetric analysis (TGA), Differential Scanning Calorimetry (DSC) and Track studies. With increasing proton doses, the optical band-gap was found to be invariant while a decrease in transmittance of PADC was observed. The thermal stability of PADC was found to be an inverse function of the proton dose. Further it has been observed that the proton irradiated PADCs when exposed to fission fragments from \(^{252}\)Cf source exhibited an improved track etching response. The bulk etch-rate was also found to increase by 90% for the PADC irradiated to the highest (8 Mrad) proton dose. Thus proton irradiation has led to degradation of the polymer by chain scission converting it into an easily etchable material. The experimental details and the major findings have been presented.

Track Theory Evolution During International Solid State Detector Conferences

Valery Ditlov

Institute of Theoretical and Experimental Physics, B.Cheremushkinskaya str. 25, 117259 Moscow, Russia.

valery.ditlov@itep.ru

This set of conferences has a large History. Now we have already 20th meeting. The first conference was organized 43 years ago due to idea of Prof. P.Cuer from Strasbourg and Prof. K.S.Bogomolov from Moscow, which was realized 1-6 July of 1957 in Strasbourg as "PREMIER COLLOQUE INTERNATIONAL DE PHOTOGRAPHIE CORPUSCULAIRE". The main subject of their idea was "d'une part, la mise au point de nos connaissances actuelles sur le mecanisme de l'action 'photographique des paritcules chargees; d'autre part, l'expose detalle des resultats obtenus dans ces dernieres annees.." A special place there had theoretical questions of different stages of track formation. For example a report "La sensibility photographie" of John W.Mitchell and a report of K.S.Bogomolov "Les relations quantitative de l'action photographique des paritcules chargees ionisant faiblement." The understanding of these fundamental questions helped to create a large assortment of nuclear photographic emulsions for different tasks and applications.

For the first time I participated in 9th conference of Munich in 1976 year. So I would like to join to those, who are going to give a review, devoted to this event, and to expose several aspects of our anniversary. I analyzed numerous statistical materials of our proceedings and with the help of histograms I shall show Great Evolution of Conferences to the last one and the input in it of Soviet and Russian participants. I am going to show the evolution of theoretical works, which was tightly bounded with general evolution of our conferences.
The result of realization of the idea Prof. P.Cuer and Prof. K.S.Bogomolov exceeded all expectations. The importance of this set of meetings in Physics turned out to be very large. Later on there were found or created tens of new detectors, joined together with nuclear AgBr emulsion in one class of Nuclear Solid State Track Detectors.

This was reflected in symbolic “Tree of Trackology” exposed by Prof. G.Somogui during Anniversary of 10th Conference in Lyon in 1979. The titles of conferences went through their own evolution to simplest form “Nuclear Tracks in Solids”... Correspondingly to it there were opened numerous fields of track methods applications. Simultaneously with appearance of new solid state detectors there were developed new methods of track visualization. It obliged to consider new mechanisms of track parameters formation and to open new directions of theoretical study. One of the main visualization method became etching procedure and there appeared some variety of calculation approaches. I will describe some general features of these works. The experience of track formation mechanism study, accumulated in works with nuclear emulsions, was generalized and successfully adapted to whole class of nuclear solid state track detectors. In the report I will discussed “How it was?” and “Why it was possible?”.

Practically at the first conferences there were presented works devoted to automatic methods of track measurements and today we have large knowledge store in this region too. Today there exist powerful computer equipment and soon it will be possible to organize a work of system “a measurement device + computer” in such an “on-line” regime, which will use algorithms based on our theoretical luggage in order to obtain any desirable characteristic of registered radiation or radiation effect. The number of works, devoted to this direction, will grow up in closest future of our Conferences.

A Track Formation Model: Ionising Particles May Create Shockwaves

Thomas Turowski, Wolfgang Enge

Institut für Experimentelle und Angewandte Physik Kiel-University, Olshausenstraße 40-60, D-24118 Kiel, Germany
Thomas@turowski.de

A track formation model will be suggested: At high fluences not all ions enter the detecting foil at the same time. When an ion penetrates the foil it creates shockwaves around its path. These shockwaves put compacting forces on earlier created latent tracks in the same foil.

To find a model that describes the gas diffusion on irradiated polymers (Makrofol KG polycarbonate) the diffusion constants have been measured with argon as diffusion gas. The polymers were irradiated with uranium, gold and lead ions of about 10 MeV/u and fluences between 1·10^{10} to 4·10^{11} ions/cm². The ion irradiated probes show two quite different dependencies of the diffusion constant on the ion energy loss. These effects are strongly related to the fluence of the irradiation. In case of low fluences the diffusion constant is up to 8 times higher than that of pristine material. In the probes with high fluences we observed a decrease of diffusion constant down to half the value of the pristine material. To understand the dependence of the diffusion constant on ion fluences we apply a model of compacting. This model describes the compacting ability of shockwaves arising from latent tracks.

KEYWORDS: Track formation model, latent tracks, heavy ions, polycarbonat, diffusion, ion energy loss, shockwave, compacting model
Electron Irradiation of Polyurethane: Study of Chemical and Structural Modifications Using FTIR, UV Spectroscopy and GPC

B. Ravat¹, Manuel Grivet¹, Y. Grohens², Alain Chambaudet³

¹Laboratoire de Microanalyses Nucléaires, La Bouloie, 16 route de Gray, 25030 Besançon cedex, France.
²ICSI-CNRS, 15 rue J. Starcky, BP 2488, 68057 Mulhouse Cedex, France.

In order to understand the effects of electronic irradiation in polymers, a polyesterurethane (PU) was irradiated by a 200 keV electron beam. The irradiation was performed perpendicular to the sample’s surface under a vacuum of 0.04 torr with a current in the range of 0.4 to 2 µA corresponding to electron fluxes of 0.25 to 1.25x10¹³ s⁻¹ on the irradiated zone. To perform a study of PU degradation versus the electron’s penetration depth, a stratified structure was made with seventeen 30-µm-thick films. The irradiation of PU films were carried out under two temperatures: room temperature (293K) and at 77K. The applied fluence was in the range of 10¹⁴ to 10¹⁷ cm⁻².

Chemical transformations, as degradation and oxidation, are studied by FTIR, by following NH and OH bond evolution, and by UV spectroscopy, by following the absorbance shift towards the visible region. These effects are analyzed versus depth and fluence. Structural transformations are characterized by GPC for soluble samples. An increase of crosslinking rate of the polymer is observed and analyzed.

Chemical Changes Induced by Ions in Cellulose Nitrate (LR 115)

Rémi Barillon¹, Robert Katz², J.P. Stoquert³

¹Université Louis Pasteur et IReS (UMR 7500), F-67037 Strasbourg Cedex 2, France
²University of Nebraska, Lincoln, NE 68588-0111, U.S.A.
³Laboratoire PHASE, UPR 292 du CNRS, BP 20, F-67037 Strasbourg Cedex 2, France
remi.barillon@ires.in2p3.fr

In this paper we present the characterization and the quantification of the chemical damages induced by ions (He²⁺, H⁺) in LR 115. Infrared spectroscopy measurements have been completed by Raman, XPS (X Ray Photoelectron Spectroscopy) and RPE studies. Comparison between the specific chemical damages and physical paramaters (TEL, REL and dose) will be performed. The track physics model of radiation action developed by Katz will be applied to define parameters with a physical and a chemical meaning for describing the number of a given chemical damage according to the particle energy and fluence. Possible relevance with the track etch velocity will be discussed.

Inter-comparison of Geometrical Track Parameters and Depth Dependent Track Etch Rates Measured for Li-7 Ions in Two Types of CR-39

Tomoya Yamauchi¹, Hirotaka Ichijo¹, Keiji Oda¹, Birgit Dörschel², Dietrich Hermsdorf², Karin Kadner², François Vaginay³, Michel Fromm³, Alain Chambaudet³

¹Department of Nuclear Engineering, Kobe University of Mercantile Marine, 5-1-1 Fukaeminami-machi, Higashinada-ku, Kobe 658-0022, Japan
²Dresden University of Technology, Physics Department, Institute of Radiation Protection Physics, D-01062 Dresden, Germany
³Laboratoire de Microanalyses Nucléaires, Université de Franche-Comté, F-25030 Besançon Cedex, France

From the view-point of the fundamental track science, the more precise response of CR-39 detector is strongly desired for light ions with low energies. In applying the CR-39 detector to the radon dosimetry, neutron dosimeter with converters, the particle identification and its energy estimation such as in laser-induced fusion experiments and
so on, the precise response for various relating light ions is also required. Because the drastic variation of track etching characteristics around the Bragg peaks prevent us from making an usual assumption of constant track etch rate, the response must be expressed as the track etch rate or etch rate ratio as a function of the residual range or the corresponding stopping parameter like REL.

In this study, the response for Li-7 ions was investigated for two types of CR-39 detectors, TASTRAK (Track Analysis Systems Ltd., UK) and BARYOTRAK (Fukuvi Chemical Ltd., Japan), by measuring the track length, \( L \), at various etching time. The detectors were irradiated perpendicularly with Li-7 ions at the tandem accelerator of the Rossendorf Research Centre with energies of 4.82, 6.75 and 10.77 MeV. The etching and the size measurements were made independently by three teams. Chemical etchings were commonly performed in 7.25 N NaOH solution at 70 \( ^\circ \)C.

The experimental results of the track length as a function of etching time, \( L(t) \), by our three teams agreed well with each other. Track etch rate, \( V_t(x) \), at a depth \( x \) along the ion trajectory was obtained by using the following relations;

\[
V_t(t) = \frac{dL(t)}{dt} + V_b \\
\text{and} \quad x = L(t) + V_b \cdot t,
\]

where \( V_b \) is the bulk etch rate and \( V_b \cdot t \) is equivalent to the thickness of layer removed. Some deviations occurred in \( dL(t)/dt \) values among three teams. The differentiation of \( L(t) \) is the most critical step in evaluation of \( V_t(t) \). Obtained curves of \( V_t(x) \) was found to have the peaks corresponding to the Bragg peak.

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Nakahiro Yasuda\(^{1,2}\), Kuniaki Amemiya\(^{1,2}\), Kazuyuki Uchikawa\(^{2,3}\), Nanae Watanabe\(^{1,2}\), Hiroyuki Takahashi\(^{1}\), Masaharu Nakazawa\(^{1}\), Mikio Yamamoto\(^{2}\), Koichi Ogura\(^{3}\)

\(^{1}\)Quantum Engineering and Systems Science, University of Tokyo, Hongo, Tokyo 113-8656, Japan
\(^{2}\)National Institute of Radiological Sciences, Inage, Chiba 263-8555, Japan
\(^{3}\)Department of physic, Toho University, Funabashi, Chiba 274-8510, Japan
\(^{4}\)College of Industrial Technology, Nihon University, Narashino, Chiba 275-8575, Japan

CR-39 were exposed to C, Fe, Xe ions at energy of 6 MeV/n with normal incidence and were etched in 70 degrees 7N NaOH solution for 0.5, 1, 2, 3, 5, 10 minutes. Atomic force microscope was used to measure the minute etch pit diameter in nanometer dimensions. The minimum size of measured track diameter was about 35 nm for three kinds of ion species etched for 0.5 minutes. The growth curve of etch pit diameter in the early stage of track etching process were obtained as a function of etching time. The diameter of latent track size was estimated to be about 10 nm by the extrapolation of the fitted growth curve. This value is comparable to the experimental data on the average ‘track core radius’ for the organic track detector materials \(^1\) which have been obtained by various experimental method, such as ‘Scavenger technique’, ‘neutron scattering’ and ‘gas flow’ etc. The so-called ‘etch induction time’ will be also discussed in relation to the growth curves of etch pit diameters for the particles having different REL values.

FTIR Study of Light, Ion-Irradiated CR-39 Detector: Correlation with the Ion Track Formation Mechanism in the Vicinity of the Bragg-Peak

Zohra Lounis – Mokrani1,2, Michel Fromm2, Rémi Barillon3, Robert Katz4, Alain Chambaudet2, K. Morsli1, M Allab5

1Laboratoire de Dosimétrie, CRNA, 2 Bd Frantz Fanon, BP 399 Alger, Algérie.
2Laboratoire de Microanalyses Nucléaires; UFR  F-25030 Besançon Cedex, France
3Université de lous pasteur et IReS (UMR 7500), F-67037 Strasbourg Cedex 2, France.
4University of Nebraska, Lincoln, NE 68588-0111, U.S.A
5Laboratoire de Physique Nucléaire, USTHB, BP. 32 Bab Ezzouar Alger - Algérie

mfromm@utinam.univ-fcomte.fr

The formation of nuclear tracks in polymers is generally accompanied by radiochemical, structural, electronic and optical property modifications. Over the last few years, many studies have been conducted to understand the chemical and physical nature of latent tracks in polymers. Most, however, have been related to the high projectile energies (GeV particles).

This paper is a study of the chemical changes induced by light ions (protons, deuteron and alpha particles) slowed down in the CR-39 nuclear track detector in energy ranges surrounding the Bragg-peak region. The study was conducted using Fourier Transform Infrared (FT-IR) spectroscopy of thin films. Irradiation was performed in a vacuum, perpendicular to the particle's beam, with fluences ranging from $10^{10}$ to $10^{15}$ particles.cm$^{-2}$.

Changes that occurred in the C-H and C-O bonds versus the ion beam fluence and $(Z^2/\beta^2)$ the particle parameters have been studied. The bond scission cross section was determined using Katz’s theory of track formation in plastics. For example, the carbonate C-O bond scission cross section was found to be about $10^{-13}$ cm$^2$ and $3.10^{-14}$ cm$^2$ for protons with energies of 1 MeV and 1.5 MeV, respectively. The variations in the obtained bond scission cross sections for protons in the CR-39 have been analyzed and discussed when plotted versus V$_T$ and the fundamental parameters, such as energy, dose and REL.

Furthermore, the geometrical parameters of the sensitive sites have been deduced and compared to the core, track radius published in the literature.

References
The etch rate ratio was studied by many authors using the track diameters measured at the detector surface at a given etching time. The derivation of V was made in these cases presuming a time-independent track etch rate \( v_T \). Comprehensive investigations during last years showed, however, that there is a distinct variation of \( v_T \) along the particle trajectory whereas \( v_B \) has been found to be approximately constant [1]. The track etch ratio V has, therefore, to be determined at several sites on the particle trajectory covering the whole track length up to the point where the ion is stopped. Then, the ion energy loss at always the same position on the trajectory has to be assigned.

The present paper shows results for the etch rate ratio derived from the track etch rate measured along the trajectories of protons, deuterons, alpha particles and lithium ions with a wide variety of energies in CR-39. Some tests are described to find a generalised relationship between the etch rate ratio and the ion energy loss. Most promising results were found assuming a correlation with restricted energy loss REL\(_{350}\). It was concluded that all data can be, on principle, fitted by a unique relationship \( V(\text{REL}_{350}) \) which is, however, not simply linear. Deviations are observed for low-energy lithium ions in that \( \text{REL}_{350} \) range which corresponds to small depths within the detector, i.e. to the track formation at the beginning of the etching process. It cannot be excluded that the same effect exists for lower energetic protons, deuterons and alpha particles, too. This supposition could, however, not be tested experimentally because the tracks were too short for length measurement in these cases. The results are discussed and compared with data of other authors who used track diameters measured on the detector surface.


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**Study on the Structure of Latent Tracks in CR-39 And SR-90 Track Detectors by FT-IR Spectroscopy**

A. F. Saad\(^1\)\(^2\), S. T. Atwa\(^2\), Masami Fujii\(^1\)

\(^1\)Faculty of Engineering, Aomori University, 2-3-1 Kobata, Aomori, Japan  
\(^2\)Faculty of Science, Zagazig University, Benha-Branch, Egypt

Ionizing particles passing through polymeric track detectors produce latent tracks which are trails of radiation damage. These tracks are usually revealed as etch pits through chemical etching. However, some information about the structure of radiation damage will be lost after etching. We introduced FT-IR spectroscopy in order to make direct analyses of the change in the molecular structure along latent tracks.

Two types of polymeric track detectors CR-39 and SR-90 were irradiated with protons, alphas and heavy ions of different energies and fluences. A FT-IR spectrometer of Jasco type 5300 was operated under transmission mode and also under ATR (Attenuated Total Reflection) mode because our CR-39 and SR-90 detectors were too thick for majority of the IR absorption bands under the transmission mode.

The results of our measurements can be summarized as follows:

1) In both CR-39 and SR-90, certain amount of CO\(_2\) is produced in the polymer through the polymerization process.

2) The CO\(_2\) escapes from the polymer by diffusion if the detector is stored in the air at room temperature.

3) Additional CO\(_2\) is produced by radiation damage through the irradiation process. Consequently, the amount of CO\(_2\) in the detector might be closely connected to the latent track formation and the track detection sensitivity.
Experimental Determination of the Critical Angle for Particle Registration and Comparison with Model Predictions

Birgit Dörschel, Dietrich Hermsdorf, Uwe Reichelt

Dresden University of Technology, Physics Department, Institute of Radiation Protection Physics, D-1062 Dresden, Germany
hermsdf@rcs.urz.tu-dresden.de

The efficiency of solid state nuclear track detectors (SSNTD) to charged particles has to be known when such detectors are applied for dosimetric purposes. The efficiency of SSNTD to α-particles is especially of interest in radon and neutron dosimetry.

The detector efficiency $\varepsilon$ is defined as ratio of the counted tracks and the particle fluence impinging on the detector surface. The efficiency depends very sensitive on the angle of incidence of the particles. Above the critical angle $\Theta_c$, no track can be made visible by the etching process and the detector efficiency equals to zero. Therefore, the measurement and the theoretical description of the critical angle in dependence on the particle energy $W$ and the etching time $t$ is very important for the practical use of SSNTD.

In the present paper experimental results for α-particles at energies $W_\alpha$ of 1.5, 4, 6.22 and 10 MeV and at etching time of 6 hours are presented. The detector material was CR-39 of TASTRAK type manufactured by TASL Ltd., UK. The detector efficiency, the axis of the elliptical tracks and the elongation parameter have been evaluated from the track geometry using an image analysing system. From both, the efficiency and the axis, the critical angles can be determined in dependence on particle energy.

The experimental results are compared with data predicted by a model proposed in an earlier publication [1]. This model proceeds from only two parameters, the track etch rate $v_T$ and the bulk etch rate $v_B$, which are the dominant physical quantities for the formation of the track. The critical angle $\Theta(W,t)$ can be predicted for any particle type at any energy and any etching time if the track etch rate along the particle’s trajectory $v_T(x)$ is known.

The model contains a parameter $L_c$, which describes a critical track length dependent on the optical properties of the microscope and the image processing hard- and software of the image analysing system. This parameter was determined by earlier experiments. A very good agreement of the experimental results with theoretical predictions can be concluded if the critical length $L_c$ is correctly determined.

At α-particle energies above 5.8 MeV two ranges for the angle of incidence exist where visible tracks can be registered. These areas are separated by a forbidden range where the formation of visible tracks is impossible. Such a behaviour results from the numerical solution of the transcendental equation on which the model is based [2].


Generation of CO$_2$ in Gamma Ray Irradiated CR-39 Plastic

Abdul Malek, C.S. Chong

School of Physics, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia
z_mam@yahoo.com

Investigation was carried out on the γ ray irradiation of CR-39 plastic. The absorption band for CO$_2$ was observed and the area under the absorption bands was measured by using FTIR spectrometer. The absorption band area plotted as a function of dose was found to increase rapidly initially with dose followed by a gradual decrease with increasing dose. The result could be explained by the diffusion of CO$_2$ at higher rates during the long irradiation time. The diffusion half time of CO$_2$ from the irradiated plastic was found to decrease from 9 to 4 days with increase.
of dose from 13 to 95 Mrad. The result is attributed to the further degradation action of the energetic photons on the plastic with increase in dose.

Submicroscopic Investigations of Heavy Ion Latent Tracks in Some Track Recorders

Gurpartap Randhawa¹, Hardev Virk²

¹Department of Physics, Khalsa College, Amritsar, India
²Department of Physics, Guru Nanak Dev University, Amritsar, India

gurpartaps@yahoo.com

The irradiation of solid materials by heavy ion beams has become a wide field of basic research, especially related to the underlying processes of damage creation, and motivated a lot of interest in science and technology ranging from basic research on ion track creation to applied fields like microtechnology and material modifications. The damaged zones created along the path of the fast heavy ions moving in solids are called heavy ion latent tracks. The size, shape and internal structure of these latent tracks resulted from many primary processes which are not directly observable. Although a lot of simple and more complicated models are proposed, we do not yet have a satisfactory explanation for the production of latent tracks in solids created by energetic ionizing charged particles. In the present investigation, the morphology, size and shape of different heavy ion latent tracks in different track recording insulators, viz., soda-glass, SR-86, makrofol, CR-39, etc. are analysed under atomic force microscope (AFM). The heavy ion irradiations were made from UNILAC, GSI Darmstadt and Heavy Ion Pelletron at Nuclear Science Center at New Delhi. The irradiated samples were etched for a very short interval (in seconds) in suitable etchants. All these samples were scanned under atomic force microscope (AFM) developed at CSIO, Chandigarh. The measured diameters and depths of heavy ion tracks are reported. Track morphology is also revealed in all these samples.


G. Giacomelli, Miriam Giorgini, Laura Patrizii, V. Popa, Paola Serra

Department of Physics and INFN, Bologna, Italy

serrap@bo.infn.it

We present new calibrations of different batches of production (from 1989 to 1999) of the Intercast CR39, using the BNL-AGS 1 A GeV iron beam. The comparison with previous results, obtained with the 158 A GeV lead ion beam of the CERN-SPS, shows that ageing effects are negligible. We also tested the dependence of the CR39 response from the time elapsed between exposure and etching times (“fading effects”).

Universal Mechanism for Displacement of Atoms in a Charged-Particle Track

V.K.Lyapidevsky¹, A.M.Marenny²

¹Moscow Physical Engineering Institute, Kashirskoye shosse 31, Moscow 115409, Russia
²Research Center of Spacecraft Radiation Safety, Shchukinskaya str. 40, Moscow 123182, Russia

radprog@stk.mmtel.ru

Displacement of atoms in a dielectric is well known to occur not only in direct collisions of a charged particle with nuclei, but also due to Coulomb scattering of product ions. Our earlier works have presented direct evidence for actual existence of the Coulomb mechanism for displacement of atoms and demonstrated the relationship between the atomic displacement and scintillation energy output.

The Coulomb mechanism of atomic displacement is regarded at large to be effective if only the ionization density is high (as, for example, in a heavy-ion track). This is not the fact, however. The ions produced in matter by a heavy
charged particle of any specie are Poisson-distributed in space. There always exists a probability, therefore, for a certain number of positively-charged ions to be so spaced such a distance apart that the electrostatic repulsion energy exceeds the energy for an ion to be displaced from its equilibrium position. At high irradiation intensities the number of the ions spaced small distances apart may prove to be great enough, so that the properties of matter get changed substantially. An ion gets displaced within time $t_d$, smaller than its lifetime $t_l$. The probability for an ion to be displaced is

$$W = 1 - \exp(-t_l/t_d).$$

The displacement time is proportional to $m^{0.5}$ ($m$ is atomic mass), and is of the order of $10^{-11}$ s. As $t_d$ decreases, $W$ increases, so the materials of lower atomic numbers show a higher sensitivity. The ion lifetime is a strong function of the composition of matter, namely, $t_l$, is reduced by the dopes with weakly bound electrons (donors) and is raised by acceptor dopes. By varying the dope types and their concentration, we can substantially change the $W$ value and, thereby, the track detector sensitivity together with the radiation tolerance of materials.

Three Dimensional Analytical Determination of the Track Parameters - Part II

Dragoslav Nikezic

Faculty of Science, 34000 Kragujevac, Yugoslavia

apnikeza@cityu.edu.hk

Three dimension analytical determination of the track parameters was applied previously for the case of conical tracks. The same approach has been used in this paper for the case of overetched tracks. The method enables the calculation of the track parameters, like minor and major axes, as well as, determination of the equation of track opening contour line. Some examples of the complex shape of the track opening are given in the report.

New Application of STM Observation of Individual Ion Damage on HOPG

Feng Liu¹, Yuyang Wang¹, Jianming Xue¹, Sixue Wang¹, Guanghua Du¹, Sha Yan¹, Weijing Zhao¹, Shimin Hou², Shouguang Zhao³

¹Institute of Heavy Ion Physics, Peking University, Beijing 100871, P.R. China
²Department of Electronics, Peking University, Beijing 100871, P.R. China
³Department of Physics, Peking University, Beijing 100871, P.R. China

ygwang@pku.edu.cn

Recently, it is found that tens of keV heavy ion beam implantation into dry seeds produces remarkable mutation effects [1]. However, normally the theoretical range of these ions in solid is below 500nm and the distance from the surface of a seed to its gene region is at least 100µm. To clarify the problem, the same ion beam with the dose in the range of $10^{15}$ - $10^{17}$ ions/cm² for the crop breeding are used to irradiate kidney bean slices with the thickness of 100um, and the detection of the possible penetrated ions is required. However, most of detectors, including semiconductor detector and normal solid track detector, are ineffective for the purpose. The measurement is realized by applying the method of STM (scanning tunneling microscope) observation of individual ion damages on HOPG (highly oriented pyrolytic graphite) to record the number of the penetrated ions. In the experiment, the HOPG was placed rightly behind the sample during the ion bombardment and was observed with STM after irradiation. The experimental results confirm the penetration of the ions and the average transmission ratios are around $10^{-6}$. From the distribution of individual ion damages on HOPG and its change with the dose of the ion beam, the possible penetration mechanism of low-energy ion in biologic sample was proposed. In this paper, the method of STM observation of individual ion damage on HOPG as a potential detector for low-energy heavy ions was also discussed.

Reference:

Graft-Polymerization into Some Fluoropolymers Irradiated by Accelerated Heavy Ions

Vera V. Shirkova,¹ I.P. Chihacheva², A.M.Evtushenko², S. Budris²

¹Flerov Laboratory of Nuclear Reactions, JINR, Dubna, 141980, Russia
²Moscow State Academy of Fine Chemical Technology, Prospect Vernadskogo, 86, 117571, Moscow, Russia
vera@nrsun.jinr.ru

The results of the grafting polymerisation of methacrylic and acrylic acids as well as methylmethacrylate to fluoropolymers (polytetrafluoroethylene, polyhexafluoropropylene, polyperfluoroallylether, polyvinylidenefluoride, polyvinylfluoride) irradiated with heavy ions (Kr, 430 MeV) are presented. It has been found that the graft-polymer quantity depends upon the matrix nature and the ion fluence. The graft polymer amount and its penetration depth were controlled with weight methods, the water contact angle determination and with electron microscopy methods. It was found that the polymer matrix volume increases significantly and the polymer structure changes. There was no change in the graft polymer structure after the graft-polymer chemical being removed from the matrix with xenon difluoride.

Modification of Optical, Chemical & Structural Response of CR-39 Polymer by 50 MeV Lithium Ion Irradiation

Hardev S. Virk, Ajeet Srivastava

Department of Physics, Guru Nanak Dev University, Amritsar –143005, India
virkhs@yahoo.com

Ion irradiation in polymers destroys the initial structure by cross-linking, scission and emission of atoms, molecules and molecular fragments. This leads to changes of their properties like density, conductivity, optical absorption, molecular weight distribution and solubility. The effectiveness of these changes produced in the polymer depends on the structure of the polymer and the experimental conditions of the ion irradiation like ion energy, fluence, mass, charge and the nature of targeted material itself.

CR-39 polymer samples were irradiated with 50 MeV lithium ion beam in a vacuum scattering chamber. The ion fluence was varied in the range of $10^{11}$ to $10^{13}$ ions cm$^{-2}$. Irradiation effects were studied using UV-Visible, FTIR spectroscopy and X-ray diffraction techniques. The observation of recorded spectra clearly shows that the UV absorption is extremely sensitive to the electronic stopping power (dE/dx). The changes observed in the FTIR spectra due to irradiation clearly indicated that the carbonate group had broken with loss of CO$_2$ and formation of additional OH groups in the polymer unit. No appreciable change has been observed in the diffraction pattern of CR-39 polymer after irradiation up to the fluence level of $10^{13}$ ions cm$^{-2}$. From the FTIR spectrum analysis it is evident that there is a chain scission in the polymer backbone and the rate of scission increases with increasing dose levels. This is further confirmed from the UV-Visible spectrum of the samples where the absorption in the region of carbonyl frequencies decreased with increasing fluence. It is also concluded from the diffraction pattern that the CR-39 polymer retains more or less its original form of physical structure.

Effect of Swelling on the Determination of Bulk Etch Rate in Various SSNTDs

F. Malik, Ehsan-Ullah Khan, S.N. Husaini, S. Karim, M. Sajid, Imtinan Qureshi

RPD, Pinstech, P.O. Nilore, Islamabad, Pakistan
ehsan.pins@dgcc.org.pk

Different types of Solid State Nuclear Track Detectors (SSNTDs) were soaked in water as well as in NaOH of different normalities at various temperatures. Measurements regarding changes in thickness and weight of CR-39 (Pershore and Homalite) as well as in Makrofol (E and N) samples were recorded for various combinations of time,
temperature and normality of the etchant used. The behavior of the detector with respect to soaking time and temperature was studied. The amount of water absorbed in all of the detectors was determined and its effect was studied on the bulk etch rate calculated by thickness and mass change methods. The increase in thickness for both types of CR-39 is maximum as observed after soaking the detector in water at 70 °C for 3 hours. This increase in thickness is irreversible and gives misleading value of the thickness and mass removed during etching. A correction factor has been obtained from the data measurements from the several detector samples.

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**Optimizing Etching Conditions for CR-39 Detectors Irradiated by Spent Reactor Fuel**

Tam Nguyen, László Lakosi

Institute of Isotope and Surface Chemistry, P.O.Box 77, H-1525 Budapest, Hungary

lakosi@alpha0.iki.kfki.hu

A number of unwanted and disturbing tracks appear during detection of fast neutrons inside power reactor spent fuel assemblies. Some phenomena, causing disturbing events, are studied as follows. Since neutrons incident on the detector are coming from all directions there are a lot of recoil protons incident almost parallel to the detector surface, producing thus long tracks. In the water of the pond containing spent fuel, the fast neutrons are slowing down so that thermal and slow flux are very high. Their track length is short, becoming spherical and highly over-etched quickly. The very short tracks (E<50 keV) are not visible, but they cause damage in the structure of CR-39, and speed up etch rate locally.

The huge gamma dose does not produce disturbing tracks itself, but it speeds up bulk etch rate, and enlarge defects on the detector surface. In order to suppress disturbing events in mixed neutron-gamma fields, etching time and/or NaOH concentration have to be decreased.

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Tomoya Yamauchi, Shuji Takada, Hirotaka Ichijo, Keiji Oda

Department of Nuclear Engineering, Kobe University of Mercantile Marine, 5-1-1 Fukaeminami-machi, Higashinada-ku, Kobe 658-0022, Japan

yamauchi@cc.kshosen.ac.jp

Many authors have already made studies on the changes in the optical property of CR-39 plastics induced by ion beam and gamma-ray irradiation by using various kinds of optical spectrometers. Some of them were performed from a view-point of the control the refractive index in CR-39 as an optical waveguide material and others are carried out to obtain the fundamental information on the chemical structure of the latent track. On the other hand, it is well known that the storage of plastic track detectors in vacuum before and during irradiation decreases the track registration sensitivity. This indicates that the oxygen dissolved plays an important role in forming latent track or the damage. However, in the optical studies, even in the later cases, little attention has been paid on the effect of the oxygen.

In this study, we have constructed a new Raman spectrometric system in a beam line of a van de Graaff accelerator in Kobe University of Mercantile Marine. Samples of CR-39 (BARYOTRAK, Fukuvi Chemical Ltd., Japan) were set on the rotatable holder in a vacuum chamber, which can act as a beam switch. Energetic proton beam (3.4 MeV) was incident with 45 degree to the surface. The used Raman monitoring system is HoloProbe532 produced by Kaiser Optical System Inc., USA. The laser with a wavelength of 532 nm was normally shot the surface out of sapphire vacuum window. Scattered lights were also collected by the same probe head (on-line measurement). Not only Raman measurements but UV and Near-IR spectral measurements were also made in air after irradiation, as off-line measurements.
Scattering of the fluorescence increased significantly with fluence. The intensity of Raman scattering by -CH₂-group hardly changed in the on-line measurements up to 10¹⁴ ions/cm². While in the case of off-line measurements in air, the intensity of -CH₂-group decreased in the same fluence region. The effect of air leak after irradiation was also examined. It was found that the fluorescence intensity decreased gradually after air leak, and its change terminated within about 30 min. Corresponding to this, the intensity of -CH₂-group also decreased after air leak. The vanished fluorescence seems to relate to some type of radicals. Reacting with the oxygen introduced, they may change themselves to other more stable ones. According to the UV-NIR spectra, the double bond of -C=C-, C=O and OH groups may be created newly in the proton irradiated CR-39 plastics.

Investigation of Heavy Ions Tracks in Polymers by Methods of High Effective Chromatography and Atomic Force Microscopy
Shubnikov Institute of Crystallography Russian academy of Science, Moscow, 117333 Moscow, Leninsky pr.,59.
track@imb.imb.ac.ru

Fine structure of latent track in Polyetelenetherepthtalate irradiated by Xe-ions (energy about 1 MeV/amu, fluence 10⁸ ions/cm², accelerator U-400, JINR, Dubna) was investigated by two methods. AFM-technique was used for examination of polymer surface. Special technique of “step-by-step” treatment by water and KOH-solution at definite temperatures was developed for “visualization” of different areas around the track. The chemical composition of these areas was investigated by inverse-phase chromatography for testing radiolysis products from different track regions.

It was shown that latent-track region have complicated structure and consists of four different areas. The first one (with diameter D₁ = 7 ± 1.5 nm) – carbon-like central area around the track axis. The second area (D₂ = 17.5 ± 3 nm, “destruction area”) is the region of polymer macromolecules decomposition; radiolysis products are proposed to be the aromatic eithers. The next two areas were found to be the regions of cross-linking: area of “dense cross-linking” (D₃ = 50 ± 5 nm) and the area of “weak cross-linking” (D₄ = 150 ± 5 nm). It is proposed that radiolysis products from these areas are eithers of therephthalic acid.

This complicated track structure could explain the disagreement between previously results, obtained by different methods. The track structure was found to determine etching speed and resulting porous shape.

The Experimental Study on the Aging Process of the LR115 Cellulose Nitrate Radon Detector
M. Siems¹, K. Freyer², H.C. Treutler², Gilbert Jönsson³, Wolfgang Enge¹

¹Institut für Experimentelle und Angewandte Physik, University Kiel, Olshausenstr. 40-60, D-24118 Kiel, Germany
²Umweltforschungszentrum Leipzig-Halle, Permoserstr.15, D-04318 Leipzig, Germany
³Lund Institute of Technology, Box 118, S-22100 Lund, Sweden
siems@physik.uni-kiel.de

An experimental determination of the aging process of cellulose nitrate detector material was based on the examination of special properties of the LR115 solid state nuclear track detectors (SSNTD) of various ages up to 18 years. The examined relevant parameters are the bulk etching rate vₐ and the track etching rate vₜ. These parameters are responsible for the appearance, the size and the registration efficiency of tracks of alpha particles from radon gas on the detector. To find a correlation between these material parameters and the detector sensitivity an experimental calibration of indoor room and outdoor soil detector devices based on LR115 took place at the Umweltforschungszentrum Leipzig-Halle (Germany). To avoid routine calibration work in external Radon exposure facilities a correction of the age dependent calibration factors with the material parameters measured in one’s own laboratory was targeted. In this study a general age dependence, however, was not found. The following statements for practical applications can be made. (i) the bulk etching rate vₐ for detectors of the same batch has a depth...
dependence and this dependence is constant over two years. (ii) detectors of different batches older than five years and stored at room temperature show an odd behaviour when \( v_b \) is used for describing track shapes. (iii) the calibration factor of detectors of different batches that were stored at about +4°C is constant over five years.

The conclusion is that LR115 detectors not older than five years and stored in a refrigerator at about +4°C should be preferred for radon measurements. Furthermore these detectors should be recalibrated every year and the microscope work of this calibrations should be performed by the same person that performs the measurements.

In addition a phenomenon related to fundamental track formation mechanisms was found, it is that the time straggling of the moment when vertical tracks penetrate the 12\( \mu \)m thick detector layer is independent of the age of the detectors and the energy of the alpha particle at the detector surface.

Keywords: LR115, cellulose nitrate, aging process, bulk etching rate, track etching rate, alpha particles, Radon, calibration factor, registration efficiency, time straggling

The Role of Low-Mass and Cross-linked Degradation Products in Formation and Local Structure of Latent Tracks in Polymers

Vladimir Hnatowicz
Nuclear Physics Institute, 250 68 Rež, Czech Republic
hnatowicz@ujf.cas.cz

New simple model [1] describing local track structure as a result of chemical reactions of transient degradation products produced by heavy ions in polymers is described. The results obtained with the model on radial track structure, track etching and other track properties are compared with existing experimental data.


Depth-dependence of the Bulk Etch Rate of Gamma-ray Irradiated CR-39 Track Detector

Tomoya Yamauchi, Hirotaka Ichijo, Keiji Oda
Department of Nuclear Engineering, Kobe University of Mercantile Marine, 5-1-1 Fukaeminami-machi, Higashinada-ku, Kobe 658-0022, Japan
yamauchi@cc.kshosen.ac.jp

Many studies have been performed on the etching characteristics of gamma-ray irradiated CR-39 plastic track detector from view-points of (1) understanding the fundamentals of damage formation in it and (2) application as high dose gamma-ray dosimeters. On the first point, we have been clarified that the bulk etch rate increased exponentially with absorbed dose under a certain conditions of a constant dose-rate and the surrounding atmosphere. It was also found that the bulk etch rate depended on the dose-rate significantly. This was explained by the model, in which the rate of damage formation may be proportional to the concentration of oxygen dissolved as well as the dose-rate. In air irradiation, we have succeed in giving the experimental equation for the bulk etch rate which was described as a function of both dose and dose-rate. Therefore, on the second point, it is impossible to use CR-39 plastics as a gamma-ray dosimeter only by measuring its bulk etch rate, because there exists various combinations of total dose and dose-rate for a given bulk etch rate.

In this study, we have investigated the depth-dependence of the bulk etch rate of gamma-ray irradiated CR-39 detector. The CR-39 plastic used in this study was BARYOTRAK (Fukuvi Chemical Ltd., Japan). Before gamma-ray irradiation, the every samples were bombarded by fission fragments from Cf-252 source. Gamma-ray irradiation was made at doses between 1 kGy to 100 kGy. The dose-rate ranged from 0.04 to 10 Gy/s. Chemical etching was made in stirred 6N, KOH kept at 70°C. The bulk etch rate was assessed from the growth behavior of pit radius and their side-view.
The damaged area where the etch rate was enhanced significantly was found to be limited in the thin layer near the surface. The thickness of the damaged area, \(d\), was strongly dependent on the dose-rate, \(R\), but hardly on the total absorbed dose. This relation can be written as;

\[ d = 6.79 R^{-0.272} \]

where \(d\) is in µm and \(R\) is in Gy/s. These indicates that the oxygen provided from the air controlled the damage formation process. A possibility was also found that CR-39 detector can be used as a dosimeter for gamma-ray at high doses, by assessing both the bulk etch rate and the thickness of the damaged area.

### Excess Electrons in the Near-threshold Spectral Region of Intrinsic Photoconductivity of Liquid Water and Alcohols

Jean-Marc Jung

Université Louis Pasteur et Institut de Recherches Subatomiques 23, rue du loess, 67037 STRASBOURG

jean-marc.jung @ ires.in2p3.fr

The interaction of ionizing radiations with dense matter invariably produces fast electrons which are responsible for the formation of excited neutral species, ions and secondary electrons of low energy. The dynamical behavior of these very unstable species is a lasting problem in fundamental radiation research. In organic and biological matter, for example, low-energy electrons initiate irreversible damages either by direct ionization, or by the production of transient reactive species (radicals, cations, anions); most part of these electrons have kinetic energies below ten electron-volt.

In order to gain a better understanding of the sequence of processes leading to the production of low-energy electrons in irradiated organic and biological matter, we focused our attention on template molecules such as alcohols and water. A new experimental approach has been developed, based on special techniques, in order to measure the one-photon absorption spectra and excess electrons quantum yields of these liquids between 6 and 11 eV. Measurements were performed at the synchrotron laboratory LURE-France with experimental setups developed at the Institut de Recherches Subatomiques (IReS) of Strasbourg.

Initial results have been compared with those of the literature [1] and with the excitation spectra of delayed recombination fluorescence measured previously by us in alkanes [2]. The analysis of the full set of data leads to a precise interpretation of the observed spectra (thresholds, laws and mechanisms of transient species production) and shows unambiguously the significant role played by the production of electron-hole pairs within the non-radiative relaxation processes. In particular, our analysis confirm the importance of the mechanism of intermolecular charge transfer, whose efficiency is at least of the same magnitude as that of the ionization process in this spectral region. First-ionization potentials of neat liquid water, methanol and other alcohols have also been determined for the first time.

He - Ne Laser Transmission Through Etched CR-39 and CN-85
Ammar A. AL-Sa'ad, Sa'eed J. Abbas

Physics Dept., Science College, Basrah University, Basrah, IRAQ

The new method which proposed by Groetz et al. for reading the SSNTDs by He-Ne laser scattering has been applied, in this work, on the irradiated CR-39 and CN-85 with neutrons and alpha particles. The intensity of the transmitted laser light through the etched SSNTD was measured by a photodiode. The method is appeared as a good technique for dose reading and extremely depend on the etching time, the type of incident particles and the type of the detector. In general, the response of CN-85 was find to be faster and better than CR-39.

Dielectric Response of SHI Irradiated and Prestine Polymers
M.Mujahid1, D.K.Avasthi2, S.Gupta2, D.S. Srivastava1

1Department of Applied Physics,Z.H. Engg. College,AMU, ALIGARH-202002, India
2Nuclear Science Centre, Aruna Asaf Ali Road, New Delhi-110067, India

Study of dielectric response reveals the types of chemical species present in the polymer sampler resulting from chemical changes caused by SHI irradiation. Its study also sketches the atomic picture, viz, how non-polar molecule induces dipole moment when placed in electric field. Its value of dielectric constant for irradiated samples are more than those for the pristine and appear to increase with increasing dose. At a particular dose the dielectric value remains constant for low frequencies and then decreases. The increase in the dielectric values on irradiation has been attributed to the increase in rigidity of the polymer. Variation of dielectric loss with frequency for the Li, Ni, O and Si irradiated polycarbonate plastic at single fluence shows that loss in O irradiated sample decreases and loss in O irradiated samples increases with frequency because thermal orientation of segments or group of polymeric materials are facilitated due to bond dissociation of O irradiated samples while cross-linking effects decrease molecular motion in Si irradiated samples.

A High-Frequency Plasma Discharge Effect on Poly(ethylene) Terephthalate Films Irradiated by Heavy Ions
Lyubov Kravets1, Serguei N. Dmitriev1, V. V. Sleptsov2, V. M. Elinson2

1Joint Institute for Nuclear Research, Flerov Laboratory of Nuclear Reactions, 141980 Dubna, Russia.
2Tsiolkovsky Moscow State Aviation Technological University, 121552 Moscow, Russia
kravets@nrsun.jinr.dubna.su, sasha@kurts.msk.ru

We have investigated the effects of plasma discharge on poly(ethylene) terephthalate (PET) films exposed to heavy ions. PET films of a thickness of 10 µm exposed to 1 MeV/nucleon xenon ions at the U-300 cyclotron (FLNR, JINR) up to the track density 9⋅10^7 cm^{-2} were used at the experiments. To raise the sensitive of the latent tracks, the films were irradiated by ultraviolet and then treated by plasma and finally etched. The plasma treatment was performed at a plasma-chemical setup (MSTAU) providing RF-discharge of 13.56 MHz frequency. Only one side of the films was exposed to plasma. Nitrogen and a mixture of nitrogen and cyclohexane in the ratio of 1:3 were used as plasma-forming gases. Discharge parameters (gas pressure and discharge power) and duration of plasma effect were varied. Etching the samples is performed in a conductometrical cell with a 3 mol/l water solution of sodium hydroxide at 60°C.

It has been shown that the non-polymerizing gases plasma effects the PET films irradiated by heavy ions and leads to decreasing the etching of both the tracks and the initial polymeric matrix itself. The tracks etch rate (longitudinal
and radial) and the polymer etch rate depend on plasma discharge parameters, i.e. increasing the discharge parameters leads to decreasing the etch rate. Changes in etching the tracks and the polymeric matrix at gas-discharge plasma treatment of the PET films irradiated by ions lead to appearing an asymmetric structure of the track membranes formed at the chemical etching. As electron microscopic investigations have shown, the pore diameter on the side exposed the plasma treatment is less than the pore diameter on the opposite side not treated by plasma. The latter can be explained by decreasing track etch rate caused by a modification maybe stitching of the polymer’s surface layer at the plasma effect.

The effect of the plasma of polymerizing gases on the PET films irradiated by heavy ions also leads to decreasing in the tracks’ etching. This results from a formation of a thin polymeric chemically resistant diamond-like film (DLF) on their surface of one of the sides (treated with the plasma) retarding the etchant effect. The chemical etching of the PET films irradiated by heavy ions with the deposited DLF layer leads to formation of composite semipermeable membranes whose selective properties result from the DLF characteristics. Changing the time of etching in an organic compounds plasma and the composition of the plasma-forming gas allows one to vary a width of the deposited polymeric layer and the selective properties of the formed composite membranes.

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**γ and Electron Studies from 10 kGy to 1000 kGy on Lexan and CR39**

Letitia Tavera¹, G. Muñoz², Miguel Balcázar¹, G. Jiménez¹, Arturo López¹

¹Instituto Nacional de Investigaciones Nucleares, Apartado Postal 181027, México D F 11801, México

²Universidad Autónoma Metropolitana, Av Michoacan y La Purísima, Iztapalapa, México D.F. 09340, México

mtd@nuclear.inin.mx

A wide dose range of doses from 10 kGy to 1000 kGy of gamma and electron radiation was employed to study the response of CR-39 and Lexan nuclear track detectors. Gamma radiation from Co-60 source and 1.3 MeV electrons from a Van de Graaff accelerator were used to irradiate several samples of CR-39 and Lexan plastic detectors. The radiation effects in these plastics were evaluated by UV, IR and EPR spectrophotometry and also by their bulk etch rate variation with dose. The chosen UV wavelengths for Lexan and CR-39 were 330 and 292 respectively, outside the absorption peak due to the saturation in the dose range studied. The increasing bulk etch rate for both plastics fit to two functions, one linear and one exponential. Physical and chemical effects of low LET radiation in these plastics are derived from spectrophotometry studies.

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**Calculation of Internal Track Lengths of Fast Ions on Annealed Olivine**

Valery Ditlov

Institute of Theoretical and Experimental Physics, B.Cheremushkinskaya str. 25, 117259 Moscow, Russia

valery.ditlov@itep.ru

In work [1] there was proposed a calculation method of internal etched track lengths $L(Z)$ in olivine for different ions $Z$. From calibration in region $Z$ of Fe-group there were presented result of $L(Z)$-calculation for all elements of Periodic Table. The results of calculations showed a good coincidence with experimental data for relativistic ion of U.

We defined as track cross-section the expression

$$\sigma(s, Z) = \int_0^\Lambda P^*_\nu(Z, s, \rho) d\rho$$

($P^*_\nu(Z, s, \rho)$ - spatial distribution of local responses over track volume $(s, \rho)$ of ion $Z$. Then we considered, that only that part $L(Z)$ of track can be etched out, for which

$$\sigma(s, Z) > \sigma_o$$

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20th International Conference on Nuclear Tracks in Solids: Book of Abstracts
In this report we consider dependence of the tracks on annealing temperature. For it we propose, that the characteristic stopping power value \( (dE/ds)_0 \) depends on annealing temperature:

\[
\frac{\mathcal{L} dE}{\mathcal{L} ds \rho_0} = A_0 \cdot \varepsilon^{\frac{\varepsilon}{kT}}
\]

(3)

Where \( \varepsilon \) - activation energy, \( k \) - Boltzman constant.

We calculated \( P_n(Z, s, \rho, T) \) and found values \( A_0 \) and \( \varepsilon \) from calibration for some ions. After that we could calculate the dependence \( L(Z,T) \).


Generation of Etchable Damage by Electrons. Preliminary Data
M.L.Gisele Saint-Martin\(^1\), Omar Bernaola\(^1\), I. Nemirovsky\(^2\)

\(^1\)Radiobiology Department and \(^2\)Physics Department, National Atomic Energy Commission, Argentina
bernaola@cnea.gov.ar

Several authors suggest that the fundamental mechanism of track formation in organic materials can be associated with the generation of secondary electrons by the interactions of the ion with the material. Although the effect of electrons in irradiated organic material has been previously reported, the possibility of "simulating" etched tracks for irradiated zones smaller than 0.1 µm\(^2\) and for electrons energy of a few keV has not been studied.

In the present work, Nuclepore filters of 0.09, 0.16 and 0.30 µm pore diameter with a Pt-C surface deposition were used as electron beam collimators. Makrofol E, 300 µm foils were irradiated with the 20 keV electron beam of a Philips 300 electron microscope, interposing the Nuclepore filters. In this way zones damaged by electrons were obtained. After etching with PEW solution "etch pits" could be observed as in the case of ion tracks. The measured diameters are greater than the original corresponding pore diameter, and no variation was observed with irradiation time. The results show that electron produced damage can be etched and enhanced as in the case of ion tracks.

Rainbow-Vicinage Effects in Latent Track Registration by High Energy Molecular and Cluster Ions
Lewis T. Chadderton\(^1\), Stephen J. Buckman\(^1\), Salvador A. Cruz\(^2\)

\(^1\)Atomic and Molecular Physics Laboratory, Research School of Physical Sciences and Engineering, Australian National University, Canberra, ACT 0020, Australia
\(^2\)Departamento de Fisica, Universidad Autonoma Metropolitana -Iztapalapa, Apartado Postal 55-534, 09340, Mexico D.F., Mexico
lewis.chadderton@anu.edu.au

New and comprehensive experimental results* on the angular dependence of the differential cross section for elastic scattering of low energy electrons (0-10 eV) from diatomic molecules (eg N\(_2\)), and of the energy dependence of the total cross section reveal, for the first time, the presence of a double 'rainbow' - a ubiquitous quantum mechanical consequence of sequential scattering**. For diatomic molecules the electron wave is essentially attractively screened-Coulomb scattered from the first atom, and focused onto the second.

The inverse problem in physics is the stopping of a high energy molecular ion by a free electron gas. We show that this orientation effect leads to a high energy stopping power for diatomic molecular ions in solids which is greater
than the sum of the parts (non-linear stopping), and that electron 'friction' generates a centro-symmetrical torque on the second atom forcing it, ultimately, into a trailing position - on the trajectory - behind the first. The relationship of this phenomenon to the electron 'wake' is also discussed.

This inverse rainbow phenomenon may be described as a first-order vicinage effect in electronic stopping, and is readily shown to operate for track registration by high energy cluster particles with increasing number of constituent atoms n (e.g. 40 MeV C$_{60}$ projectiles). There is also an additional and new detailed dependence of stopping power on projectile size, structure and orientation (compare, for example, a simple linear hydrogen or nitrogen molecular ion with the larger and near-spherical C$_{60}$), and on the orientation of any single crystalline target.

For 40 MeV C$_{60}$ track-producing projectiles in yttrium iron garnet there is a second-order gross vicinage effect by means of which the leading part of the fullerene cluster creates a hot plasma through which the trailing part must pass - further enhancing the energy loss. Initially all 60 carbon atoms are completely stripped of electrons, so that the carrot-like tailing structure of tracks observed in the TEM, and the very short projected ranges, are due to progressive pick-up of orbital electrons in the slowing-down process. Branching of the tracks is shown to be due to a cascade of carbon displacements in the projectile - triggered by a single high-angle ballistic collision event, which leads to "fission" of the cluster. Electronic and nuclear stopping are never completely separable.

We have observed compounded 'giant' rainbows in low energy electron scattering from the planar molecule benzene. This strongly suggests that an experimental investigation of track formation by high energy benzene cluster ions, and a more quantitative study of vicinage effects with amorphous (random) and single crystalline targets, would in this case be very fruitful in further understanding the detailed physics of track registration.

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**Chadderton, L. T., Buckman, S. J. and Cruz, S. A. to be published (2000).
Radial Variation of Track Damage in Polycarbonate

D.H. Francisco¹, L. Vanni¹, Omar Bernaola¹, M.L. Gisele Saint-Martin², W. Kirschbaum², A. Filevich³

¹Buenos Aires National University, ²Radiobiology Department and ³Physics Department, National Atomic Energy Commission, Argentina
bernaola@cnea.gov.ar

Several techniques can be applied to analyse the radial distribution of damage around the ion incidence axis. The observation of tracks in Makrofol at submicroscopic level by transmission electron microscopy, showed four different zones: core, halo, cross linking region and bulk. Data obtained for specific energies higher than 0.5 MeV/n were reported in previous works. Nevertheless there is a lack of experimental data for low specific energy values, where the thermal spike process prevails.

In the present work data corresponding to the evolution of the track diameter of ions with 2.6 and 0.09 MeV/n are reported. For ions of 2.6 MeV/n the four typical zones are easily identified. Conversely for 0.09 MeV/n ions the experimental curve variation is smooth and the difference between regions is not clear. These data could be explained by the effect of the thermal spike process. This process would induce a partial mixing of the material corresponding to different zones.

On Selection Rules of Crystals for Latent Track Registration

Lewis T. Chadderton¹, Dietmar Fink²

¹Atomic and Molecular Physics Laboratory, Research School of Physical Sciences and Engineering, Australian National University, Canberra, ACT 0020, Australia
²Hahn-Meitner-Institut Berlin GmbH, Glienicker Str. 100, D-14109 Berlin, Germany
lewis.chadderton@anu.edu.au

Experiments (TEM) on the production of radiation damage in single crystals of silicon, graphite, fluorite and yttrium iron garnet by energetic charged projectiles (fission fragments, GeV heavy ions, and MeV cluster ions) are compared and contrasted. It is shown that both the absence of latent tracks in some targets, and the detailed structure of real tracks in others, cannot be explained by any model of an idealized thermal spike. Theoretical considerations of track formation based on direct 'melting' into an amorphous state (or other irreversible phase transitions), on the simple linear and macroscopic thermodynamics of immediate electron/lattice energy transfer, and on time-attenuated Gaussian temperature distributions mostly fail to provide any adequate embracing description of the damage in different targets.

We show that there are very specific crystal lattice properties which ultimately determine the nature of the latent track, if there is one. For silicon and graphite a mechanism referred to as particle activated prompt anneal (or PAPA) can take place*. A reverse cooling and annealing wave permits recovery by epitaxy of the 'random' disorder induced by the primary heat wave. Radiation enhanced recovery processes may also play a role (the divacancy in silicon). For fluorite it is the one-dimensional <100> dynamics (and also, later, diffusion) of molecular crowdions on the anion sublattice (Vₖ centres) which leads to a linear intermittent array of faceted calcium colloids on the projectile trajectory. Only in the case of yttrium iron garnet does the track 'width' have any meaning here, but even in this case in order to describe track structure due to molecular clusters it is necessary to allow for first and second order vicinage effects in non-linear electronic stopping.

Bragg's rule (1905) for the additivity of electronic stopping due to the atomic components of a compound target, considered 'random', fails totally for real single crystal targets. The orientation of the target, and of the projectile - for molecular and cluster (e.g C₆₀) projectiles - also has a strong influence on latent track characteristics.

In the face of atomistic (defect) and lattice (non-linear phonon) processes which determine the shape and form of heterogenous latent track formation computer programs based on random targets (e.g. TRIM or SHIM) do not apply.
And for single crystals it is now necessary to lay down selection rules for track registration based on real crystal response - lattice structure and target orientation, specifically dominant point defect mechanisms, and on vicinage effects in stopping power which have so far been neglected.


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### Modifications in Etching Characteristics and Surface Topography of Some Electron Irradiated Polymers


1Department of Physics, North-Eastern Hill University, Shillong-793 022, India.
2Hahn-Meitner Institute, Glienicker Strasse 100, D-14109 Berlin, Germany.
3Arunachal University, Rono Hills, Itanagar-791 111, India.

kkdwivedi@yahoo.com; kkdau@hotmail.com

Particle track technology offers the opportunity of fabricating membranes with cylindrical pores of defined pore size and adjustable porosity. Track formation in polymers is a complex phenomena due to involvement of not only primary but also secondary processes such as formation of radicals and chemical processes etc. Electrons are low LET radiations, which mostly affect the physical and chemical properties of polymeric films without creating etchable tracks. In the present work, impact of 2MeV electrons on the etching properties and the surface topography of Polyethylene terephthalate and Polyimide are studied.

(1) The electron irradiated polymers were further exposed to fission fragments from $^{252}$Cf source and the track registration properties were studied. The etch-rate values were found to be increased by electron irradiation. The activation energy for bulk etching was found to be decreased by about 10% in Polyethylene terephthalate and by about 34% in Polyimide. This increase in the etch-rate values is presumably due to the scissioning of the polymeric chain caused by electron irradiation.

(2) Atomic force microscopy was used to image the surface topography and to quantify the surface roughness properties of the electron irradiated polymers in the nanoscopic level. The surface roughness of both the polymers was found to be reduced due to electron irradiation. The results are presented and discussed.

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### Proton Induced Modification in Polyethylene Terephthalate (PET)


1Arunachal University, Rono Hills, Itanagar-791 111, India
2Department of Physics, North-Eastern Hill University, Shillong-793 022, India
3Hahn-Heine Institute, Glienicker Strasse 100, D-14109 Berlin, Germany

Polymer irradiation induces several intra-chain and inter-chain modifications leading to irreversible changes of the structure and the chemical composition which includes the processes such as radical formation, main-chain scission, inter-molecular cross-linking, creation of unsaturated bonds, loss of volatile fragments etc. The nature of the defects and the relative radiation sensitivity of different polymers depends on properties such as composition and molecular weight of the polymer, mass and energy of the impinging ion and environmental conditions during irradiation. The aim of our study was to describe the proton induced modifications in Polyethylene terephthalate (PET) by using Fourier transform IR, Thermogravimetric analysis, Differential scanning calorimetry, X-ray diffraction, Atomic force microscopy and Track techniques. PET samples were irradiated to four different doses (viz. 1 Mrad, 3 Mrad, 6 Mrad and 8 Mrad) of 62 MeV protons from heavy ion accelerator (ISL) at HMI, Berlin. The modification in different properties of PET as a function of dose were studied. Oxidative degradation of the polymer leading to amorphisation was observed with increase in proton dose. X-ray diffraction spectra of the irradiated PET showed a shifting of the main peak with simultaneous reduction in its intensity. It indicates a distortion of the crystal structure due to proton irradiation. Thermal stability of PET was found to be decreasing with increase in dose. The bulk-etch
rate of PET was found to be increasing with dose (about 60% for the PET irradiated to the highest dose). The proton irradiation led to a reduction in the activation energy. The proton irradiation has caused chain scission in the PET making it an easily etchable polymer.

Novel Ultra-Fast Luminescence from Incipient Ion Tracks of Insulator Crystals
Kazuie Kimura, Sumit Sharma, Anatolijs Popovs
RIKEN (The Institute of Physical and Chemical Research)

Recently, we found a novel ultra fast luminescence by measuring time-resolved luminescence spectra (resolution of 80 ps) of heavy-ion-irradiated \( \gamma \)-alumina. Further measurements on single crystals of LiF, NaF, NaCl, KCl, KBr, KI, Rbl, CsCl, CsBr, CsI, MgO, SiO\(_2\), and diamond revealed the corresponding luminescence except for SiO\(_2\) and diamond. The luminescence showed the following common characteristics:

1) The ultra-short lived (<100 ps)
2) The wavelength different from all known bands and unusually broad band widths.
3) The super-linear increase in efficiency with an increase in the excitation density.
4) The decay rate and the efficiency invariant to temperature changes.

The results show that the luminescence does not originate self-trapped excitons, free excitons, excited defects, and excited impurity centers, that is, is not the localized excited state, but multiply bound states among short-lived (at most 100 ps) excited states. The state which suits these characteristics may be the e-h plasma or the free exciton complex, considering that almost all energy deposited by ions (as large as a few hundred eV/\( \mu \)m along the ion track) is given to electronic systems to produce e-h pairs.

Theory and Experimental Observation of Neyman’s Statistics Violation and Nonlinear Dependence «Doze-Effect» in Track Biodetectors in Area of Low Doses
Vitaly D. Rusov, Tatyana N. Zelentsova, M.M. Ovsyanko, I.S. Melenchuk
Odessa Polytechnic University, Department of theoretical and experimental nuclear physics 1, Shevchenko av., Odessa, 270044, Ukraine

Based on the developed biophysical model of radiation effects the new cascade-stochastic approach for a solution of direct and inverse tasks of statistics of radiation-induced effects in track biodetectors is offered. This approach contains all possibilities as for identification and quantitative analysis of ionizing radiation (biospectrometry) and for study of a stochastics of energy transfer in living cells (microdozimetry).

The obtained results show that the statistics of radiation-induced effects in cells within the framework of the considered experiments is well described by doubly stochastic Poisson processes, controlled by an exponential response function \( h(x) \). It is confirmed by the comparative analysis of the theoretical and experimental distributions of the micro-nuclei on human lymphocytes cells irradiated by X-radiation in the area of low doses (0.1-1.0 Gy).

The analysis of experimental data has allowed to establish a nonlinear character of «doze - effect» dependence in the area of low doses, and to detect essential increase (in 1.3 times) of sizes of biodetector sensitive volume (nuclear chromatin) at doses over 0.4 Gy. Based on thermodynamic theory of biological phase transition induced by low doses the quantitative and qualitative explanation of the physical mechanism of a nonlinear response human lymphocytes of a type «doze - effect» to action of low doses of X-radiation was given. For the first time the new determination of relative biological efficiency and quality coefficient of ionizing radiation in area of low doses are proposed.
A New Method to Measure the Range and to Study the Structure of ECE Tracks in Polycarbonate Detectors

Mehdi Sohrabi*, S. Hosseini Toudashki and M. Taheri

National Radiation Protection Department, Atomic Energy Organization of Iran, P.O. Box 14155-4494, Tehran, Iran

m.sohrabi@iaea.org; msohrabi@cic.aku.ac.ir

A new method is introduced here by which the structure and dimensions, in particular the range, of electrochemically etched (ECE) tracks of alpha particles, as example, were investigated in polycarbonate (PC) detectors, in the registration range of 0.3 to 1.8 MeV. The ECE alpha tracks were treated by a solution of ethylendiamine in water having a high bulk etch rate (50 µm h\(^{-1}\)), as it was recently introduced in our laboratory. Precise layers of PC were removed from the front or back side of ECE tracks. For dimension and range studies, layers removed were from the backside. Based on the results, a three dimensional structure of the post ECE treated tracks was simulated by computer, as shown below.

Simulation of a 1 MeV \(\alpha\)-Particle track after post-ECE treatment

An ECE track looks like a jar with breakdown trees spreading from the mouth to the bottom. So the term “range” means the depth or height of the jar. The diameter is the maximum diameter (MD) of an ECE track, as observed under a microscope; i.e. MD of the jar. While the MD in PC depends strongly on alpha energy, its range has less dependency. The diameter of opening mouth is usually less than 10 µm. Under the applied conditions, MD ranges from \(~90\) µm at 0.3 MeV to \(~60\) µm at 1.8 MeV. The range increases from \(~57\) µm at 0.3 MeV to a maximum of \(~70\) µm at 1.5 MeV after which strongly decreases to \(~50\) µm at 1.8 MeV. Both the MD and the range indicate that the treeing process in an ECE track spreads more horizontally than perpendicularly; i.e. more in the sides than in depth. In this paper, the method, structure and dimensions in particular the range, and computer simulation of ECE tracks are presented and discussed.

*Presently at the Department of Nuclear Safety, International Atomic Energy Agency, Vienna, Austria; E-mail:M.Sohrabi@iaea.org
Optical and Electrical Properties of Gamma Irradiated PADC Detector

Dipak Sinha¹, T. Phukan², S.P. Tripathy³, R. Mishra³, Kamal K. Dwivedi⁴

¹Department of Chemistry, Nagaland University, Lumami, Mokokchung-798601, Nagaland, India.
²Department of Physics, Guwahati University, Guwahati-781014, India.
³Department of Physics, North-Eastern Hill University, Shillong-793022, India.
⁴Arunachal University, Rono Hills, Itanagar-791111, India.

sam@nehus.ren.nic.in

PADC (Polyallyldiglycol carbonate) detector subjected to gamma rays undergoes change in optical and electrical properties. The optical band gap is determined using Tauc’s plot. The band gap is found to be unchanged up to the dose of 10³ Gy, and then start decreasing with increasing dose. The band gap is lowered from 4.04 eV for the pristine material to 2.46 eV for the highest dose (10⁶ Gy). The dielectric constant of the detector is influenced due to the gamma exposure. At lower doses (upto 10⁴ Gy), the detector seems to be not polarised, so no change in dielectric constant is observed. But at the dose of 10⁵ Gy, the value is increased slightly while at highest dose (10⁶ Gy) the dielectric constant of the detector is found to be enhanced significantly.

Photoparticle Production in Solid State Detectors Used for Neutron Dosimetry in Presence of Photons

M. Anwar Chaudhri¹, P. D. Allen²

¹Abt. Med. Physik, Radiologische Universitaetsklinikum, Univ.of Tübingen, Germany
²Australian Radiation Laboratory, Yallambie, Melbourne, Australia

Anwar.Chaudhri@gmx.net

Photon-induced neutron, proton and alpha particle production in polythene and CR-39 has been estimated for the photon energy range of 2-30 MeV, using our established method and the photo nuclear cross section data for hydrogen, carbon and oxygen. The rarer isotopes of the constituents of CR-39 and polythene, namely H-2, C-13, O-17 and O-18 have been taken into account. Neutrons and protons are produced in these materials for photon energies of as low as 2.2 MeV, the (gamma, np) threshold for H-2. Photoparticles produced in these materials must therefore be taken into consideration when using them for neutron dosimetry in the presence of photons of greater than 2.2 MeV, especially when the expected neutron flux is several orders of magnitude less than that of the photons.
The Method of Trajectory Tracing of $Z < 20$ Ions in the Energy Region Below 300 MeV/u

Jure Skvarc$^1$, Alexander Golovchenko$^2$

$^1$Institut “Jožef Stefan”, Jamova 39, 1001 Ljubljana, Slovenia
$^2$Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia

We present a method which enhances the measurements of charge removal and other reactions with etched track detectors by tracing trajectories of charged particles through a stack of detectors. Using an automatic track analysis system with computer controlled microscope we measure track positions with accuracy of better than 5 µm. Measured positions of tracks from different detectors along the stack are combined using pattern matching algorithms. For particles which undergo significant scattering from the original perpendicular direction the trajectories are connected manually using a specially developed program which shows track positions throughout the stack. Using the technique we are able to analyze the destiny of each individual particle thus reducing the error in analysis and possible confusion with background events such as radon tracks and bubbles in the detector. For this method to be operational, a complex track information system using database server and several client programs was developed.

A New Method to Measure Track Density and to Differentiate Nuclear Tracks in CR-39 and LR-115 SSNT Detectors

Daniel Palacios Fernández$^1$, Francisco Palacios Fernández$^2$, Laszlo Sajo-Bohus$^1$ and Jozsef Pálfalvi$^3$

$^1$Universidad Simón Bolívar, Caracas, Venezuela.
$^2$Universidad de Oriente, Santiago de Cuba, Cuba.
$^3$AEKI-Atomic Energy Research Institute, Budapest, Hungary.

sajobohus@netscape.net

An alternative method to count and to differentiate nuclear tracks in SSNTD is described. The method is new and is based on analysis of Fraunhofer diffraction pattern formed when a beam of coherent light crosses the track left in an etched CR-39 SSNT detector. This new method to process etched tracks was also simulated applying computational Fourier Optic. Comparison between results obtained by simulation and by theoretical model gave satisfactory concordance demonstrating the validity of the method. Statistical error for diameter tracks distribution is less than 1% while count error when varying distribution of tracks is about 3%. Discrimination of genuine etched tracks from defects and background anomalies is demonstrated. The incidence angle did not influence significantly the total count and the method discrimination capability. Errors in determinations due to track overlapping are only significant for track densities higher than $10^6$ cm$^{-2}$. The proposed method allows to determine number of tracks also in LR-115 detectors with good approximation and the method is capable to differentiate tracks for their diameter and for ion energies with great accuracy and precision in CR-39. The ion mass discrimination of tracks is a weak part of the method and improvement is under consideration.
3-D Confocal Microscopy Track Analysis: A Promising Tool for the Determination of CR-39 Response Functions

François Vaginay, Michel Fromm, Geert Meesen, Alain Chambaudet, André Poffijn

1Laboratoire de Microanalyses Nucléaires, La bouloie, 16 route de Gray, 25030 Besançon Cedex, France.
2Department of Subatomic and Radiation Physics, University Gent, Proeftuinstraat 86, B-9000 Gent, Belgium.

In general, the response function \( S(R) = V_T/V_B \) and the reduced etch ratio \( (V_T/V_B - 1) \) are determined using geometrical parameter measurements: the variation in track length or track diameter versus the etching time. First, the response function of CR-39 detectors irradiated with normal incident Li ions with various energies has been measured by different teams [1] using a sequential etching process, as proposed by Doerschel [2]. These measurements were carried out under an optical microscope coupled with an image analyzing system. The technique was very time consuming and strenuous. The manual scanning, as well as the differentiation step, needed to obtain the \( V_T(t) \) from the curves \( L(t) \) increase the influence of the "human parameter". Indeed, all the teams that participated in the inter-comparative study of the Li in CR-39 response function observed some deviations when using the sequential etching method.

The proposed method is based on the use of the confocal microscope, which provides three-dimensional track images [3]. The obtained set of 3-D co-ordinates can be treated mathematically, giving the diameter (D), the length (L) and, in the framework of the two etch-velocity models, the \( V_T \) and \( S \) for one single track. Contrary to the method using stepwise etching and conventional optical microscopy, with this new approach, tracks are analyzed one by one; \( V_T \) and \( S \) functions are obtained for each track. Moreover, the method we propose is applied semi-automatically and could easily be automated in the near future.

The results presented in this paper deal with the \( V_T \) in the vicinity of the Bragg-Peak. The proposed method can also be used where high energy ions are studied. In that way, \( V_T \) can be considered as constant and the model is simplified.

[1] T. Yamauchi and al., "Inter-Comparison of Geometrical Track Parameters and Depth Dependent Track Etch Rates Measured for Li-7 Ions in Two Types of CR-39". This conference.

Parametric Studies of Different Shapes of Radon Dosimeters Using Monte Carlo Simulation Technique

Khalid Jamil, Ashiq Hussain Dogar and Safdar Ali

Environmental Radiation Group, Radiation Physics Division, PINSTECH, P.O. Nilore, Islamabad, Pakistan

Research conducted in various countries revealed that radon (\(^{222}\)Rn) in mines cause carcinogenic effects on miners. It is, therefore, important to develop methods to mitigate the radon in closed environments. The first step towards mitigation is the measurements of radon concentrations in a closed environment. Different laboratories of the world use various shapes and sizes of radon dosimeters. A Computer code based on Monte Carlo method has been developed to compare the working of these dosimeters. This code simulates a cylindrical as well as a spherical dosimeter mounted with a CR-39 track detector. The code is capable of computing track densities ( \( \# \text{ cm}^{-2} \)) from a known value of radon concentration (Bq m\(^{-3}\)), detector efficiency, and dosimeter efficiency. In some cases the computed values have been experimentally verified. The Monte Carlo simulation has been used to determine the optimum dimensions of the radon dosimeter. To economise the mass production of these dosimeters the optimum size and shape would be very conducive.
Measurements of High Energy Neutrons by Fission-Induced Reactions

Rakesh Kumar Jain¹, A. V. Prokofiev², Andrei N. Smirnov², Luigi Tommasino¹

¹National Agency for Environmental Protection. ANPA, 00144 Rome, Italy
²V.G. Khlopin Radium Institute, St. Petersburg 194021, Russia
e-mail: LARA@ANPA.IT

In most high energy radiation fields, such as those encountered around accelerators or in cosmic rays in the atmosphere, neutrons produce the largest percentage of the hadron dose. In these radiation fields, the neutron spectrum is typically formed by low energy neutrons (evaporation spectrum) and high energy neutrons (knock-on spectrum). Neutron spectrometry and dosimetry is better understood for low energy neutrons (i.e., neutrons with energy below 20 MeV) than for those of higher energies. This paper reports the study of different detectors based on the registration of fission fragments in different heavy elements (namely bismuth, gold and tantalum), which have their principal response to high energy neutrons.

Scanning Film Pictures to Determine a Nuclear Beam Profile

Vera Bradnova, Boris Aleksandrovich Kulakov

Joint Institute for Nuclear Research, 141980 Dubna, Russia
bradnova@sunhe.jinr.ru

This paper describes technique to obtain geometrical parameters of the charged particles beams by scanning their film pictures.

Process is presented by the following way:

Source - original (photo…) → Scanner → Output: file BMP → Converter bmp → txt → Loading-processing (Excel, Origin e.t.c) → Results

The original of two kinds were used:
- reflecting black and white Polaroid photo and
- transparency black and white film with nuclear emulsion

This method allows also receiving results from strongly irradiated polymeric detectors, when microscopic account of tracks is impossible.

Using a Confocal Microscope for the Extraction of Track Parameters in CR-39 SSNTDs

François Vaginay¹, Michel Fromm¹, Geert Meesen², Alain Chambaudet¹, André Poffijn²

¹Laboratoire de Microanalyses Nucléaires, La bouloie, 16 route de Gray, 25030 Besançon Cedex, France
²Department of Subatomic and Radiation Physics, University Gent, Proeftuinstraat 86, B-9000 Gent, Belgium

A lot of studies have been carried out to determine the response function of various Solid State Nuclear Track Detectors. Such functions are usually used in the field of dosimetry, but also for particle identification. Scanning Electron Microscopy observations of track replicas is the most commonly used technique for measuring track parameters in SSNTDs for short etching times. Optical microscopy is usually used for longer etching times. These
techniques are tedious when used in routine mode. Thus, we propose using a Confocal Microscope to measure the geometrical parameters (diameter and length) of Li-tracks in CR-39 to obtain the response function $V^{-1}$.

Samples of CR-39 (Tastrak, Track Analysis Systems Ltd, United Kingdom and Baryotrak, Fukuv Chemical Ltd., Japan) were perpendicularly irradiated with Li ions of several energies in the tandem accelerator of the Rossendorf Research Center. The irradiated samples were etched in NaOH, 7.25 N solution at $70^\circ$C for different etching times. After staining the CR-39 with the fluorochrome “Nile Blue A”[1], a BioRad MRC-1024 confocal microscope was used to record 3-D images of the tracks in fluorescent mode. Semi-automated image analysis routines were used to extract the geometrical parameters [2].

The method used for determining the track etch velocity ($V_T$) is based on the track length ($L$) measurements for several etching times [3] using the following relation:

$$V_T(t) = \frac{dL(t)}{dt} + V_B$$

where $V_B$ represents the bulk etch rate.

The diameter, length measurements and $V_T$ curves obtained using the confocal microscope have been compared with our recent results [4] obtained with the optical microscope. The advantages of this new method (accuracy, 3-D images, automatic measurements etc...) have also been discussed.

[4] T. Yamauchi et al., Inter-Comparison of Geometrical Track Parameters and Depth Dependent Track Etch Rates Measured for Li-7 Ions in Two Types of CR-39, this conference.

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**Theoretical Estimation of Sensitivity for the Cup Type SSNTD Radon Measurements**

**Bassam Aharmim, A. Sabir**

Laboratoire de Physique Nucléaire et Applications, Faculté des Sciences BP 133 Kenitra Morocco

bassam.aharmim@caramail.com

In this work sensitivity of radon measurements with solid state nuclear track detector (LR-115) in cylindrical chamber was determined theoretically. The concept of the constructed simulation was based on a combinative between: (1) a steady state macroscopic mass-balances model, used to determine the partitioning of short-lived radon progeny between airborne and surface deposited states within the detecting volume. (2) A Monte Carlo calculation to estimate partial detection efficiencies for $^{222}$Rn, $^{218}$Po and $^{214}$Po, based on a determined LR-115 response described in a companion paper and a residual range of alpha particles in air. Validation of the expected sensitivities by these models is presented in the form of comparisons between theoretically computed values and experimentally determined ones; the agreement has been found satisfactory.

**Keywords:** Radon measurements, SSNTD, Monte Carlo simulation, detection efficiency, mass-balances model, sensitivity.
Software Development for Physical and Chemical Applications

E.G. Boulyga, Sergei F. Boulyga

1 Mathematician, self-employed, Pr. Slobodskoj 6-201, 220025, Minsk, Belarus
2 Central Department of Analytical Chemistry, Research Centre Juelich, D-52425 Juelich
3 Radiation Physics and Chemistry Problems Institute, 220109 Sosny, Minsk, Belarus

s.boulyga@fz-juelich.de

In spite of the fact that modern analytical instruments are equipped with corresponding software there is a need in software development for some special analytical tasks. The paper presents the results of algorithms and software development in the field of physical and chemical computing and image analysis. A computer programs are described for recognition of nuclear tracks on the SSNTD surface and for determination of microdistribution of betta-irradiation intensity in nuclear emulsions. Furthermore a software package is described, which calculates induced activities of isotopes after irradiation in a known neutron field, thermal and epithermal neutron fluxes from the measured induced activities and from nuclear data of 2-4 monitor nuclides as well as the element concentrations in samples irradiated together with monitors using k0-method of neutron activation analysis. The programs are developed using object oriented environment and operate in Windows 3.1 or higher.

Type Tests of An Extremity Ring Dosemeter Provided by a Brazilian Dosimetry Service

Eudice Vilela, R.A. Lima, M.S. Nogueira, A.L. Ferreira Filho, W.A. Castro

CRCN/CNEN, R. Cônego Barata, 999. 52110-120 Recife PE, Brasil
vilela@irpmai.bologna.enea.it

Data concerning calibration and type tests of an extremity system based on XD100 rings (Harshaw) are presented. Dosemeter used is a thermoluminescent chip inserted in a sealed pouch and was read out using a Harshaw 6600 reader. Aiming to reduce the lower detectable dose and to improve reproducibility of response, two different methods of analysis were carried out and compared. The first performed a background correction based on an average value obtained from the evaluation of a group of non-irradiated dosemeters and manually subtracted. The second method employed a glow curve deconvolution algorithm. The dosimetric system complied with all ISO/DIS 12794-1 draft report suggested tests, in which this work was based on. This work obtained results point to the applicability of those recommendations to Brazilian institutes, which can be adopted by the national regulatory commission.

Simultaneous Measurement of Radon, Radon Progeny and Thoron Concentrations Using Makrofol-DE Detectors

Khalil Amgarou, Lluis Font, Carlos Domingo, Francisco Fernandez, C. Baixeras

Grup de Física de les Radiacions. Edifici Cc, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain

In this study we describe the set up of a new passive integrating system to measure simultaneously radon, radon progeny ($^{218}$Po and $^{214}$Po) and thoron concentration indoors. It consists of four Makrofol-DE (polycarbonate) circular foils. Two are enclosed within two diffusion chambers $\lambda$ each one with different filter membrane $\lambda$ to measure $^{222}$Rn and $^{222}$Rn + $^{220}$Rn. The other two foils are kept in direct contact with air and are electrochemically etched at different conditions to obtain the radon progeny. Theoretical sensibilities of each Makrofol-DE foil are calculated using Monte Carlo technique. The calculations are performed taking into account: 1) the Bethe-Bloch’s expression for the stopping power of heavy charged particles in a medium, 2) the properties and behaviour of radon, thoron and their progeny in the open air and within the diffusion chamber, and 3) the etch-track formation process. Preliminary results of both experimental and theoretical studies are compared and discussed.
Measurement of Indoor $^{222}$Rn Using CR-39 Under a Thin Film Geometry

Rodrigo Neman$^1$, I.D. Schmitman$^1$, Julio Cesar Hadler Neto$^1$, P.J. Iunes$^1$, S.R. Paulo$^2$, Sandro Guedes Oliveira$^1$

$^1$Instituto de Física “Gleb Wataghin”, Universidade Estadual de Campinas, UNICAMP, SP, Brazil
$^2$Departamento de Física, Instituto de Ciências Exatas e da Terra, Universidade Federal de Mato Grosso, UFMT, 78060-900, Cuiaba, MT, Brazil.
rsneman@ifi.unicamp.br

In this work an assembly for indoor $^{222}$Rn measurement is presented. This assembly is made up by two acrylic plates (14 cm x 14 cm) separated by a distance of 4 mm. To avoid that radon daughters from outside can enter the assembly (and produce alpha particle tracks striking the CR-39 detector placed in the central region of one of these plates), the border of these plates were closed remaining open a only rectangular opening of 5 mm x 4 mm. The size of this opening was determined experimentally, by exposing in ventilated environments assemblies with different openings: i) all borders open, ii) two borders closed, iii) three borders closed, iv) four borders closed but one containing a 6cm x 4 mm opening, v) four borders closed but one containing a 2.5 cm x 4 mm opening and, finally, vi) four borders closed but one containing a 0.5 cm x 4 mm opening.

Track density shows a noticeable decrease between “assembly i)” and assembly iii), remaining constant for smaller openings. Only $^{222}$Rn, a noble gas, should enter the assembly independently of the opening size.

Nuclear Track Analysis by a Fully Automated Optical Microscope

Reza Hashemi-Nezhad, M. Dolleiser, J. Slezak

Department of High Energy Physics, School of Physics, A28, University of Sydney, NSW 2006, Australia.
reza@physics.usyd.edu.au

Counting of particle tracks in large track detectors (tens of centimetre long) is feasible only if an automatic track counting system is used. We have developed a Fully Automated Optical Microscope (FAOM) for this purpose. It is shown that track density measurements in SSNTDs can be affected with parameters such as luminosity of the sample, use of light filters, colour of the light filters and variations in the thickness of the sample. We used FAOM to investigate the effects of above mentioned parameters on the track density measurements in LR-115 IIB detectors of 31 cm long that were exposed to spallation neutrons.
A PC Compatible Brazilian Software for Obtaining Thermal Histories Using Apatite Fission Track Analysis (AFTA)

Julio Cesar Hadler Neto¹, S.R. Paulo², P.J. Iunes¹, C.A. Tello³, Maria Laura Balestrieri⁴, Giulio Bigazzi⁵, P. Hackspacher¹

¹Instituto de Física “Gleb Wataghin”, Universidade Estadual de Campinas, UNICAMP, SP, Brazil
²Departamento de Física, Instituto de Ciências Exatas e da Terra, Universidade Federal de Mato Grosso, UFMT, MT, Brazil.
³Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista, UNESP, SP, Brazil
⁴Dipartimento de Scienze della Terra, Università di Firenze, Via La Pira 4, 50121 Firenze, Italy.
⁵Istituto di Geocronologia Isotopica del CNR, Via C. Maffi 36, 52100 Pisa, Italy.

hadler@ifi.unicamp.br

In this work a software developed in the Instituto de Física Gleb Wataghin, IFGW, UNICAMP, Campinas, SP, Brazil for obtaining thermal histories using AFTA is presented. This software works in Microsoft-windows environment. It will be freely disposable in the web site of the Departamento de Raios Cósmicos, IFGW, UNICAMP. Thermal histories obtained through this software are compared with Monte Trax (compatible with Apple Mc Intoch) ones, the software developed by Gallagher (Gallagher, 1995).

System for Calibration of Track Detectors Used in Gaseous and Solid Alpha Radionuclide Monitoring

Ana Danis, M.Oncescu, Mariana Ciubotariu

“Horia Hulubei” National Institute for Physics and Nuclear Engineering - IFIN-HH, Department 360, P.O.Box MG-6, 76900 Bucharest, Romania
danis@ifin.nipne.ro

A system for the calibration of track detectors which are used in monitoring of gaseous and/or solid alpha radionuclides / aerosols, is proposed. The system consists of two component parts:
1. The $^{226}\text{Ra}$ calibrated source, fixed in the airtight device by which it meets the requirement to keep on the radioactive equilibrium for all the radioactive descendants of $^{226}\text{Ra}$ after this one was established. As a consequence, the source can assures the producing of gaseous (radon)/solid alpha radionuclides at a constant rate;
2. Alpha monitoring tubular chamber, in which the alpha track monitoring devices are hung at different heights, established by us. The gaseous and solid alpha radionuclides get into this chamber by a connection with the device that contains the $^{226}\text{Ra}$ source, mounted at this chamber base.

The alpha track monitoring device, used by us, was designed and produced in our laboratory. The CR-39 track detectors (Page, England), included in such devices, were calibrated both for the $^{222}\text{Rn}$ gaseous radionuclide and for the solid alpha radionuclides/aerosols using the monitoring device equipped /or not with a special filter for solid radionuclides/aerosols stopping.

Results and discussion on the use of this system for the CR-39 alpha track detector calibration in radon monitoring are given in our paper.

Semi-Automated Analysis of Three-dimensional Track Images

Geert Meesen, André Poffijn

Department of Subatomic and Radiation Physics, University Gent, Proeftuinstraat 86, B-9000 Gent, Belgium.
geert.meesen@rug.ac.be

In the past, 3 dimensional track images in solid state detectors were difficult to obtain. With the introduction of the Confocal Scanning Laser Microscope it is now possible to record 3D track images in a non-destructive way. These
3D track images can latter on be used to measure typical track parameters. Preparing the detectors and recording the 3D images however is only the first step. The second step in this process is enhancing the image quality by means of deconvolution techniques to obtain the maximum possible resolution. The third step is extracting the typical track parameters. This can be done on-screen by an experienced operator. For large sets of data however, this manual technique is not desirable. This paper will present some techniques to analyse 3D track data in an automated way by means of image analysis routines. Advanced thresholding techniques guarantee stable results in different recording situations. By using pre-knowledge about the track shape, a reliable object identification is obtained. In case of ambiguity, manual intervention is possible.

The Reduction in Etching Time for Fission Tracks in Diallyl Phthalate Resin
Takao Tsuruta

Atomic Energy Research Institute, Kinki University, Kowakae, Higashi osaka, Osaka 577-8502, Japan

The diallyl phthalate resin (DAP) is excellent in the detection of fission fragments. The fission fragments can be selectively detected by DAP without the effects of backgrounds of alpha particles or fast neutrons. There was a demand for shortened etching time for the practical use of DAP. In the case of the etching made in an aqueous solution of 30% KOH at 90°C, an etching time of 2-4 hours was required in order to obtain etch-pits suitable for the microscopy. In this study, the PEW solution was tried which previously had been applied to the electrochemical etching of CR-39 by G. Somogyi et al. The fundamental composition of the PEW solution was 15% KOH, 65% ethanol and 20% water. It was found that the etching time can be reduced to 4-8 minutes as a result of adopting the PEW solution at 60°C. The solution enlarges the tracks to greatly expanded elliptic or circular etch-pits on smooth surfaces. This is advantageous for the automatic track counting in the case of low density.

Improvement of Neutron Detection Efficiency with High-Sensitive CR-39 Track Detector
Keiji Oda, Hirotaka Ichijo, Nobumasa Miyawaki, Tomoya Yamauchi

Department of Nuclear Engineering, Kobe University of Mercantile Marine, 5-1-1 Fukae-Minamimimachi, Higashinada-ku, Kobe 658-0022, Japan
oda@cc.kshosen.ac.jp

In early 90’s, we have designed several year ago a dose-equivalent response detector, i.e. boron-doped CR-39 plastic (TS-16) with a two-layer radiator consisting of deuterized dotriacontane and polyethylene. Its sensitivity, however, was not sufficient for practical personnel monitoring because of a lack of sensitivity to higher energy protons. For these several years, the following technical improvements and new situations have motivated us to discuss again promising neutron monitors based on CR-39: (a) grade-up of performance of image processing system, (b) development of high-sensitive CR-39, (c) increase of recommended conversion factor from neutron fluence to dose equivalent, (d) importance of neutron dosimetry in space and around high-energy accelerators, and so on.

Thus, we have estimated the sensitization effect by introducing both high-grade image processor and new CR-39 detector. The efficiency enhanced by CH$_2$ radiator is expressed by following formula:

$$\varepsilon_r = \int_{\Omega} \frac{d\sigma}{d\Omega} dz d\Omega$$

The integral ranges must be reduced by the two conditions in terms of the critical angle and the track size (e.g. track diameter larger than 5 µm for 15 µm bulk etch), characteristic of etched track detectors. If we can reduce the countable track size from 5 µm to 3 µm owing to high-grade image processor, more than 40 % increase in the efficiency is expected by calculating the double integral.
Dr. Ogura et al. (1997) succeeded in developing an extremely high-sensitive plastic, copolymer of CR-39 and N-isopropylacrylamide (NIPAAm), which can record a 27-MeV proton. The new detector can relax the regulation on the integral ranges, and the efficiency is estimated to increase to about 7 times at 10 MeV, 20 times at 20 MeV.

New Detectors of the Basis of Copolymer of Tetrafluoroethylene with Ethylene (PTFE-E)

Vera Shirkova, Svetlana P. Tretyakova

Flerov Laboratory of Nuclear Reactions, JINR, Dubna, 141980, Russia

vera@nrsun.jinr.ru

The registration properties of PTFE-E (F-40, Russia; Tefzel, DuPont, USA; Hostaflon ET, Germany) having exceptional chemical (near to PTFE) and thermal (using temperature is about 300°C) resistance are considered. The polymer specimens were irradiated with ions in a wide region of masses (from O up to Xe) and energies (from 1 to 6 Mev/amu). For etching, KmnO₄ solutions with NaOh at ~100°C were used. It is shown that the polymer registration properties depend on the ethylene content in the copolymer composition. For copolymer with 2-3%wt hydrogen the registration threshold is about 8 Mev cm² mg⁻¹. For copolymer with 1%wt hydrogen the ion tracks were not found after chemical etching. Track membranes were produced and examined.

A Theoretical Design of an Excluded Radon Daughters Plate-out Container

Ammar A. Al-Saad

Physics Dept., Science College, Basrah University, Basrah, IRAQ

A container for exclusion the Radon daughters that plating - out its walls during the radon measurement has been designed theoretically. This container was consist of two parts. The first part has been built depending on the results of the critical angle of etching for α-particles incident with a different energies on the SSNTD, LR - 115 (II), so that any radon daughters plated - out on this part of the container will not be registered.

The second part has been built in a shape that screen any emitted α-particles from the plated - out Radon daughters (²¹⁸Po, ²¹⁴Po) on the internal walls to reach the Plastic Track Etch Detector, i. e. the detector will not see the plated - out daughters.

Manufacturing of the Graphite Calorimeter at Yazd Radiation Processing & Research Center

Farhood Ziaie¹,²,³, A. Karimi⁴, Hossein Afarideh¹,², S. M. Hadji-Saeid¹,³

¹Nuclear Research Center for Agriculture & Medicine, POB 31585-4395, Karaj, Iran.
²Amir Kabir University of Technology, Physics Department, POB 15875-4413, Tehran, Iran.
³Radiation Processing & Research Center, POB 89175-389, Yazd, Iran
⁴Yazd University, Physics Department, POB 89195-741, Yazd, Iran.

ziaie@123iran.com

In recent years, the radiation processing using the electron beam accelerator (Rhodotron type 10 MeV, 100kW) has been introduced in Radiation Processing & Research Center of Yazd/Iran. In electron beam processing, accurate evaluation of irradiation parameters such as absorbed dose is required for quality assurance of irradiation products.

In this work, a few quasi-adiabatic graphite calorimeters with different dimensions have been manufactured and studied for accurate absorbed dose measurements in high-energy electron beam. It is pointed out that a surrounding
ring (graphite jacket) for calorimeter makes an effective role for accurate measurements. In order to prove the accuracy and reliability of the measurements with the graphite calorimeters, an inter comparison study were conducted between made calorimeters (MC) and the Riso’s graphite calorimeters (SC, Standard Calorimeter) at different doses by using Rhodotron accelerator. Our results indicate that for the MC with the optimum size, measurements agree with those of the SC within 1%.

Monte Carlo Simulation of Radon SSNTD Detectors
Octavian Sima

Physics Department, Bucharest University, Bucharest-Magurele, P.O.Box MG-11, RO-76900, Romania
osima@pcnet.pcnet.ro

A Monte Carlo based software for the computation of the calibration factor of etched alpha track detectors was developed. It can be applied to the measurement of radon and radon daughters in free air or inside of a measurement chamber. LR-115 and CR-39 detectors, with or without filter, are specifically addressed. Various etching conditions and observation criteria for counting the track density may be specified. The latent track formation and the etching process are realistically modelled. The dependence of the etch rate ratio on the energy is taken into account. The plate-out phenomenon is included in the model. An inhomogeneous distribution of $^{222}\text{Rn}$ in the detector cup can be considered.

The software combines Monte Carlo computation routines with user friendly interfaces. It can be executed on IBM-compatible personal computers.

An Automatic Image Analysis System for the Evaluation of Dielectric Track Detectors
V.A. Ponomarenko\textsuperscript{1}, J. Molnar\textsuperscript{2}

\textsuperscript{1}Joint Institute for Nuclear Research, 141980 Dubna, Russia
\textsuperscript{2}Institute of Nuclear Research of the Hungarian Academy of Sciences, H-4001 Debrecen, Hungary

An automatic image analysis system was developed for the processing of dielectric track detectors. This system consists of two main parts:

1. Optical-mechanical part: microdensitometer MD-100 equipped with step motors and a CCD camera.
2. Image analyzer: computer IBM compatible PC equipped with FrameGrabber X7 and control block for the step motor movements.

The software developed for the system is to provide the microdensitometer stage motion, the focusing, measuring and counting of the etched nuclear tracks.

Automated Identification and Activity Measurement of Alpha Emitting Particulates of Micron Size Using SSNTD
Yu.N.Onishchuk\textsuperscript{1}, Oleg A.Bondarenko\textsuperscript{2}, S.Yu.Medvedev\textsuperscript{2}, V.M.Petryshyn\textsuperscript{2}

\textsuperscript{1}Kiev National Taras Shevchenko University, Physics Department, Kiev 252022, Ukraine
\textsuperscript{2}Radiation Protection Institute, 53 Melnikov Street, Kiev 253050, Ukraine

Automated approach for alpha emitting hot particulates (HP) processing using SSNTD were described. A result of processing procedure is an activity distribution of HP contained in bioassays. Usage of several exposure periods
gives the possibility to determine activity distributions as high as low active HP. On the first stage the surface of etched detector were scanned using an optical microscope and a motorised stage. Set of parameters determined for every localised track: global co-ordinates on detector surface, an azimuth angle, major and minor axes, a perimeter, an area. On the second stage obtained parameters used for computer analysis which comprises the next several stages: input data filtration (improper tracks and events of some track underlying rejected), cluster (single HP) localisation, determination of a track number for every clusters. The described automated approach was applied for processing of aerosol filters collected at a working zone of a plutonium reprocessing plant.

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Nowadays Possibilities of Gaps and Blobs Measurements in Ion Tracks of Nuclear Photographic Emulsions

Valery Ditlov, V.A.Smirnitsky, E.A.Pojarova, V.I.Krotkova, V.V.Dubinina
Institute of Theoretical and Experimental Physics, B.Cheremushinskaya str. 25, 117259 Moscow, Russia
valery.ditlov@itep.ru

When we use semi-automatic or automatic measurements with help of system “microscope plus computer”, we can easily use mathematical methods of ion identification in regime on/off-line. The longitudinal coordinates of gaps between blobs coincident with longitudinal coordinates of beginning and end of blobs, as gaps are alternating by blobs. If we have these coordinates, we can use simultaneously both methods of gaps and blobs measurements.

In our report we use method Monte-Carlo in the base of which we put Fluctuation Theory of K.S.Bogomolov [1]. We took into account whole statistic of events occurred inside of nuclear emulsion during exposure:

1. Distribution of emulsion microscopic crystal (MC) over size.
2. Probability of a MC meeting of given size in given place.
3. The probability, that effective ionization will be in sensitive area of given MC.

The results of calculation for Z from 1 to 7 are presented and the boundary of Z identification in emulsion type-R2 is discussed.


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The Atomic Force Microscope as a Fine Tool for Nuclear Track Studies

C. Vazquez1, R. Fragoso1, J.I. Golzarri2, Fermin Castillo-Mejia3, Masami Fujii4, Guillermo Espinosa5
1. Depto. de Física, CINVESTAV, IPN, México.
2. Instituto de Física, UNAM. Apdo. Postal 20-364, 01000 México, D.F.
3 Instituto de Ciencias Nucleares, UNAM. Apdo. Postal 70-543, México, D.F.
4 Aomori Univerisity, Faculty of Engineering, 2-3-1 Kabota, Aomori 030-0943, Japan
espinosa@fenix.ifisica.unam.mx

The Atomic Force Microscope (AFM) can be considered as relative new tool for the study of materials used in Nuclear Track Methodology and for the analysis of the Nuclear Tracks them selves. The AFM may be useful to obtain valuable information at the level of atomic structure of the detector materials and of the nuclear tracks, due to its high resolution and very easy operation involving also a simple sample preparation. In this contribution we present the results of the analyses of the surfaces of several polycarbonates and other commercial materials used as detectors, before and after being exposed to ionizing radiation.

Keywords: Atomic Force Microscope; Nuclear Tracks; Surface and Track Analysis.
Saturation of LR-115 Detectors when Spark-Counter Technique is Used for Track Counting
Francesco Bochicchio, Marco Diociaiuti
Istituto Superiore di Sanità (National Institute of Health), Physics Laboratory, I-00161 Roma (Italy)
bochicchio@iss.infn.it

Regulations on radon indoors are generally based on concentration reference values above which remedial actions are recommended or required. An accurate estimate of radon concentration is necessary for the correct application of such regulations. There are many factors that could affect accuracy of radon concentration measurements based on NTD. In this work we deal with an inaccuracy source which is related to the measuring technique. In particular, the saturation of a LR-115 based radon dosemeter, which is widely used in Italy, will be analysed. For this dosemeter a strippable version of LR-115 detectors is generally used, and tracks are counted by spark counters. To estimate saturation effects, some groups of dosemeters have been exposed for different periods in a radon monitored room. Moreover, the area size distribution of aluminum evaporated by sparks during the track counting process has been measured by an image analyser. The results of these measurements will be presented.

Spectrometry of the LET with Track Etched Detectors – Correlation with Proportional Counter Measured Spectra
František Spurný¹, J.-F. Bottollier-Depois², B. Vlcek
¹Nuclear Physics Institute, Czech Academy of Sciences, Prague, Czech Republic
²Dosimetry Department Institute for Nuclear Safety and Protection, Fontenay-aux-Roses, France
spurny@ujf.cas.cz

A spectrometer of the linear energy transfer (LET) based on the chemically etched polyallyldiglycolcarbonate (PADC) track etched detector was developed. The LET spectra are determined through the measurements of track parameters, it covers LET range between 10 and 700 keV/µm in tissue. Combined experimental and theoretical approach permitted to estimate the critical dimensions of the sensitive volume necessary for the developing of a track to several nm. It seemed to us to be interesting to compare the LET spectra obtained with this method with the microdosimetric spectra available on the base of a classical experimental microdosimetry method, a tissue equivalent proportional counter, for which the critical dimensions simulated are of the order of few µm.

Both methods of experimental microdosimetry were compared in the field of neutron sources as well as in the high energy radiation reference fields. It was found out that the microdosimetric distributions are rather similar, the experimental results are confronted with the theoretical estimation.

Monte Carlo Calculations and Experimental Calibrations of Bonner Spheres Systems with a New Cylindrical Helium-3 Proportional Counter
H. Müller¹, J.L. Pochat¹, L. Van Ryckeghem¹, Francisco Fernandez², T. Bouassoule², M. Bakali²
¹Institut de Protection et de Sûreté Nucléaire. Département de Protection de la Santé de l’Homme et de Dosimétrie.
CE/Cadarache. Bât. 159 – 13108 Saint-Paul-Lez-Durance Cedex (France)
²Grup de Física de les Radiacions. Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra (Spain)

The determination of dose equivalent and integral fluence quantities in mixed photon-neutron fields and the characterisation of the neutron energy distribution are possible with a spectrometry system as the Bonner sphere system which covers the whole energy range from thermal energy to 20 MeV. A new set of 13 polyethylene
moderating spheres with a cylindrical counter type ‘F’ was calibrated at P.T.B. (Germany) for I.S.O recommended energies of mono-energetic neutrons (ISO 8529), then the response functions were confirmed by measurements in wide neutron fields (I.S.O.) as Am-Be and $^{252}$Cf, and with the CANEL and SIGMA I.P.S.N. Cadarache (France) facilities, which simulate realistic field and thermal neutron response.

A realistic geometry model of the Bonner sphere is described in detail. The response functions to mono-energetic neutrons between thermal energy to 20 MeV of this new set were calculated with the MCNP-4B code for each moderator and compared to experimental measurements.

### Detection of Colored Tracks of Heavy Ion Particles Using Photographic Color Film

Ken’ichi Kuge¹, Nakahiro Yasuda²,³, Naokazu Aoki¹, Akira Hasegawa¹

¹Faculty of Engineering, Chiba University, Yayoi-cho, Inage, Chiba 263-8522, Japan
²Quantum Engineering and Systems Science, University of Tokyo, Hongo, Tokyo 113-8656, Japan
³National Institute of Radiological Sciences, Anagawa, Inage, Chiba 263-8555, Japan

Photographic emulsion has been used for a long time as a detector of the radiation. We had obtained the black and white image after development and measure track depth and angle in using the depth of field of microscope. When a photographic color film is exposed to radiation particles, the tracks of the particles are obtained not in a black silver image but in a colored dye image. The film consists of several photographic emulsion layers and each layer includes different coupler. As different colors are developed by the coated multilayer emulsions on film, three-dimensional data including track depth and angle in a layer can be obtained. Exposing the photographic color film to heavy ion particles and observing the tracks after color development, we obtained the tracks in different colors which represented the difference of track depth in the photographic film layer. This technique is useful and makes it easier to detect the track depth and angle.

### Track Detection System for Neutron Dosimetry

Vadim A. Nikolaev, I.B. Vorobjev

V.G. Khlopin Radium Institute, 2d Murinski ave., 28, 194021, Sankt-Petersburg, Russia

An express pre-estimation (≤ 15 min) of the dose range at accidents the dosimeter is supplied with the component including a glass track detector. The range of measurements using targets with different thickness and automatic counting of tracks is from 0.1 up to 10000 mSv.
The track monitor-spectrometer DNESTR contains sets of different targets, filters and track detectors registering neutrons by different threshold nuclear reactions \((n, f), (n, a)\) and fragmentation at the range of thresholds from \(\sim\) eV up to \(\sim\) GeV (6-8 types). The variants of sets are installed in the inspected location. After exposure, etching and counting of the track number on the detectors a differential spectrum of neutron energies is determined by a special software. The spectrum data can be used for calculation of the dose in the working rooms at an accident, for obtaining the maps of neutron fields of different hardness, for making dose sensitivity of individual dosimeters more exact.

The set AIST-TRAL is applied for temperature-controlled chemical etching of track detectors and for automatic counting of tracks by an electrospark method.

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**Semi-Automatic System for Chemical and Electrochemical Track Evaluation Based on a Commercial Digital TV-Board**

Khalil Amgarou, Lluis Font, J. Lopez, Carlos Domingo, Francisco Fernández, C. Baixeras

Grup de Física de les Radiacions. Edifici Cc, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain

ll.font@cc.uab.es

A new semi-automatic system based on a commercially available digital TV-board has been set up in our laboratory - as a replacement of the existing technique - to evaluate chemically and electrochemically etched tracks in LR-115 and Makrofol-DE detectors, respectively. This simple and low cost system reduces the required equipment to a Pentium PC of 90 MHz with at least 16 Mbytes of RAM and an operating system of Windows 95 ensuring a good interface with the user. By using a convenient image analysis software the tracks in the specified area are identified with a resolution of 1600 \( \times \) 1200 pixels and the track density is obtained for the corresponding detector. A detailed description of this system and a comparison study with our existing technique are presented in this paper.

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**Development of Radon Pollution Monitoring Technique in Drinking Water Using SSNTDs**

Khalid Jamil, Safdar Ali, Ashiq Dogar

Radiation Physics Division, PINSTECH, P.O. Nilore, Islamabad, Pakistan

kjamil.pins@dgcc.org.pk

Radon \(^{222}\text{Rn}\) in water is responsible for the whole body internal radiation dose that may be more harmful than radon in air. It is, therefore, of paramount importance to study the presence of radon \(^{222}\text{Rn}\) in drinking water. Experiments were performed to develop an economical technique to monitor radon concentrations in drinking water using CR-39 track detectors. Known radon sources were dissolved in known quantity of distilled water kept in air-tight plastic containers. One CR-39 detector was immersed in the water and the other was hung outside in the air of the container. Experiments showed that a linear relationship exists between radon source and alpha track density both in the air and water in the air-tight container. The ratio of the track densities in water to air \(\rho_{\text{water}}/\rho_{\text{air}}\) was determined as \(\sim 35.8 \pm 4.5\). Using the experimentally obtained calibration curve, the radon concentrations (Bq m\(^{-3}\)) in water samples from some cities of Pakistan were determined.
Further Studies on Theoretical Sensitivity of a LR-115 Based Radon Dosemeter

F. Bagnoli¹, Francesco Bochicchio², Silvia Bucci³

¹Dipartimento di Matematica Applicata, Università di Firenze, via Santa Marta 3, I-50139 Firenze, Italy
²Istituto Superiore di Sanità (National Institute of Health), Physics Laboratory, viale Regina Elena 299, I-00161 Roma, Italy
³Fisica Ambientale, ARPAT, via San Salvi 12, I-50135 Firenze, Italy
bochicchio@iss.infn.it

The radon dosemeter used for the Italian National Survey, and presently used by most laboratories in Italy, contains two LR-115 detectors covered by a thin film of absorber used as an energy degrader. The sensitivity of the dosemeter was first studied by means of a simplified model based on three parameters ($E_{\text{min}}$, $E_{\text{max}}$ and the critical angle $\theta_c$) that define the ability of the detecting a track (Bagnoli et al. 1999). In this work the model has been updated introducing the measured values and the functional dependence of $E_{\text{min}}$, $E_{\text{max}}$ and $\theta_c$. The new computed sensitivity has been compared with the experimental values measured as a function of absorber thickness. Moreover, a theoretical estimate of the same dosemeter sensitivity to thoron decay products is given, in open configuration and with an absorber thickness such that radon decay products cannot be detected.


Effect of Variation in the Ambient Temperature on the NIST Encapsulated 222Rn Emanation Standard Source

Mohamed Mansy¹, Hussein M. El Samman², M. Hassan¹, E. Mahfouz², Hoda Eissa¹, Mohammed El-Fiki¹

¹National Institute for Standards (NIS), P.O.Box 136, Giza, Code No. 12211, Egypt
²Physics Department, Faculty of Science, El-Monofia University, El-Monofia, Egypt
mahelfiki@frcu.eun.eg

The effect of ambient temperature variation on radon emanation fraction from the RSM (4968) polyethylene encapsulated $^{222}$Rn emanation NIST standard source was studied using a good constructed chamber for this purpose. The monitoring of the radon emanated from the source was performed by a well calibrated (NIST treatable) Alpha Guard radon monitor. All the sources of uncertainty in the measurements were defined and calculated. The evaluation results indicate that, the effect of decreasing temperature rather than the certification value of the standard source (at $21 \pm 3\,^\circ\text{C}$) has a considerable effect on decreasing of the radon emanated from the source. On the other hand, the radon emanation fraction factor of the source is tendentious to the unity when the temperature was increased to more than $30\,^\circ\text{C}$. The effect of the accumulation time on the radon emanation is very exhibiting whatever the temperature decrease.
Calibration of Radon Monitors and its Associated Uncertainties in NIS Egypt Radon Calibration Chamber

Mohamed Mansy\textsuperscript{1}, Hussein M. El Samman\textsuperscript{2}, M. Hassan\textsuperscript{1}, E. Mahfouz\textsuperscript{2}, Hoda Eissa\textsuperscript{1}, Mohammed El-Fiki\textsuperscript{1}

\textsuperscript{1}National Institute for Standards (NIS), P.O.Box 136, Giza, Code No. 12211, Egypt
\textsuperscript{2}Physics Department, Faculty of Science, El-Monofia University, El-Monofia, Egypt
mahelfiki@frcu.eun.eg

The Radon calibration chamber was designed and constructed in NIS Egypt to development of the NIS Egypt facilities for radon gas measurements with high precision. The factors affecting the calibration process for radon monitors or sources, such as a good sealing, temperature controlling, ventilation ... etc., were taken into account in the design and construction. The experimental half life time of radon inside the chamber was measured in a high ventilation and over normal pressure conditions and it was 90 h with associated uncertainty of ± 1.8%. The temperature has been controlled inside the chamber from 0 to 70°C with a maximum fluctuation of ± 0.3 per °C to provide stable temperature during the calibration. The verification of the calibration inside constructed chamber evaluated a good results. All the sources of uncertainty in the calibration were evaluated.
Escape of Charged Particles at Stopping Annihilation of Antiprotons in the Heavy Nuclei of Nuclear Photoemulsion

Yury Batusov\(^1\), F. Balestra\(^2\), M.P. Bussa\(^2\), G. Piragino\(^2\), G.B. Pontecorvo\(^1\)

\(^1\)Joint Institute for Nuclear Research, Dubna, Moscow region, 141980, Russia
\(^2\)Universita degli Studi di Torino and Istituto Nazionale di Fisica Nucleare, I-10125 Torino, Italy

yuabat@nusun.jinr.dubna.su

"Rare" annihilation channels for antiprotons stopping on heavy (Ag, Br) nuclei of photoemulsion, have been sought. 4872 stops of antiprotons on photoemulsion nuclei are analysed. Events of formation and decay of the hyperfragment \(^4\Lambda H\), escape of \(^8\)He and \(^8\)Li nuclei, one-prong stars with the mean range 79.5 \(\pm\) 5.1 \(\mu\)m of secondary slow "b"-particles are found among the annihilation stars form at \(\vec{p}\) capture on nuclei (Ag, Br). The lower limits for the production probability of \(^4\Lambda H\) and \(^8\)He, \(^8\)Li nuclei per antiproton stopping in the nuclei (Ag, Br) are

\[
W_{^4\Lambda H} = 2 \cdot 10^{-4} \quad \text{and} \quad W_{^8\text{He,}^8\text{Li}} = (1.3 \pm 0.6) \cdot 10^{-3}.
\]

The branching ratio for the production of one-prong stars with the secondary "b"-particles is at least \((1.3 \pm 0.6) \cdot 10^{-3}\). Possible mechanisms for production of these events in annihilation processes are considered.

Heavy Ion Interaction of (14.0 MeV/u) Pb + U

Ehsan-Ullah Khan, Imtinan Qureshi, J.J. Baluch, Muhammad Shahzad, S. Karim, M. Sajid, F. Malik, S.N. Husaini

RPD, Pinstech, P.O. Nilore, Islamabad, Pakistan
ehsan.pins@dgcc.org.pk

The interaction of \(^{208}\text{Pb}\) projectile with \(^{nat}\text{U}\) target has been studied at 14.0 MeV/u beam energy using two different threshold detectors; mica and Lexan. Tracks of reaction products in both the detectors emerging from events of various multiplicities were counted. The partial cross sections belonging to different multiplicities have been measured through the direct counting of relevant events. Our results indicate that while the total cross sections as determined by different detectors agree with each other and with theoretical estimates, there are important differences in partial cross sections which give hint to the emission of the intermediate mass fragments in this reaction. Moreover, the observed events were of two types; one, in which the azimuthal angle between the two consecutive tracks, is \(<180^\circ\). These events apparently seem to be kinematically complete where all the fragments in the exit channel have been registered. In the other group, however, the azimuthal angle between a pair of correlated tracks is \(>180^\circ\). In such events, one can realize that at least one fragment, balancing the momentum of the fragments emitted in the other direction has not been registered due to mass threshold of registration. The difference in the number of these events in two detectors of significantly different thresholds confirms the emission of the intermediate mass fragments.
Fission of Pb in the 4He Induced Reactions at 0.65 - 12.7 Gev

Živojin Todorović¹, Svetislav Savovic², Stevan Jokic³

¹Institute of Physics, P. O. Box 68, 11080 Belgrade, Yugoslavia
²Faculty of Science, P. O. Box 60, 34000 Kragujevac, Yugoslavia
³Institute of Nuclear Sciences "Vinca", P. O. Box 522, 11001 Belgrade, Yugoslavia
savovic@knez.uis.kg.ac.yu

The fission processes from the interactions of 0.65, 1.74, 5.1, 8.8 and 12.7 GeV ⁴He with Pb have been analyzed using the polycarbonate track detector Makrofol in the form of a sandwich. The decay channels ending with one, two, or more (three, four) fragments were detected. We analyzed events in which only two heavy fragments (Z > 20) are detected, irrespective of the existence of coincident intermediate mass fragments (8 ≤ Z ≤ 20). Using the correlation between the common observables which characterize fission events, we identified events originated from thermal (soft) fission and more violent processes. Cross sections, angular distributions and excitation energy have been determined for two fission mechanisms, and their variation as a function of the incident energy has been investigated.

Projectile Fragmentation of Silicon Ions at 490 A MeV

Frank Flesch, G. Iancu, Wolfgang Heinrich

Department of Physics, University of Siegen, 57068 Siegen, Germany
flesch@hig.physik.uni-siegen.de

Fragmentation cross sections are essential input parameters for propagation calculations which describe the effect of shielding against cosmic ray heavy nuclei by the walls of space craft or planetary habitat. Cross sections for the break up of different elements are needed for different types of target material and for a wide range of energy. For this purpose we have extended our studies of projectile fragmentation. By using stacks containing CR-39 track detectors and targets ranging from CH₂ to Pb we have measured total and elemental fragmentation cross sections for fragments with charges Z ≥ 6, for silicon projectiles with energies of 490 A MeV. These new data sets allow us to improve our knowledge about the target and energy dependence of fragmentation cross sections.

Furthermore we have measured the transverse momenta for the projectile fragments produced in interactions of silicon nuclei in different targets. This knowledge about the emission angles of projectile fragments is essential for three dimensional propagation models.

Study of Cluster Decay of 242Cm Using SSNTD

Svetlana P. Tretyakova¹, R. Bonetti², Alexander Golovchenko¹, A. Guglielmetti³, Radomir Illic⁴, Ch. Mazzocchi³, V. L. Mikheev¹, A. A. Ogloblin³, Jure Skvarc⁴, A. Shigin¹

¹Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia
²Institute of Physics (General Applied), University of Milano, Via Celoria 16, I-20133 Milano, Italy
³Russian Research Centre “Kurchatov Institute”, Moscow, Russia
⁴Institut “Jožef Stefan”, Ljubljana, Slovenia
tsvetl@sungraph.jinr.ru

We present data on observation cluster decay ²⁴²Cm → ⁴⁰Si + ²⁰⁸Pb. ²⁴²Cm was produced by neutron irradiation of ²⁴¹Am sample at Kurchatov Institute research reactor IRT. After chemical processing two sources containing about 0.5 mg of ²⁴²Cm each were prepared. The sources were placed in two semispherical vacuum chambers with track detectors (phosphate glasses). The detectors were shielded by Al or plastic foils to stop fission fragments and Al
recoils and deposit in the detectors $20 - 30$ MeV for expected Si clusters. Four runs with total duration 292 days were performed. After irradiation the detectors were treated by normal etching procedure. Element identification was done using the ratio of two etching velocities $V_t/V_g$ and replic method. 15 tracks were identified as those belonging to $^{34}$Si with the energy $(81\pm2)$ MeV. It is in good agreement with expectations. According to the observed events corresponding to cluster radioactivity of $^{242}$Cm its partial half life is $T_{1/2} = (1.4\pm0.4) \times 10^{23}$ s.

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**Energy Spectrum of Stopping HZE-Particles Inside the International Space Station**

**Werner Günter¹, Wolfgang Heinrich¹, Frank Flesch¹, Günther Reitz²**

¹Department of Physics, University of Siegen, 57068 Siegen, Germany  
²DLR Institute of Aerospace Medicine, Radiobiology Section, 51140 Köln, Germany  
guenther@hig.physik.uni-siegen.de  
uni-siegen.de

To measure the energy spectrum of low energy cosmic ray ions inside the ISS we will expose three stacks of CR-39 plastic nuclear track detectors aligned to the three coordinate axes of the space station. In order to suppress all tracks of high energetic particles and to measure only stopping HZE ions with charges of $Z \leq 6$ a special batch of CR-39 detectors with low sensitivity will be used. This detector material has been already tested by an exposure at the GSI accelerator to carbon ions. The energies at the stack surface of the experiment can be determined by the ranges of the reconstructed trajectories of the ions inside detector material. First results of an earlier experiment of this type, which was performed inside the MIR space craft, were reported at the last conference. Here we present additionally the measured spectra of iron nuclei for two perpendicular directions inside MIR and compare the results to model predictions.

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**Total Fragmention Cross Sections of 158 A GeV Lead Ions in Copper and Cr-39**

Shahid Manzoor¹, Imtinan Qureshi¹, Mukhtar Rana¹, Muhammad Shahzad¹, G. Sher¹, M. Sajid¹, Hameed Khan¹, G. Giacomelli², Miriam Giorgini², G. Mandrioli², Laura Patrizii², V. Popa³, Paola Serra³, V. Togo²

¹Radiation Physics Division, PINSTECH, Islamabad, Pakistan  
²University of Bologna and INFN, V. Berti Pichat 6/2, Bologna I-40127, Italy  
manzoor@bo.infn.it

A stack of CR-39 detectors with thick copper target was exposed to 158 A GeV Pb$^{207}$ ions at the CERN-SPS beam facility. The objective of this experiment was to find out the total fragmentation cross sections of ultra-relativistic lead ions with the target material and also with the constituents of CR-39 (C, H & O). The exposure of this stack was performed at normal incidence with a fluence of about 1500 ions/cm². The total number of lead ions in each spill was about $7.8 \times 10^4$ and there were eight spills incident on the stack. The lengths of etched cones on one face of the CR-39 were measured at three different positions in the stack. From this measurement procedure, a new calibration curve has been generated. Based on the charge identification, the total fragmentation cross-sections of 158 A GeV Pb$^{207}$ ions in Cu and CR-39 have been measured.
The Fission Systematics of (15.9 MeV/u) Au Ions in Polymer CR-39
Imtinan Qureshi, Ashiq Dogar, Amjad Farooq, Muhammad Shahzad, Shahid Manzoor, Hameed Khan
Radiation Physics Division, Pinstech, P.O.Nilore, Islamabad, Pakistan
imtinan.pins@dgcc.org.pk

It has been demonstrated that the high-energy heavy ions undergo fission while propagating in dielectric solids. Since these materials act as particle detectors because of their ability to retain primary ionization damage, which can be fixed and enlarged with chemical etching, therefore, in principle, a complete kinematical analysis of fission events is possible. The crucial question in this regard is the availability of well-calibrated range-energy relation, which is necessary for mass identification. We have developed an analytical method to convert the geometrical parameter of fission fragment tracks into physical parameters using an equation which expresses velocity as a polynomial of mass and range. In the case of (15.9 MeV/u) Au ions incident normally on CR-39, we have found about 300 events which can be categorized as in-flight fission of Au ions inside the body of the detector. Mass distributions and cross sections of fission events have been calculated.

Determination of Z/ß for Strange Quark Matter Candidates with CR-39 Track Detector
Masami Fujii¹, A. F. Saad¹, Y. Hatano², A. Osawa², T. Saito², T. Yamamoto², T. Hasebe³, T. Nakamura¹, H. Sasaki¹, T. Yanagita¹, M. Aglietta⁶, S. Vernetto⁶, A. Castellina⁶, W. Fulgione⁶, O. Saavedra⁶, G. C. Trinchero⁶
¹Faculty of Engineering, Aomori University, 2-3-1 Kobata, Aomori 030-0943, Japan
²Institute for Cosmic Ray Research, University of Tokyo, Tokyo, Japan
³Waseda University, 3-4-1 Okubo, Shinjuku, Japan
⁴Department of Physics, Kochi University, Kochi, Japan
⁵Gumma College of Technology, Gumma, Japan
⁶Istituto di Cosmogeofisica del CNR, Torino, Italy
fujii@aomori-u.ac.jp

Anomalous massive nuclei of charge of Z = 14 and mass of about 370 amu were observed for the first time in cosmic rays by a balloon launched from Sanriku, Japan in 1990. These nuclei are supposed to be SQM (Strange Quark Matter). In order to search for SQM with a higher detection sensitivity, a series of international balloon experiments was conducted under the collaboration between Japan and Italy.

The second balloon carrying a heavy instrument was launched from the Milo station, Sicily in 1997. This instrument is a hybrid system combining a counter telescope and passive detectors. The counter telescope is composed of scintillation counters, Cherenkov counters and multi-tube proportional counters, which respectively can measure the charges, velocities and trajectories of incident particles. The passive detectors of 1 m² in area are composed of X-ray films, nuclear emulsion plates and CR-39 plates.

Seven events have been picked up as SQM candidates from the analysis of the counter signals. Now it is highly required to determine Z/ß for these events independently from scintillation and Cherenkov counters. Tracing of tracks from the counter telescope to the passive detectors and the determination of Z/ß for these events will be discussed at the conference.
Search for Massive Rare Particles with the MACRO Track-Etch Detector at Gran Sasso
Laura Patrizii

Department of Physics, INFN, Viale Berti Pichat, 6/2, I-40127 Bologna, Italy
patrizii@bo.infn.it

Searches for massive penetrating particles in the cosmic radiation have been performed with the MACRO nuclear track detector used as "stand alone detector". In absence of candidates, updated estimates of the flux upper limits are presented for magnetic monopoles and nuclearites as slow as $\sim 10^5$ c.

Identification of Ultra–Heavy Cosmic Ray Ions Recorded in Polycarbonate Detectors Using a Corrected Bethe–Bloch Formula
Carlos Domingo, J. Font, C. Baixeras, Lluis Font, Francisco Fernandez

Grup de Física de les Radiacions. Departament de Física, Universitat Autònoma de Barcelona. E-08193 Bellaterra, Spain
ll.font@cc.uab.es

A "corrected" Bethe–Bloch formula has been obtained by adding several terms to the well known "uncorrected" expression, with the aim of extending its applicability to a wider range of charges and energies of the incident ions and of stopping materials. Of these "new" terms, only a few are found to be relevant for energy loss calculations of fast ions with charge $Z \lambda$, 65 passing through nuclear track detectors (NTDs): the Mott correction, the relativistic Bloch correction, and the density effect. The Restricted Energy Loss (REL) track formation model assumes that only the energy deposition due to distant collisions of the incident ion with the absorber atoms contributes effectively to track formation. In this work, cosmic ray ions with $Z \lambda$, 65 recorded in polycarbonate track detectors on the Ultra Heavy Cosmic Ray Experiment are identified using the "corrected" expression, and the influence of each of the "new" terms on the ion identification process through the REL model is investigated. The charge uncertainty achieved is compared to that obtained using the "uncorrected" expression.

Multifragmentation Induced by GeV 4 He Beams
Bojana Grabez

Institute of Physics, P.O.Box 57, 11001 Beograd, Yugoslavia
grabez@atom.phy.bg.ac.yu

Multifragmentation of natAg and Au induced by 7 GeV and 14.4 GeV 4He has been investigated by using CR-39 plastic track detector. Since our experimental technique enables the determination of the multiplicity of intermediate mass fragments (IMF’s) with uncertainty of only a few percent the results obtained point out the inconsistency in the data regarding this quantity reported by other authors. To investigate the source size and the time dependence of multifragmentation reaction we also calculated the small- and large-angle relative velocity correlations between coincident intermediate mass fragments. Of particular relevance to this analysis is the very low energy threshold for IMF’s in our experiment ($E/A \sim 0.3$ MeV in comparison with $E/A \sim 0.7$ MeV in counter experiments) what enabled the careful examination of the sub-Coulomb component of the multifragmentation yield. These fragments originate from the most highly excited residues and their relative velocities are particularly sensitive to the source size and the breakup time. Our results indicate that the production times of fragments are dependent on their atomic numbers and that the breakup times are dependent on the violence of the primary collision.
Characteristics of Heavy Ion Tracks in Bubble Detectors

Shi-Lun Guo\textsuperscript{1}, Li Li \textsuperscript{1}, Tadayoshi Doke\textsuperscript{2}, J. Kikuchi\textsuperscript{2}, Atsushi Kyan\textsuperscript{2}, Eiichi Yoshihira\textsuperscript{2}, T. Kato\textsuperscript{2}, T. Murakami\textsuperscript{3}

\textsuperscript{1}China Institute of Atomic Energy, P. O. Box 275 (96), Beijing 102413, China.
\textsuperscript{2}Advanced Research Institute for Science and Engineering, Waseda University, 17 Kikui-cho, Shinjuku-ku, Tokyo, 162-0044, Japan.
\textsuperscript{3}National Institute of Radiological Sciences, Division of Radiotoxicology and Protection, Anagawa 4-9-1, Inage-ku, Chiba\_shi 263-8555, Japan.

\texttt{guosl@iris.ciae.ac.cn}

Characteristics of tracks created by heavy ions in bubble detectors have been studied in detail by using four categories of super long (23 cm) self-made bubble detectors and six kinds of high energy heavy ions: 290 MeV/u $^{12}\text{C}$, 600 MeV/u $^{28}\text{Si}$, 650 MeV/u $^{40}\text{Ar}$, 500 MeV/u $^{56}\text{Fe}$, 400 MeV/u $^{84}\text{Kr}$ and 290 MeV/u $^{132}\text{Xe}$. The following characteristics of heavy ion tracks in bubble detectors have been recognized:

1. Heavy ion tracks are lines of tiny bubbles, which are measurable in positions, lengths and directions.
2. Threshold property is verified to be the governing factor for track formation. The essence of the threshold seems to be critical rate of energy loss ($dE/dX$). The threshold of 3 categories of the detectors are $1.69\pm0.03 \text{ MeV mg}^{-1}\text{cm}^2$, $2.23\pm0.06 \text{ MeV mg}^{-1}\text{cm}^2$ and $6.04\pm0.80 \text{ MeV mg}^{-1}\text{cm}^2$, respectively, which are appropriate to detection of heavy ions.
3. Maximum track length $L_m$ (distance between the starting point and ending point over the threshold) is fixed in a given category of detectors for a given kind of heavy ions, which proposes a new approach to identification of high energy heavy ions by maximum track lengths in bubble detectors.
4. The linear bubble density $dN/dX$ (number of bubbles in unit length of track) in some part of the track is correlated with the energy loss rate $dE/dX$ of heavy ion in the detector. This characteristics proposes another independent way to identify heavy ions through the $dN/dX$-$dE/dX$ relationship in bubble detectors.

The values of thresholds obtained in this study have been applied to estimation of the parameters in bubble formation mechanisms. This paper gives details in calibrations, derivations, conclusions and prospects of applications of heavy ion tracks in bubble detectors.

Keywords: Track formation; Heavy ion; Bubble detector; Track detector; Threshold detector; Identification of Heavy ion.

The Relative Abundance of Actinides in the Cosmic Radiation

Justin Donnelly\textsuperscript{1}, Denis F. O’Sullivan\textsuperscript{1}, Alexander Thompson\textsuperscript{1}, L.O’C Drury\textsuperscript{1}, K.-P. Wenzel\textsuperscript{2}

\textsuperscript{1}Dublin Institute for Advanced Studies, School of Cosmic Physics, 5, Merrion Square, Dublin 2, Ireland
\textsuperscript{2}Space Science Dept. of ESA, ESTEC, Noordwijk, The Netherlands

\texttt{jd@cp.dias.ie}

The DIAS-ESTEC Ultra Heavy Cosmic Ray Experiment (UHCRE) on the Long Duration Exposure Facility (LDEF) collected approximately 3000 cosmic ray nuclei with $Z>65$ in the energy region $E>1.5 \text{ GeV/nucleon}$ during a six year exposure in Earth orbit. The entire accessible collecting area of the solid state nuclear track detector (SSNTD) array has been scanned for actinides, yielding a sample of thirty (from an exposure of about 150 $\text{m}^2 \text{ sr y}$). The observed charge spectrum will be presented. Ongoing refinement of calibration procedures, track response studies and analysis of systematic errors will be reported and their importance with respect to charge assignment and overall resolution will be examined. The current best value for the cosmic ray actinide relative abundance, $(Z\Lambda_{88})/(74\Lambda_{87})$, will be given. This value will be considered in the context of the predictions of source/propagation models.
Investigation of Cosmic Rays and Their Secondaries at Aircraft Altitudes
Denis F. O'Sullivan, D. Zhou
Dublin Institute for Advanced Studies, School of Cosmic Physics, 5 Merrion Square, Dublin 2, Ireland
dos@cp.dias.ie
A very extensive study of the radiation field at aircraft altitudes has been carried out over the last few years. These investigations formed part of a European wide collaboration involving several laboratories with extensive experience in cosmic ray research and/or dosimetry. Among the main topics investigated were the charge spectra, LET spectra, anisotropy and dose values. The measurements were performed on subsonic and supersonic flights covering a wide range of altitudes and latitudes. Comparisons are made with the results of other experiments and theoretical estimates using computer codes.

Determination of Charge States of Single Swift Heavy Projectiles by High-Energy Deltaelectrons
Matthias M. Meier
German Aerospace Center, Institute of Aerospace Medicine, DLR, Porz-Wahnheide, Linder Höhe, D-51147 Köln, Germany
matthias.meier@dlr.de
The effective charge state is an important particle parameter which is required for the calculation of many effects concerning the interaction of radiation and matter such as an estimate of the radial dose of swift heavy projectiles, stopping power and so on. First formulae for the determination of the effective charge state in equilibrium in dependence on the ion velocity, which had been checked experimentally, were published in the 1960s. The experiments were based on measurements of the stopping power of elements up to argon and velocities corresponding to about 20 MeV/n. The development in the field of particle accelerators led to the availability of higher velocities even for heavier particles for which these formulae turned out to become less applicable. A new method for the determination of effective charge states of heavy ions is the measurement of the number of high-energy deltaelectrons for known particle velocities with a CCD-detector, which is even applicable to operation with single swift heavy ions.

SSNTD Studies of Lead Nuclei Fission Induced by 0.5 and 1.0 GeV Protons Inside Massive Hg, Pb and U Targets
Vladimir P. Perelygin¹, Radka I. Petrova¹, G.P. Kniazeva¹, O.S. Zaveriokha¹, Boris Kulakov⁵, Misha I. Krivopustov⁵, Reinhard Brandt², M. Ochs¹, Peter Vater², J. - S. Wan²
¹Joint Institute for Nuclear Research, 141980, Dubna, Russia.
²Kernchemie, FB 15,Philipps-University D-35032 Marburg, Germany.
A series with experiments was carried out with 0.5 GeV protons accelerated at SYNCROPHASOTRON LHE, Dubna, which hits massive Hg, Pb and U target. The beam profiles and volume intensities of both primary relativistic protons secondary fast particles - mainly neutron were measured using polyterephtalate plastic track detectors inside the massive cylinder metallic block target mentioned above by counting of fission fragment tracks due to the induced fission of Pb nuclei. The beam diameter increases typically at the depth 10 cm of the target. With decreasing of the proton energy from 1.0 GeV to 0.5 GeV the number of fast projectiles drops down very significantly at the depth 20 cm.
It means that the effective thickness of heavy metallic target for the electronuclear transmutation reactor assembly shall not exceed 20 cm for proton energy 0.5 GeV and 25-30 cm for 1.0 GeV protons. The further studies of beam profile and energy spectra of secondary particles inside massive heavy metal targets with different threshold target nuclease are planed.

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**Fission of Copper Induced by (1068 MeV) \( \bar{\pi} \) Using CR-39 Detector**

Imtinan Qureshi, Muhammad Shahzad, G. Sher, Shahid Manzoor, Mukhtar Rana, Hameed Khan, R. J. Peterson

Radiation Physics Division, PINSTECH, P.O. Nilore, Islamabad, Pakistan
Nuclear Physics Laboratory, University of Colorado, Boulder, Colorado, 80309, USA

Imtinan.pins@dgcc.org.pk

The fission cross section of Cu, induced by (1068 MeV) \( \bar{\pi} \) has been studied using CR-39 track detectors. A thin film of Cu target was sandwiched between two detectors and a stack comprising of four such sandwiches was exposed to a beam of negative pions at LAMPF, USA. The detectors were scanned for fission fragment tracks after etching in 6N NaOH at 70 °C. It was found that there is a marked asymmetry of of registered tracks with respect to the forward and backward hemisphere. This asymmetry could be accounted for on the basis of momentum transfer to the struck nucleus. The fission cross section of the reaction is measured and compared with the values found in the literature for same target but different energies of the negative pions.

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**Track Density Gradient in the Meteorite Silicate Crystals: Modified Measuring Technique to Obtain Energy Spectrum of the Cosmic Ray VH-NUCLEI**

Leonid Kashkarov, G.V. Kalinina

Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow 117975, Russia.

ugeochem@geochem.home.chg.ru

One of the notable problem in the investigation of the solar system matter history is determination of the low energy (EA100 Mev/nucleon) spectrum of the cosmic ray VH-nuclei, tracks from which are observed in meteorite silicate minerals [1]. With this aim slope (index \( \alpha \)) of the track-density gradient with the depth in separate crystals was measured, and on the base of experimentally found relation of \( \alpha=1.17\gamma^{0.605} \) [2] the spectral index \( \gamma \) of the differential energy spectrum \( dN/dE=A\cdot E^{-\gamma} \) can be accounted. However there are some uncertainties: (i) environmental conditions during of irradiation of the meteorite matter, and (ii) geometry factor connected with observation of tracks on the randomly oriented internal polished and etched crystal surface.

Recently we reported the first observations of some particularities of the VH-nuclei tracks in a number of ordinary chondrites containing no solar noble gases [3,4]. This report presents the results obtained by the track-density gradient measuring undertaken on individual olivine crystals separated from the Chainpur LL3, Khohar L3 and Tieschitz H3 chondrites. In so doing we used modified measuring technique, when the chemical etching and account of tracks are performed on the three normally oriented each other internal polished surfaces in the crystals under investigation. Angular and track-length distributions also were measured for each analysed crystal surface. It allowed us to obtain as much as possible the high slope of a track density variation vs crystal depth. Corresponding energy spectra of VH-nuclei with \( \gamma=(0.7±2.0) \) were registered that is suggested to the essentially more energy-rigid irradiation in comparison with VH-nuclei of the contemporary solar cosmic rays with \( \gamma\approx 3 \) [5].

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The Particularity of the Pseudorapidity Distributions in Proton and Heavy Ion Collisions in Nuclear Track Emulsion at Energies from 4.5 to 200 A GeV

Galina I. Orlova

P.N. Lebedev Physics Institute of Academy of Sciences of Russia (LPI), Leninsky prospect 53, 117924 Moscow, Russia

orlova@sci.lebedev.ru

The regular deviations of the experimentally observed pseudorapidity distributions of a particles produced in the ultrarelativistic proton and heavy ion interactions in nuclear track emulsion from their Gaussian fit are found.

It is shown that the shape of said deviations is very stable and is not directly connected with the pseudorapidity distribution itself. The deviation curve only shifts with the incident energy, but significantly weaker then the pseudorapidity density distribution itself. The form and position of the deviation curve is not depend of the mass and centrality of the colliding system. The reason of the effect may be the rescattering of the produced particles inside the target nucleus.

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About Imitation of Anomalous Cosmic Ray Carbon’s Tracks in CN-Kodak

M.A.Kondratyeva¹, Charmen A.Tretyakova¹, Svetlana P.Tretyakova², D.A.Zhuravlev¹

¹Skobeltsyn Research Institute for Nuclear Physics, Moscow State University, Moscow 119899, Russia
²Joint Institute for Nuclear Research, Dubna 141980, Russia
tsvetl@sungraph.jinr.ru

For observation of law energy cosmic ray particles we use expositions of CN-Kodak nuclear track detectors on Cosmos satellites. In solar quiet periods during solar minima conditions the detectors registrate anomalous cosmic rays (ACRs). The ACRs are characterized by flux enhancements of several elements and it being known that the carbon enchancement is small compared with that of oxygen. In all our quiet-time expositions the relation between carbon and oxygen was extremely small (C/O~0.04). But in two last expositions during quiet-time periods 14.03.96-11.06.96 and 15.12.97-14.04.98 we find many tracks which correspond to carbon in L-R diagram. As a result the observed C/O ratio appears to be more than 0.5, whereas all the other measurements show no evidence for remarcable flux of carbon ions during these periods. The reasons of inadequate response of CN -Kodak are discussed.

KEY-WORDS: nuclear track detectors, anomalous cosmic rays, response of detector
Fragmentation of Ag and Pb Targets Induced by 0.5A GeV and 1A GeV Au Projectiles
Bojana Grabež¹, G. Wirth²

¹Institute of Physics, P.O.Box 57, 11001 Beograd, Yugoslavia
²GSI, Postfach 110552, D-64291 Darmstadt, Germany
grabez@atom.phy.bg.ac.yu

In this experiment the multifragmentation of \textsuperscript{nat}Ag and \textsuperscript{nat}Pb targets induced by 0.5 A GeV and 1 A GeV Au projectiles was studied. The CR-39 plastic track detector was used in 4π geometry. Our analysis included the charge, velocity and angular characteristics of the emitted fragments and correlations between them. The behaviour of these variables in dependence of the atomic number of the target and of the energy of the projectile has been also examined. The data were compared with results of other authors obtained for projectile fragmentation in experiments with inverse kinematics.

Range of Heavy Ions in Different Track Recording Dielectrics: Measurements and an Analysis
Gurpartap Randhawa, Hardev S. Virk*

Department of Physics, Khalsa College, Amritsar 143003, India
*Department of Physics, Guru Nanak Dev University, Amritsar 143005, India
gurpartaps@yahoo.com

A critical analysis of various range formulations has been made by comparing the calculated range values with corresponding experimental values for different heavy ion in different targets, e.g. CR-39, Lexan, Mylar, LR-115, Makrofol-KG, TRIFOL-TN, Hostaphan, BP-1 phosphate and soda-glass etc. at various low and high energies. A comparative study has been made by taking into consideration different target and projectile combinations. Ziegler et al. (1985) formulation (TRIM-95) overestimates the range data in the limited range of energy for heavy ion-light target combination. Mukherjee and Nayak (1979) formulation fails at high and low energies of the projectile, irrespective of the projectile-target combination. Northcliffe and Schilling (1970) formulation does not show any particular trend. Benton and Henke (1969) formulation gives agreement between experimental and theoretical range data within the range of experimental errors (10 percent).

Study of the Reaction Step Preceding Sequential Fission in the Reaction (16.7 MeV/u) \textsuperscript{238}U + \textsuperscript{nat}Au Using MICA Track Detector
Muhammad Shahzad, Imtinam Qureshi, Shahid Manzoor, Ehsan-Ullah Khan, Hameed Khan

Radiation Physics Division, PINSTECH, P.O. Nilore, Islamabad, PAKISTAN
manzoor@bo.infn.it

The kinematical analysis of the heavy ion reaction (16.7 MeV/u) \textsuperscript{238}U + \textsuperscript{nat}Au has been performed using mica as a solid state nuclear track detector. The reaction products originating from the interaction of uranium ions with the atoms of gold were registered in the detector in the form of tracks and identified by performing the detailed kinematical analysis using the spherical polar coordinates of the correlated tracks of multipronged events, on event-by-event basis. It was concluded that two highly excited fragments are formed as a result of inelastic collision between projectile and target atoms in the first reaction step while in the second step the fission of one or both of the nuclei of the previous step takes place resulting in three or four particle in the exit channel. This process is so called ‘sequential fission process’.
In this paper the results of analysis of first reaction step of the sequential fission process observed in the reaction (16.7 MeV/u) $^{238}$U + $^{nat}$Au on the basis of computed kinematical quantities like mass transfer between projectile & target, total kinetic energy loss etc. are presented.

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**Total Charge-Changing and Partial Cross-Section Measurements in the Reaction Of 110 MeV/u 12C with Paraffin**

Alexander Golovchenko$^1$, Jure Skvarc$^2$, Nakahiro Yasuda$^3$

$^1$Joint Institute for Nuclear Research, 141980 Dubna, Russia  
$^2$Jožef Stefan Institute, Jamova 39, 1001 Ljubljana, Slovenia  
$^3$Department of Quantum Engineering and Systems Science, University of Tokyo, Hongo, Tokyo 113-8656, Japan

sasha@cv.jinr.ru

We have measured total charge-changing and partial cross-sections (3 $\Lambda$Z $\Lambda$5) after a passage of 110 MeV/u $^{12}$C NIRS-HIMAC beam through an assembly consisting of CR-39 thin detectors and paraffin targets. These experimental cross-sections were compared to the predictions of known models and, the discrepancy was found for production of fragments with Z = 3 and 4 (summed up over the corresponding detectable isotopes). Using our present results in combination with those obtained by us in reactions of the same beam with graphite and water targets, we will be able extracting realistic values of cross-sections for C on H, C and O in the energy region of ~ 100 down to ~ 40 MeV/u.

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**Measurements of Neutron Yields and Spacial Distributions in U/Pb, Pb and Hg Thick Targets Bombarded by 0.5 And 1.0 Gev Protons**

Shi-Lun Guo$^1$, Li Li, Qingbiao Shen$^1$, Yong-Qian Sh$^1$, Reinhard Brandt$^2$, Peter Vater$^2$ J. - S. Wan$^2$, W. Ensinger$^2$, Boris Kulakov$^3$, Misha I. Krivopustov$^3$, A.N. Sosnin$^3$, Vera Bradnova$^3$, W. Westmeier$^2$

$^1$China Institute of Atomic Energy, P. O. Box 275 (96), Beijing 102413, China.  
$^2$Kernchemie FB14, Universitat Marburg, Marburg, Germany.  
$^3$Joint Institute for Nuclear Research, Dabna, Russia.

guosl@iris.ciae.ac.cn

Measurements have been carried out on neutron yields and spacial distributions in U/Pb, Pb and Hg thick targets and the surrounding paraffin moderators bombarded by 0.533 GeV and 1.0 Gev protons. The sizes of targets were 8 cm in diameter and 20 cm in length. The moderators were 6 cm in thickness surrounding the targets. CR-39 detectors were deployed on the surfaces of targets and moderators to record the neutrons produced in the targets. After irradiation by ~1013 incident protons, the CR-39 detectors were etched in 70ºC 6.5 N NaOH for 30-90 minutes. The tracks were counted by an image analyser. The yields and spacial distributions of neutrons have been calculated and compared with theoretical calculations.
Spatial and Spectral Characteristics of Neutron Field Formed by Relativistic Protons with Energy from 0.5 to 7.4 Gev on Lead and Uranium Targets
Igor V. Zhuk¹, M. K. Kieve⁴, Elena M. Lomonosova¹, Sergei Boulyga¹, I. L. Rakho², Boris Kulakov³, Reinhard Brandt², J. - S. Wan³
¹Institute of Power Engineering Problems, 220109 Minsk, Sosny, Belarus,
²Radiation Physics and Chemistry Problems Institute, 220109 Minsk, Sosny, Belarus
³Joint Institute of Nuclear Research, 141980 Dubna, Russia
⁴Kernchemie, FB 15, Philipps-Universität, D-35032 Marburg, Germany
lab3@sosny.bas-net.by

To study the transmutation of ¹²⁹I and ²³⁷Np a series of experiments was carried out at the Synchrophasotron, Laboratory for High Energies, JINR using relativistic protons and target with different composition (containing uranium and/or lead with or without paraffin moderator)[1]. In these experiments we have continued the study of spatial and energy distribution of neutrons inside and outside the targets. Nuclear track radiography was used as detection technique [2]. The sandwiches consisting of targets containing fissile substance and solid state nuclear track detectors (SSNTD) were applied for the measurement of the axial and radial distributions of fission density of thorium and uranium isotopes as well as for the measurement of average fission cross-section ratios. The distribution of neutron flux density on the surface of a paraffin block was determined for experiments carried out for the U+Pb facility with paraffin moderator and relativistic protons with energies 0.5 - 7.4 GeV. The spectral indices \( \frac{\sigma_{235U}}{\sigma_{237Np}} \), \( \frac{\sigma_{235U}}{\sigma_{236U}} \), \( \frac{\sigma_{235U}}{\sigma_{237Np}} \), and ratios of ²³⁵U fission densities with and without cadmium and boron filters were measured in the central point on the surface of paraffin moderator.

References:

Range and Energy Loss Rate of 118 MeV ²⁸Si in Some Polymers Using PADC as Detector
D. T. Khathing¹, S. P. Tripathy¹, R. Mishra¹, B.K. Verma¹, Kamal K. Dwivedi²
¹Department of Physics, North-Eastern Hill University, Shillong-793 022, India
²Arunachal University, Rono Hills, Itanagar-791 111, Aranachal Pradesh, India
kkdwivedi@yahoo.com; kkdau@hotmail.com

Heavy ion range and energy-loss data provides useful information for designing several nuclear physics experiments where the polymers employed find their use as absorbers, in chamber windows and target backings. In the present work, the range and energy loss rate of 118 MeV ²⁸Si in LR-115 (Cellulose nitrate) and Polypropylene have been determined by track technique where PADC was used as a backing detector. The mean range of 118 MeV ²⁸Si in LR-115 has been found to be 59.4 \( \pm \) 2 micrometer and that in Polypropylene the corresponding range has been estimated to be 74.9 \( \pm \) 2 micrometer. The experimentally evaluated range values are in agreement with the theoretical range values derived using the computer codes TRIM, BENTON, RANGE and from the data tables of HUBERT et.al. The Bragg peak has also been obtained at 2.5 MeV/nucleon and 1.8 MeV/nucleon for ²⁸Si in LR-115 and Polypropylene respectively. Further, this track technique has also been utilised in determining different track parameters such as track rate, bulk etch rate, track diameter, critical angle of etching, etching efficiency and etching response in PADC.
Detection of Phase Transition Signal “Hadrons - ???“ in Inelastic $p\bar{p}$-Collisions in Track
UA5 and CDF Experiments

Vitaly D. Rusov, Tatyana N. Zelentsova, S.I. Kosenko, M.M. Ovsyanko, I.V. Sharf

Odessa Polytechnic University, Department of theoretical and experimental nuclear physics 1, Shevchenko av.,
Odessa, 270044, Ukraine
siiis@te.net.ua

Based on Saleh-Teich cascade-stochastic formalism and Regge scheme of quark-gluon strings model corresponding
to supercritical pomeron with intercept $\Delta \sigma \alpha_p(0) - 1 > 0$ the naive cascade model of multiple charged particles
production in inelastic hadron-hadron collisions at high energies is offered. It is shown that the multiplicity charged
particles distributions in inelastic $pp$- and $pp$-collisions in all the range of ISR energies and available now
$S\bar{p} - pS$ energies up to energy of Fermilab Tevatron Collider $\sqrt{s} = 1800$ GeV obey three-parametrical ST-
distribution belonging to a special class of Markov (generally inhomogeneous) branching Neyman-Scott processes.

The properties of ST-distribution have allowed to detect anomalous behaviour of multiplicity KNO-distributions of
charged particles produced in hadron collisions: KNO-scaling is well satisfied in the energy range $\sqrt{s} = 21.7 - 62.2$
GeV and at ultrahigh energies starting from energy of $S\bar{p} - pS$ -collider $\sqrt{s} = 900$ GeV, but it is completely
violated in the energy range $\sqrt{s} = 200-900$ GeV.

The analysis of distribution function of spatial-temporal intervals between two sequential secondary events
constructed on the basis of multiplicity ST-distribution of charged particles has allowed to establish and to
determine the order parameter describing a degree of hadron events grouping. It is shown that the singularities of
behaviour of order parameters describe singularities of development of internal dynamics of multi-pomeron
production (depending on $\sqrt{s}$), i.e $k$-pomeron showers.

As the result of research of relaxation of general order parameter realized within the framework of known UA5 and
CDF multiplicity experimental distributions of charged particles in a wide range of energies $\sqrt{s} = 20\div1800$ GeV the
signal of phase transition “hadrons – unknown phase” in inelastic $pp$- collisions at energies of $S\bar{p} - pS$ -collider
over $\sqrt{s} = 540$GeV was detected ($\sqrt{s} = 770$ GeV).
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Intrinsic Efficiency for Alpha Particles Detection in LR-115 Simulations and Experiments

Bassam Aharmim, H. Marah, A. Sabir

Laboratoire de Physique Nucléaire et Applications, Faculté des Sciences BP 133 Kenitra Morocco
Centre National de l’Energie des Sciences et des Technique Nucléaire, Rabat, Morocco

bassam.aharmim@caramail.com

In this paper, a numerical simulation is developed to characterise the response of the cellulose nitrate detector “LR-115 type II” to alpha particles of different incidences and energies. Its permit to known whether an alpha particle at a given energy and direction is able to produce a visible etched track or not. For this purpose a theoretical \( V_t \) variable model ,in which the track etch rate \( V_t \) is correlated to specific energy loss inside the detector, is used. Validation of the model is presented in the form of comparisons between theoretically computed values, of energy window and critical angles of registration, and experimentally determined ones.

Keywords: LR-115, chemical etching, specific energy loss, variable track etch rate, intrinsic efficiency of detection.

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A Particle Track Detector ? Measurement Without Neutron Irradiation

Sandro Guedes Oliveira\(^1\), Julio Cesar Hadler Neto\(^1\), P.J. Iunes\(^1\), M.H. Kakazu\(^2\), J.E.S. Sarkis\(^2\), A.K.M.J. Burke\(^1\), S.R. Paulo\(^3\), C.A. Tello\(^4\)

\(^1\)Instituto de Física “Gleb Wataghin”, Universidade Estadual de Campinas, UNICAMP, SP, Brazil
\(^2\)Divisão de Caracterização Química, Instituto de Pesquisas Energéticas e Nucleares, IPEN/CNEN, SP, Brazil.
\(^3\)Departamento de Física, Instituto de Ciências Exatas e da Terra, Universidade Federal de Mato Grosso, UFMT, MT, Brazil.
\(^4\)Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista, UNESP, SP, Brazil

guedes@ifi.unicamp.br

We developed a methodology to measure the \(^{238}\)U spontaneous fission decay constant, \( \lambda_f \), employing nuclear particle track detectors where thermal neutron irradiation is unnecessary. This methodology is based in the fact that the radiation damages caused by spontaneous fission of transuranic elements bearing mass number close to 238 are similar to \(^{238}\)U spontaneous fission ones. Loading a thick source of uranium (thickness greater than the fission fragment range) with a small amount of a suitable transuranic element (\(^{242}\)Pu, which presents a spontaneous fission half-life of \( 6.75 \times 10^{10} \) a.) it is possible to determine the observation efficiency of a particle track detector for fission fragments.

The results of observation efficiency measurements of muscovite mica for fission fragments from a thick \( \text{U}_3\text{O}_8 \) source are presented. Besides, procedures concerning ours thick sources manufacturing and uniformity tests of the transuranic distribution are also presented. This results make possible that a exposure of thick uranium sources (without transuranic element) led to a \( \lambda_f \) value.
Spatial Structure and Energy Spectrum of Ion Beams Studied with CN-Detectors Within a Small PF-Device

Elzbieta Skladnik-Sadowska¹, Jaroslaw Baranowski¹, M. Milanese², R. Moroso², J. Pouzo², Marek Sadowski¹, J. Zebrowski¹

¹The Andrzej Soltan Institute for Nuclear Studies, 05-400 Swierk by Warsaw, Poland
²Instituto de Fisica Arroyo Seco (IFAS), UNCPBA and CONICET, 7000 Tandil, Argentina

eskladnik@ipj.gov.pl, pouzo@ifas.exa.unicen.edu.ar

The paper reports on investigations of pulsed plasma-ion streams emitted from Plasma-Focus (PF) type discharges, as performed within a low-energy PACO device constructed at IFAS. The PACO device was operated under static initial gas-conditions or with the dynamic gas puffing. In order to analyze a spatial structure of the studied ion beams, the use was made of ion pinhole cameras equipped with solid-state nuclear track detectors (SSNTDs) of the CN type. Particular attention was paid to relatively high-energy (> 80 keV) deuteron beams emitted mostly along the symmetry axis of the electrode system. To facilitate the ion measurements at different distances from the electrode outlet and to obtain the ion images with different magnification, the ion pinhole camera was fixed upon a special support, which could be shifted along the z-axis. To register images of the ion beams of various energy, the applied SSNTDs were covered with selected absorption filters made of pure Al-foils of a different thickness, ranging from 0.75 µm to 10 µm. It made possible to register deuteron beams of energy above the corresponding absorption limits.

To investigate an angular distribution of the ion emission there were applied the CN-type SSNTDs fixed upon a special semi-circular support, which was placed in the front of the electrode outlet. To make possible a rough energy analysis of investigated ions the SSNTDs were also covered with narrow strips of the absorption filters of different thickness. The total numbers of ion tracks, as registered at different angles and behind various absorption filters, have been measured and compared. It enabled the angular distributions of ions within different energy ranges to be determined.

Nuclear Tracks in CR-39 Produced by Carbon, Oxygen, Aluminum and Titanium Ions

J. Rickards, V. Romo, J.I. Golzarri, Guillermo Espinosa

Instituto de Física, UNAM. Apdo. Postal 20-364, 01000 México, D.F. MEXICO
espinosa@fenix.ifisica.unam.mx

This work describes the response of CR-39 (Allyl Diglycol Policarbonate) to different ions (C, O, Al and Ti) produced by the Instituto de Física 3 MV 9SDH-2 Pelletron Accelerator, backscattered from a thin Au film on a C support, and reaching the detector at 90°. The ion energies were chosen in series such that the ranges of the different ions in the detector were 2, 3, 4, 5, 6, 7 and 8 µm, respectively for each series.

A surface barrier detector monitored each run, in order to verify the energy and energy spread of each group of ions. Range calculations were carried out using the code TRIM. Once exposed, the detectors were etched with a solution of KOH, 6.25 M, at 60°C, and the reading was carried out using a Digital Image Analysis System. The etching was performed in two hours intervals, and the track diameters were measured at each interval. The diameters measured are plotted vs surface removal, and the results compared for groups with similar ranges.

Keywords: Accelerator; Ions; CR-39.

Jean-Emmanuel Groetz¹, Bernard Tournier², Alain Chambaudet¹, Nicolas Raimondi¹²

¹Laboratoire de Microanalyses Nucléaires, Université de Franche-Comté, 16 route de Gray, 25030 Besançon Cedex, France
²CEA Service de Protection contre les Rayonnements - Centre de Valduc, 21120 Is sur Tille, France
jean-emmanuel.groetz@univ-fcomte.fr

In the present work, we try to evaluate the performance of the etched track detector Tastrak (Bristol, UK) as a neutron dosemeter in particular configurations, such as bremsstrahlung production or nuclear facilities with fissile materials, to determine the ambient dose equivalent H*(10). In the first case, neutrons are produced by (γ,n) reactions and the gamma component of the radiation field induces a strong perturbation of the electronic or bubbles dosemeters.

The track detector is used bare, without any radiator for recording thermal neutrons. Track etching was performed with a hydroxide sodium solution at 7.25 M at 70°C during 6 hours. The detector calibrations were performed using AmBe, PuBe and Californium sources, bared or with a polyethylene container. To improve the calibration, we used the standard Monte Carlo code MCNP4B2 with the new conversion coefficients fluence to dose from ICRP 74.

Determination of Slow Neutron Flux and Spatial Distribution Using LR-115 2B Detectors and Comparison of the Results With Monte Carlo Simulations

Reza Hashemi-Nezhad¹, Reinhard Brandt², J. - S. Wan³, Peter Vater²

¹Department of High Energy Physics, School of Physics, A28, University of Sydney, NSW 2006, Australia.
²Institut fuer Physikalische Chemie, Kernchemie und Makromolekulare Chemie, Philipps-Universitaet Marburg, Germany
reza@physics.usyd.edu.au

The fluence and spatial distribution of slow neutrons on the surface of a cylindrical paraffin moderator, surrounding a Pu/Be neutron source was measured using LR-115 2B detectors via ¹⁰B(n,α)⁷Li reaction. The obtained results were compared with Monte Carlo simulation using MCNP-4B code.

Advantage of PM-355 Nuclear Track Detectors in Light-Ion Registration and High-Temperature Plasma Diagnostics

Adam Szydlowski, Marek Sadowski, M. Jaskola, T. Czyzewski, A. Korman, I. Fijal, A. Banaszak

The Andrzej Soltan Institute for Nuclear Studies, Department of Plasma Physics & Technology, Radiation Shielding and Dosimetry, 05-400 Swierk by Warsaw, Poland
p5office@ipj.gov.pl

Among numerous applications in various fields of science and technology, the solid–state nuclear-track detectors (SSNTDs) have also appeared to be suitable tools for corpuscular diagnostics in high-temperature plasma experiments. In order to use such detectors in the optimal way and to take advantage of the modern plastic detectors, detailed calibration studies of different SSNTDs were undertaken at the Soltan Institute for Nuclear Studies several years ago. These studies have shown that amidst the track detectors investigated up to now (CR-39, PM-355, PM-500, PM-600, CN-80, and CN-LR115A) the PM-355 plastic appeared to be the most suitable one for the registration (and rough energy analysis) of light ions emitted from hot-plasmas. Tracks formed in the PM-355 detector by protons, deuterons, and He–ions of energy within the range of 70 – 300 keV, are more distinct and better
discernible from microdamages of the detector surface than those produced in the other investigated detectors. The PM-355 plastic is then the most relevant to be scanned automatically with a computerized system. The PM-355 plastic appeared to be sensitive to protons and deuterons within a broader energy range (0.07 – 4.5 MeV) than the popular CR-39 detector, which is sensitive to protons and deuterons of energy lower than 1.5 MeV. Recently it has also been found that the evolution of tracks (during the etching process) is correlated with a range of detected particles in the detector material, a bulk etching rate of the detector, and a thickness of the external layer removed by the etching.

The detection characteristics (e.g. track diameters as a function of particle energy and etching time) were investigated in our laboratory mainly for light-ions of energy ranging from 0.3 MeV to 4.5 MeV, because such calibration studies were needed for the application of SSNTDs in high-temperature plasma experiments. Recently, taking into consideration that the modern plastic detectors can be used (and in fact they have already been used) in various domains of science and technology (e.g. cosmic-ray physics, medical studies, material surface technology etc), we have extended our calibration studies by irradiating the detectors in question with heavier ions of energy ranging dozens of MeV. This paper reports on the main parameters (diameters, length, V_T) of tracks formed in the PM-355 detector by energetic ions of Z = 6. An attempt to identify particles on the basis of their tracks is also described.

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Response of Nuclear Track Detectors to 1-3 MeV \(^3\)He and \(^4\)He Ions

Mohammed Al-Jarallah, A.A. Naqvi, Falah Abu-Jarad, Fazal-Ur-Rehman, S.M. Ayub, R. Nassar, S. Kidwai

Physics Department, Center for Applied Physical Sciences, Department of Physics, King Fahd University of Petroleum and Minerals, P.O. Box 2020, Dhahran 31261, Saudi Arabia

Response of PM-355 nuclear track detectors (NTD’s) has been measured for \(^3\)He and \(^4\)He ions with 1-3 MeV energies. \(^3\)He and \(^4\)He particles with 2.0-2.7 and 1.4-2.1 MeV energies respectively, were produced via \(^6\)Li(p,\(\alpha\))\(^3\)He reaction using 140 keV proton beam from the KFUPM 350 keV accelerator. The results have shown that PM-355 detector has excellent capabilities to distinguish between these two particles through their track diameters. As expected, lower energy alpha particles have larger track diameters as compared to \(^3\)He particles. Also the standard deviation (FWHM) of the distribution of the track diameters of \(^4\)He particles is larger than that of the \(^3\)He particles. Results of this study along with measured angular distribution of \(^6\)Li(p,\(\alpha\))\(^3\)He reaction at proton effective energy of 107 keV using NTD’s will be presented in this paper.

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Low-Energy Ion Measurements by Means of CR-39 Nuclear Track Detectors

Elzbieta Skladnik-Sadowska, Jaroslaw Baranowski, Marek Sadowski

Department of Plasma Physics & Technology, The Andrzejsoltan Institute for Nuclear Studies, 05-400 Swierk by Warsaw, Poland

eskladnik@ipj.gov.pl

It is well known that possibility to apply Solid-State Nuclear Track Detectors (SSNTDs) for measurements of low energy ions is limited. While high-energy ions can be registered behind appropriate absorption filters, low-energy ions can be investigated above the energy threshold of 30-40 keV, depending on a kind of the applied SSNTD. In order to make possible also measurements of low-energy ions, this paper describes a new method based on the application of an additional acceleration system, designed for an energy rise of the studied ion beam without considerable injuring of a character of its velocity (energy) distribution. It makes possible to register also ions of energy well below the threshold characteristic for the chosen SSNTD.

The paper presents the additional acceleration system used to shift up an ion energy spectrum by 25 keV, and some examples of the ion parabolas registered by means of a Thomson-type spectrometer. The presented ion parabolas have been obtained within the RPI (Multi-Rod Plasma Injector) device designed for basic plasma research and for
application-oriented studies. The use of the described 25-kV acceleration system and the CR-39 track detectors has enabled the registration of ions of energy above 20 keV to be performed. It has made possible to measure the ion (deuteron) energy spectrum more exactly, particularly in the low-energy wing, what is of importance for the determination of ion emission characteristics.

Additionally, using a special computerized system for analysis of tracks etched in the applied CR-39 detector there were determined dimensions of micro-craters produced by low-energy protons and deuterons. It has extended the know characteristics of responses of the CR-39 detector.

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Neutron Angular Distribution in a Plasma Focus Obtained Through Nuclear Track Detectors

Fermin Castillo-Mejia\textsuperscript{1}, J. Rangel, Guillermo Espinosa\textsuperscript{2}, J.I. Golzarri\textsuperscript{2}, Carlos Amero\textsuperscript{2}, J.J.E. Herrera\textsuperscript{1}

\textsuperscript{1}Instituto de Ciencias Nucleares, UNAM. Apdo. Postal 70-543, México, D.F.
\textsuperscript{2}Instituto de Física, UNAM. Apdo. Postal 20-364, México, D.F.

ciro@nuclecu.unam.mx

The Dense Plasma Focus (DPF) is a coaxial plasma gun where a high density and temperature plasma is obtained, in a focused column, for a few \textit{nsec}. When the filling gas is deuterium, neutrons can be obtained from fusion reactions. These are partially due to a beam of deuterons which is accelerated against the background hot plasma, by large electric fields originated by the plasma instabilities.

Since its invention, the DPF has been recognized as copious pulsed neutron source, which is of interest for applications, specially if a small portable version can be designed. As most of the neutrons are produced by beam-target effect, the angular distribution of the neutron emission is anisotropic, peaked in the forward direction on the axis of the gun, and decaying for large angles. The knowledge of the precise shape of this distribution is of vital interest for applications. The purpose of this work is to illustrate the use of CR-39 nuclear track detectors in the determination of the time integrated neutron angular distribution.

Keywords: Neutrons; Dense Plasma Focus; CR-39

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\textsuperscript{148}Gd, \textsuperscript{238}U, \textsuperscript{239}Pu and \textsuperscript{244}Cm Alpha Particle Energy Analysis Using Tracks in Solids

Carlos Amero, J.I. Golzarri, Guillermo Espinosa

Instituto de Física, UNAM. Apdo. Postal 20-364. 01000 México, D.F. Mexico

espinosa@fenix.ifisicacu.unam.mx

This paper presents advances in a procedure alpha particles analysis using the nuclear tracks formed in solid state materials. This method is based on the relationship between the energy deposited in the material by ionizing particles and the track developed after a well established chemical process. The experimental study included alpha particles in the energy range from 3.2 MeV to 5.8 MeV emitted by \textsuperscript{148}Gd, \textsuperscript{238}U, \textsuperscript{239}Pu and \textsuperscript{244}Cm.

The quantitative results provide a clear signature to identify each one of the radioisotopes based on the formed track parameters. The track analysis is performed with a digital image analysis system associated with a PC mathematical processor. The wide range energy response make this method a promising analysis system.

Keywords: Isotope Identification; Nuclear Tracks; CR-39
Boron Determination in Tourmaline by Neutron induced Alpha Autoradiography for Use in the Interpretation of Geological History

M. Akram, N. U. Khattak, Aziz Qureshi, K. Mehmood, Imtinan Qureshi, Hameed Khan

Radiation Physics Division, PINSTECH, P. O. Nilore, Islamabad, Pakistan

Light elements such as boron is present in trace amounts in various silicate minerals. Due to its ability to form volatile compounds, the boron tends to be enriched in last stages of magmatic differentiation. Boron is present in certain silicate minerals like tourmaline, axinite and datolite. Thus it is possible to use boron as tracer for petrological and geochemical evolution of rocks in the magmatic series. Neutron Induced Alpha Autoradiography is particularly useful for light element determination in solids. We have applied this method to determine boron concentration and its spatial distribution in tourmaline collected from Northern Pakistan. The technique involves the use of thermal neutrons for simultaneous irradiation of unknown and known specimen, fixed on a track detectors and subsequent registration of α-tracks from the $^{10}$B (n,α) $^{7}$Li reaction. The alpha tracks are then counted with an optical microscope after chemical etching. Boron concentration and distribution in tourmaline has been used by us to interpret the petrological history of an area in the Northern Pakistan.

Attempt to Determine Tritium, Na-22, Cl-36 and Radon on the Territory of Mud Volcanos in Taman

Igor Nevinsky$^1$, Victor Nevinsky$^1$, Viktor Panyushkin$^2$, Vasilii Ferronsky$^3$, Tatyana Tsvetkova$^1$

$^1$Research Center of Natural Radioactivity, 82, Frunze St., set.Kholmsky, Abinsk District, Krasnodar region,353302,Russia

$^2$Kuban State University,350040, Krasnodar,Russia

$^3$International Atomic Energy Agency, A-1400, Vienna, Austria

mera@mail.kuban.su

Radioelements in water and clay in a mud volcanos of Taman (Krasnodar region) has not been investigation. Since 1998 y. we had started determination of Radon in soil air at the territory of mud volcano "Shapshugsky". Solid state nuclear track detectors (SSNTDs) was changed every month. In 1999 y. the mapping of some mud volcano with SSNTDs began to determine high Rn-concentratin in soil.

Besides, in 10 volcanos samples for tritium, Na-22, Cl-36 were taken away. Water samples for tritium were enriched and then scintillation counter was used. For determination Na-22 and Cl-36 preliminary chemical procedure was used. With gamma- detector NaI(Tl) gamma-line 0,511 MeV of Na-22 and Cl-36 was determined with big proportional counter . Very low background chamber was created at the depth 100 m in underground laboratory for measurement of Na-22 and Cl-36. Count of this very low activity is very difficult , but preliminary data are given.
**B₀ Value of Dosimeter Glasses for Fission-track Dating**

Tatsuo Suzuki

Department of Geology, Faculty of Education, Kagoshima University, Kagoshima, Japan

t_suzuki@edu.kagoshima-u.ac.jp

The zeta age calibration method (Hurford and Green, 1983) has been successfully applied to fission track dating of crystal minerals like zircon, apatite and sphene. However, suitable age-standard materials have not been proposed until the present for volcanic glasses, such as obsidians, and other kind of minerals except for those mentioned above. Furthermore, in many cases of usual fission track dating, zeta values have not been measured directly from age standards in every irradiation run because of actual limitation of space of the capsules and because of non-convenient routine works. Therefore the zeta value means the values actually fixed to dosimeter glasses and irradiation facilities for many researchers. Accordingly, more characterised parameters for dosimeter glasses are potentially to be used for usual works of fission track dating at least for the cases using well-thermalized irradiation facilities. For this purpose, B₀ value, instead of B-value (Hurford and Gleadow, 1976) was introduced as a parameter for dosimeter glasses. This is independent from neutron energy spectra in neutron irradiation fields because total fission reaction rate of U-235 was used instead of thermal neutron fluence. From these points of view, absolute determination of fission reaction rate of U-235 for dosimeter glasses has been carried out using activation reaction rate of neutron monitors, gold, lutetium and zirconium. These results would be useful to evaluate various experimental results of fission track dating.

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**Plastic Track Detector for Estimation of α-Activity in Plack Sand**

Mohyi El-Din Kenawy, A. Morsy, T. D. Hegazy

Physics Department, Faculty of Women for Art, Science and Education, Ain Shams University, 18 El-Koroum Street, 12311 Doki, Cairo, Egypt

asugrl@asunet.shams.eun.eg

Black sand is important economic sediment of river Nile, which is carried along flood water from Ethiopian mountains and deposited in considerable amounts at the Nile mouth shore, where it meets the Mediterranean. Among many constituents such as monazite, radioactive elements are present in considerable concentrations. Different techniques have been applied to analyze and determine the concentration of different constituents of black sand. Nuclear track etch detectors provide an excellent low cost reliable technique for estimating the concentration of alpha-activity. CR-39 foils were placed in intimate contact with plack sand samples collected from various sites on the shore, for the period of 8-weeks. The exposed detectors were etched scanned for track counting. ²³²Th was founded with appreciable concentration ranging 50-300 ppm.

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**Measurement of Effective Radium and Radon Exhalation Rate in Soil Samples Using LR-115 Type II Plastic Track Detectors**

Ameer Azam, Manoj Gupta, A.H. Naqvi, D.S. Srivastava

Department of Applied Physics, Z.H. College of Engineering & Technology, Aligarh Muslim University, ALIGARH-202002, India

apt05aa@amu.up.nic.in

‘Radon-Alpha’ technique using LR-115 Type II plastic track detectors of Somogyi 1986 has been used for the measurement of effective radium and radon exhalation rate in different samples of soil. Soil samples have been
collected from different places as well as from different depths at a particular place. Effect of grain size has also been studied. The results will be presented and discussed.

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**Determination of Uranium Contents In Rock Samples From Kakul Phosphate Deposit, Abbotabad (Pakistan) Using Fission Track Technique**

Hameed Khan¹, Aziz Qureshi¹, N. U. Khattak¹, M. Sardar¹, Mohamed Tufail², M. Akram¹, K. Mehmood¹

¹Radiation Physics Division, PINSTECH, P. O. Nilore, Islamabad
²Pakistan Institute of Engineering and Applied Sciences, PIEAS, P.O. Nilore, Islamabad, Pakistan

Ten representative rock samples from Kakul phosphate deposit, Abbotabad, Pakistan were studied for uranium content determination with the help of fission track and neutron activation analysis techniques. The fission track analysis technique consists of counting of nuclear tracks in a track detector created by the heavy charged particles emitted by any isotope either due to its spontaneous decay or as a result of induced fission in a reactor.

Each sample was split into three parts. The first and second part of each sample (solid slabs and pellets) were subjected to fission track analysis, while the third part was analysed using neutron activation analysis technique for comparison. The results of uranium content determinations with the help of fission track and neutron activation analysis techniques show a remarked resemblance. The average of six samples determined with the help of fission track on solid slabs is 37.67 ppm, and of seven samples on pellet is 38.71 ppm while the average of eight samples determined with the help of neutron activation analysis technique is 37.13 ppm. This indicates that the fission track analysis technique of uranium content determination is a reliable method in spite of its simplicity.

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**Seasonal Variation of Radon-222 Concentrations in Specific Locations in Jordan**

Mahmoud Kullab, Barakat A. Al-Bataina, A. M. Ismail, Khalid Abumurad

Physics Department, Yarmouk University, 211-63 Irbid, Jordan

mkullab@yu.edu.jo

Previously calibrated passive detectors (CR-39) and an active radon device (Radon Monitor RM3) are used to study seasonal variation of radon-222 concentration levels inside and outside specific locations in Jordan. The study sites are located in area that used to be an old phosphate mine. We found that the maximum value of radon concentration in air inside the dwellings, as measured by the passive dosimeters, was 1532.9 Bq/m³ during the winter season, and the minimum one was 46.3 Bq/m³ during fall season. While the highest and lowest readings of the active monitor were 892 Bq/m³ and 4 Bq/m³ during fall and summer seasons, respectively. The radon concentration in soil ranges from 0.2 kBq/m³ in spring to 37.8 kBq/m³ in fall.

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**The Effect of Soil Grain Size on Soil Radon Concentration**

Ali Khayrat¹, M. Oliver², Saeed A. Durrani³

¹Taiz University, Faculty of Science, Department of Physics, Taiz, Republic of Yemen
²Department of Soil Science, The University of Reading, Whiteknights. Reading RG6 6DW, UK
³School of Physics & Astronomy, University of Birmingham, Birmingham B15 2TT, UK

khayrat@hotmail.com

It has been suggested in the literature that the radon concentration in the soil gas depends on its particle size distribution. The aim of this paper is to examine this relation. Radon concentration was measured in the soil on the
Carboniferous limestone south of Buxton in Derbyshire, England, and soil samples were taken. Radon concentration in the soil was measured using the can technique.

The correlations between the raw values of radon concentration, soil particle size fractions and elevation were weak. Nevertheless, the kriged maps of radon, silt, clay and elevation showed some spatial relation to one another. The kriged estimates showed stronger correlations among these properties, especially between radon and elevation.

It is concluded from the kriged maps that there is a relation between clay content, radon concentration, and elevation. Where the radon concentration is small the soil contains more clay and the elevation is high.

An International Research Project on Armenian Archaeological Sites: Fission-Track Dating of Obsidians

Ruben Badalian\textsuperscript{1}, Giulio Bigazzi\textsuperscript{2}, Marie-Claire Cauvin\textsuperscript{3}, Christine Chataigner\textsuperscript{3}, Ruben Jrbashyan\textsuperscript{4}, Serguei Karapetian\textsuperscript{4}, Massimo Oddone\textsuperscript{5}, Jean-Louis Poidevin\textsuperscript{6}

\textsuperscript{1}National Academy of Sciences, Institute of Archaeology and Ethnography, Yerevan, Armenia
\textsuperscript{2}C.N.R., Institute of Geochronology and Isotope Geochemistry, Area delle Ricerca, Via Alfieri, 1, I-56010 Ghezzano, Pisa, Italy
\textsuperscript{3}Lumière University, Maison de l’Orient Méditerranéen, Lyon, France
\textsuperscript{4}National Academy of Sciences, Institute of Geological Sciences, Yerevan, Armenia
\textsuperscript{5}University of Pavia, Department of General Chemistry, Pavia, Italy
\textsuperscript{6}Blaise Pascal University, Department of Earth Sciences, Clermont-Ferrand, France

g.bigazzi@iggi.pi.cnr.it

In the Mediterranean and adjacent regions, the Caucasus is one of the less studied areas in relationship to provenance studies of prehistoric obsidian artefacts. In the frame of an international research project entitled “Geographic Information System for Armenian archaeological sites from the Palaeolithic to the 4th century AD”, an extensive surveying and sampling campaign was carried out in the numerous obsidian bearing volcanic complexes of Armenia. 36 obsidian samples were analysed using the fission-track dating method in order to characterise the potential sources of the numerous artefacts found in prehistoric sites of the region. Ages distributed in a wide interval and clustered into four groups – Upper Pleistocene, Middle Pleistocene, Lower Pleistocene and Middle-Lower Pliocene groups. This research represents a significant contribution to a better knowledge of chronology of Armenian volcanism for which only few data were available. The resulting data-set appears to be a solid base for future provenance studies.

Helium/ Radon Precursory Anomalies of Chamoli Earthquake, Garhwal Himalaya

Hardev S. Virk, Vivek Walia

Department of Physics, Guru Nanak Dev University, Amritsar-143005, India

virkhs@yahoo.com

Alaknanda valley in the Garhwal Himalaya is a good example of tectonically active region. This region had earlier suffered several major earthquakes, viz. the Badrinath earthquake (1803), Gangotri (1816) and Mussoorie earthquake(1865). During this decade only, the valley was rocked by two major earthquakes; Uttarkashi earthquake of magnitude $M_s = 7.0$ on October 19, 1991 and Chamoli earthquake of $M_s = 6.8$ on March 29, 1999. The helium and radon anomalies were recorded on March 24 and March 27, 1999 respectively, at Palampur which is about 393 km from Chamoli earthquake epicentre. Helium/Radon ratio anomaly was also recorded on March 20; 9 days before the Chamoli earthquake. The precursory nature of radon and helium anomalies is a strong indicator of the physical basis of earthquake prediction and a preliminary test for helium/radon ratio model.
AFM Investigations for a Better Understanding of the Etching Track Process in Apatite

Raphaël Tisserand¹, Michel Rebetez¹, Manuel Grivet¹, Christina Trautmann², Frank Palmino³

¹Laboratoire de Microanalyses Nucléaires, UFR ST, 16 route de Gray, F-25030 Besançon Cedex, France
²Gesellschaft für Schwerionenforschung, Planckstrasse 1, D-64231 Darmstadt, Germany
³Laboratoire de Métrologie des Interfaces Techniques, Place Tharradin, F-25200 Montbéliard, France

With the aim of understanding nuclear track etching process in crystallographic structures, Durango apatite monocrystals were irradiated with ¹²⁹Xe and ²³⁸U ion beams at GSI (Darmstadt). We have previously been able to highlight, by chemical etching, a track fragmentation phenomenon, after annealing or slowing down of incident ions.

In this study, etched track parameters, such as diameter, depth and opening angle of aperture figures are measured by Atomic Force Microscopy. A 3D-representation computer model of etched track profiles is simultaneously developed, taking into account a variable etching speed model ($V_T/V_B$).

Track parameters are studied versus etching time and nitric acid concentration, in order to link these two parameters. Moreover, the study of two ions, ¹²⁹Xe and ²³⁸U, gives an information about dE/dx influence on the etched track morphology. This study allows us to include in our model a $V_T$ speed depending on the studied parameters and then to apply it to the dissolution of apatite, material which is nowadays examined in the context of nuclear waste disposal management.


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²²⁶Ra in Geothermal and Bottled Mineral Waters of Hungary

Eszter Baradács¹, Ilona Hunyadi¹, Zoltán Dezsö², István Csige¹, Pável Szerbin³

¹Institute of Nuclear Research of the Hung. Acad. Sci., H-4001 Debrecen, POB. 51, Hungary
²Isotope Laboratory of Debrecen University, H-4010 Debrecen, POB. 8, Hungary
³J. Curie National Research Institute for Radiobiology and Radiohygiene, H-1775 Budapest POB. 101, Hungary

baradacs@moon.atomki.hu

Due to favorable geology of Hungary many natural springs and drilled wells produce geothermal and mineral waters enriched in minerals. They represent significant economic, therapeutic value and the interest for thermal and medical waters of Hungary is increasing. Commercially available bottled mineral waters for daily consumption become more and more popular as well. In the '90s we have developed and recently improved an etched track detector method to determine radon and radium content of water samples. Main advantage of the method is that large number of small volume (0.5 liter) and untreated water samples can be studied simultaneously at relatively low cost per sample. The lower limit of detection is a few Bq/m³, and the accuracy of the method is about 10% at higher ²²⁶Ra levels.

We have measured ²²²Rn and ²²⁶Ra activity concentrations of 14 thermal springs that supply world famous thermal bates along the riverside of the Danube in Budapest. These geothermal waters show high values, up to about 100 kBq/m³ and 1 kBq/m³ in the case of ²²²Rn and ²²⁶Ra, respectively. Further studies are planned including assessment of dosimetric consequences due to different use of these waters. Determination of the ²²⁶Ra content of bottled mineral and medical waters commercially available in Hungary is in progress. Preliminary results of 40 studied samples (from the nearly 100), possible connections with geology and radiological consequences of daily consume will be presented.

This work was partly supported by the Hungarian National Research Fund, OTKA T022985 and T029306.
Investigation of Radon Dynamics in the Seismic Active Structures of Kopetdag

Jumanazar Ishankuliev¹, Svetlana P.Tretyakova², B.A.Muradov¹, Gulbahar Annakova¹

¹ Research Institute of Seismology, P.O.Box 40, Krugozor, 744000 Ashkabad, Turkmenistan
² Joint Institute for Nuclear Research, (FLNR, JINR), St. Vekslera 14-17, 141980 Dubna, Moscow Region, Russia
formatia@cat.glasnet.ru

This talk presents the results of experimental and methodical work concerning the study of soil radon in the seismogenic break up zone of Turkmenistan by the track method (in a discrete regime) and results of registration of beta active products of radon decay (in an uninterrupted regime). The measurements of the subsoil radon concentrations were performed in the tectonically active Kopetdag area of Alpine mobile zone in Euroasia. It is shown that in this region the temporary subsoil radon dynamic is a nonstable and the gas regime has seasonal variations. These temporary changes of the radon concentrations are small and can be ignored in the analysis of data of the regime observations. Bigger changes of radon concentration (period, amplitude and so on) are seen during the period of tectonic activation. As an example, the reaction of radon subsoil field during seismic events in Kopetdag with an energy class K>10 is shown. In this case radon stream in subsoil and land atmosphere was increased by more than 1.35 – 1.5 times in dependence on the energy and distance from the epicentre of seismic events.

Influence of Geotectonic Structure on Radon Behavior in the Environment

V.A.Akimov, Abdurashid Yafasov, A.A.Yafasov

Scientific Association "Akademiasbob", Uzbekistan Academy of Sciences, Tashkent, Uzbekistan
bahramov@online.ru; zinaen@suninp.tashkent.su

Territory of Uzbekistan is a seismically active region and has extensive geotectonic structure. The full length of the meridian rupture failures in the Tashkent city is over 150 km, and latitude failure is ~ 200 km. Thus, the geotectonics of the Uzbekistan territory is able to affect strongly a radiation background in the atmosphere. To study effect of geotectonic structure on the radon field formation, radon concentration measurements have been made in air of all 23 Tashkent subway stations. The measurements were made with "Alpha-GUARD" PQ-2000-M radiometer, "Gamma-Tracer" (Germany) and a semiconductor spectrometer "RATON" (Uzbekistan).

Radon concentration variations during the day have been measured for two Tashkent subway stations - "Eshlik" and "Pushkinskaya". These stations are located at the identical geological formations, and both have tunnel exits at the Earth surface. In addition, there are two rivers - Salar and Burdjar nearby those two stations. The difference between those stations is that there is one of the terrestrial crust failures nearby "Pushkinskaya" station responsible for one of the greatest earthquake in 1966. The "Eshlik" station is located far from failures. Experimental results showed that the radon concentration at the "Pushkinskaya" station at night (from 1:30 to 4:30 a.m. at minimum ventilation) was 3.7 times higher than that at the "Eshlik" station. At the period of intensive train traffic (6:30 - 9:30 a.m.) and maximum ventilation, the difference in radon concentration was 4.4.

Statistical data of average daily radon concentration for all 23 Tashkent subway stations lead to the following statements:
- There are two groups of stations with difference in radon concentration of 1.7.
- At the stations located nearby tectonic anomalies, the average daily radon concentration is ~ 70% higher than that at other stations.
- Radon exhalation from soil and ground of tectonic anomaly regions is ~3 times higher in compare with average value for given locations when other geochemical and geophysical parameters are equal.

Thus, at the regions of tectonic failures, even low radioactive ores and rocks can contain in their voids a high volumetric radon concentration and be a reason for enhancement of radon level in basements of nearby located buildings.
The Large Detector as an Indicator of Radon Field Variations Before the Earthquakes in Central Italy, Greece, Turkey, Aegean and Mediterranean Seas


LVD Collaboration

1University of Bologna and INFN-Bologna, Bologna, Italy; 2Brown University, Providence, Rhode Island; 3University of Campinas, Campinas, Brazil; 4INFN-LNF, Frascati, Italy; 5INFN-LNGS, Assergi, Italy; 6University of Houston, Houston, Texas; 7Indiana University, Bloomington Indiana; 8Massachusetts Institute of Technology, Cambridge, Massachusetts; 9Northeastern University, Boston, Massachusetts; 10Institute for Nuclear Research, Russian Academy of Sciences, Moscow, Russia; 11Okayama University, Okayama, Japan; 12Okayama University of Science, Okayama, Japan; 13University of Perugia and INPN-Perugia, Perugia, Italy; 14Saitama University, Saitama, Japan; 15Ashikaga Institute of Technology, Ashikaga, Japan; 16Inst-Cosmo-Geophysics, CNR, Torino, University of Torino and INFN-Torino, Italy Torino, Italy; 17University of Urbino and INFN-Firenze, Firenze, Italy; 18Branch of Kurchatov Institute of Atomic Energy (TRINITI)

The data on a series of earthquakes in North-East Mediterranean are presented here. Radon field variations were measured in an underground laboratory located in a tunnel under the Gran Sasso mountain in Central Italy near the Apennines great transversal fault. The area is injected through the surface of an underground cave where the installation is mounted. The variations of radon concentration in cave atmosphere were monitored with the 400-ton scintillation detector LVD (Large Volume Detector). Radon is one of background sources under study in the field of the astrophysics and cosmic ray physics. The method used is the detection of γ radiation from radon group nuclei. The vast surface area through which γ quanta penetrate into the counters (about 600 m²) provided high statistic reliability of results obtained. The earthquakes with the magnitude from M = 3.8 to 7.0 having epicenters in Italy, Greece, Turkey, Aegean and Mediterranean Seas in the second half-year of 1997 and 1999 have been chosen for the analysis. Those earthquakes propagated in complex tectonic structures, including zones of compression and tension. The earthquakes resulted in radon field changes in Central Italy, which proves the uniform deformation structure of this vast geotectonic region.

Measurement of Alpha-Particles with CR-39 Film in the Units of Northern Tajikistan

Khatam Murtazaev, Michel M. Monnin, Vladimir P. Perelygin, A. Murtazaev

1Khujand State University, 735700, Khujand, Tajikistan
2CNRS, USTLD, Laboratoire Geofluides-Bassins-Eau, Université de Montpellier II, Place Eugene Bataillon, F-34095 Montpellier, France
3Joint Institute for Nuclear Research, LNP, JINR, Jolid Cuzie 6, 141 980 Dubna, Moscow, Russia

murtaza@khj.td.silk.org

In Northern Tajikistan there are many units of accumulation of the rare gas -radon. To such units there refer mountainous-geological mines, adits, geological fissures; houses of various constructions: iron-concrete, brick, clay, stone, reeds ones; air, soils and etc. For the definition of microquantity of alpha-particles we included the basin of the Syr-Darya river lying within the northern part of the Turkestan and the southern part of the Kuramin
mountains. In the places selected by our group we arranged CR-39 film for the period of 20 days. For this purpose we took films of 2x4 cm dimensions and cut them in the middle into two parts. We left one part for control and comparison and as for the second part, we arranged it on the point studied. When the time of “radiation” had elapsed we wrought out both a working and a control film in NaOH solution. Then using an optical microscope magnifying for 300-400x, we calculated the quantity of tracks from alpha-particles. Microquantities of alpha-particles in different researched units vary in the range of 20 Bq/m$^3$ - 140 Bq/m$^3$. It is necessary to note that in totally closed units the quantity of alpha-particles is twice or thrice higher (70-90 Bq/m$^3$) in relation to analogical unclosed units. For the last years central Heating lines in communal households of cities and towns of Tajikistan don’t function, that’s why the population closes their dwellings for preservation of warmth in autumnal-winter season. Due to this alpha-particles are being accumulated in houses, tenants breathe their air and it is quite possible that they get an additional doze of radiation. In the opinion of some medical experts the enhancement of the number of bronchial, lung diseases is namely associated with the accumulation of radon in closed houses and units. According to our observations microquantities of alpha-particles are considerable higher in closed iron-concrete houses, badly ventilated mines and adits, closed wells and they reach the magnitude of 100 Bq/m$^3$. Minimal microquantity of alpha-particles - 20-30 Bq/m$^3$ - is observed in reeds and clay houses. It is necessary to note that microquantities of alpha-particles in closed mines, adits and geological fissures reaches 140 Bq/m$^3$ in the period of strong earthquakes.

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**Evolution of the Bragin Pallasite: Evidence from the Fission-track Analyses**

Julia Bondar$^1$, Vladimir P.Perelygin$^2$

$^1$Ukraine State Scientific Center of Environmental Radiogeochemistry, 252680, Kiev, Ukraine

$^2$Joint Institute for Nuclear Research, 141980, Dubna, Russia

center@radgeo.freenet.kiev.ua

Chronology is rather a weak point in an investigation of pallasites, the stony-iron meteorites, due to practically full lack of minerals applied for traditional gas chronological methods. Such a situation does not allow considering their parent body cosmic evolution correctly. That is why a fission-track dating method is very attractive for filling in this gap. No chronological data are known for the Bragin pallasite. Our attempt to reconstruct its cosmic history was based on interpretation of some metamorphic structures, arisen as a result of shock events, and data from a fission-track analysis.

To apply the latter, the only uranium-rich phosphates can be used. Extremely rare grains of stanfildite were extracted from the silicate sawing residue and the pallasite sample directly. Among a possible sources of ancient tracks (due to galactic cosmic rays; U and Th induced fission by cosmic rays; $^{238}$U spontaneous fission and $^{244}$Pu spontaneous fission) the basic contribution to the total track density was formed by $^{238}$U and $^{244}$Pu spontaneous fission.

Their contribution was submitted by two track generations. The tracks of the first one were greatly annealed (l ~ 5-6µm instead of ~11-12 for induced), irregularly distributed. Their density reached to 6$\times$10$^6$ cm$^{-2}$ in local sites. The tracks of the second one – practically non annealed (l ~ 10-12 µm), rather regularly distributed. Their density slightly varied from a grain to a grain and was in ~6 times below, than density of the first track generation - (1.05 ± 0.05) $\times$10$^6$ cm$^{-2}$. Only nonannaled tracks were used for future calculation.

The uranium content has been measured in stanfildite grains (98±13 ppb), which could not have led to the production of more than (2.2 ± 0.3 ) $\times$10$^7$ spontaneous fission tracks/cm$^2$ due to $^{238}$U. So the main contribution to the total density of ancient tracks was formed by $^{244}$Pu - (0.83+0.06) $\times$10$^6$ cm$^{-2}$. Such a situation testifies about the ancient fission-track age of the Bragin pallasite (T>4.0$\times$10$^9$ years).

Assuming a value for initial ratio ($^{244}$Pu/$^{238}$U)$_0$ of 0.016, a Bragin fission-track age of (4.2-4.3) $\times$10$^9$ years was obtained. The time interval between 4.45$\times$10$^9$ and 4.2$\times$10$^9$ years is required to interpret observed density of the first track generation. In this connection the fission-track age does not exceed 4.2$\times$10$^9$ years. This value determines the age of the last intensive shock/thermal event, which had caused the partial annealing of tracks presented to that time and “fission-track clock” reset.
The obtained results of the fission-track analysis perfectly correlate with the data of structure-mineralogical investigation. According to the latter, there was an intensive shock/thermal event in the cosmic history of studied pallasite, which was followed by the heating of bulk pallasite mass up to 400-450°C.

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**Study of Particles of Actinides in Soil Samples Using Nuclear Track Detectors**

Oleg Povetko, Kathryn Higley

Department of Nuclear Engineering, Oregon State University, 116 Radiation Center, Corvallis, Oregon 97331-5902

povetko@ucs.orst.edu; povetko@hotmail.com

Solidified thin soil sections were prepared from the intact soil samples containing weapons-grade plutonium from Rocky Flats, Colorado. Combination of alpha track and fission fragment track detection was used to study microparticles of contaminants containing in the soil thin sections. The combination of two autoradiographic methods allowed distinguishing alpha-emitting particles of natural U, $^{239+240}$Pu and non-fissile alpha-emitters. Locations of 990 alpha track clusters caused by $^{239+240}$Pu and $^{241}$Am “hot particles” were recorded, particles were sized, their size-frequency, depth and activity distributions were analyzed. It was found that the upper 6.5 cm of soil contained 20% of all recorded particles with mean equivalent size 0.35 microns and, deeper located 6.5 cm soil layer contained 80% of the particles with mean equivalent size 0.25 microns. One of the observed conglomerates of actinide “hot particles” was approximately 500 microns in diameter, but accounted for 94% of the total recorded alpha activity of all 990 particles.

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**Fission-Track Dating of Impact Craters Using Glass Track Detector: Some Methodological Aspects**

Leonid Kashkarov, G.V. Kalinina, K.A. Lorentc, M.A. Nazarov

Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, 117975, Moscow, Russia.

ugeochem@geochem.home.chg.ru

We have determined the ages of formation of Kara (Russia) [1] and Boltish (Ukraine) [2] impact craters by the fission-track method. For this the natural glasses as fission-track detectors were used. About some hundreds fragments of the clean and pure glass were picked out from 0.25-1 mm grain-size fraction, polished and etched by the mixture of HBF$_4$ (48%), HNO$_3$ (10%) and CH$_3$COOH (0.5%) of 2:1:2 for 30-150 min at 20°C. Density and diameter distributions of fossil ($p$, $D$) and neutron-induced ($p$, $D$) tracks were measured. To correct annealing of fossil tracks the diameter-ratio ($D_f$/$D_i$) procedure was used. All glass fragments under track investigation were analyzed with electron microprobe for major elements, that do not show significant compositional variations. After annealing correction the fossil $p$, values correlate strongly with $p_i$/$F$ values ($F$ is integral neutron flux). Correlation coefficient equal to 0.94 and 0.85 correspondly for Kara and Boltish craters means the glass fragments have the same age but different uranium concentrations and/or different track-etching characteristics. The results of age determination are given in Table.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Number of glass fragments</th>
<th>Number of counted tracks</th>
<th>$t \pm \sigma*$ $(10^6 \text{ yr.})$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N_s$</td>
<td>$N_i$</td>
<td></td>
</tr>
<tr>
<td>Kara</td>
<td>132</td>
<td>1046</td>
<td>21609</td>
</tr>
<tr>
<td>Boltish</td>
<td>288</td>
<td>5456</td>
<td>59467</td>
</tr>
</tbody>
</table>

* The ages and the errors on $t$ have been calculated according to ref. [1,2]

The accuracy of the age values depends mainly on $N^{-1/2}$ ($N$ is a number of identified fossil tracks). The average age values were obtained taking the individual glass fragment age from the weighted by $N$ histogram. The error ($\sigma$)
depends on errors of individual ages. The fission track isochrone ages [1] were computed by regressing of \( \rho_o \) and \( \rho_i/F \) values using the method [3]. Some glass fragments were dated also by the plateau-annealing technique [4]. All age estimates are independent and their joint leads to age values which for two investigated craters are not distinguishable from the K/T (Chicxulub) impact age, and, hence, do not contrary to scenario of a multiple impact events at the K/T boundary.

References:

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Radon Anomalies on Five Faults in Southwest of Irbid City North of Jordan

Mahmoud Al-Tamimi, Khalid Abumurad

Physics Department, Yarmouk University, P.O. Box 566, Irbid 211-63, Jordan
maltamimi@yu.edu.jo

Radon gas has been used as a geophysical tool as a uranium exploration, earthquake and volcanic activity prediction, and fault zones confirmation. Aim of this study was to a sure the suitability of this method in the existence of fault zones. Study area was chosen with a uniform lithology, which is located in northwest of Jordan. Radon concentration in soil along four different well-known traceable fault zones was measured along a normal traverse line across each of these faults. Radon concentration was anomalously high in all fault zones by a factor of two to four above background values. This method was applied along a fifth expected fault zone and anomalously radon concentration was recorded in measurement stations near the fault zone, which gave higher radon anomalies than background value by two to three times. This study confirms strongly that radon gas is a good tool for fault zones detection in similar areas.

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Radon Microquantity Definition in Water Sources of the Kuramin Mountains

Khatam Murtazaev\(^1\), Michel M. Monnin\(^2\), Vladimir P. Perelygin\(^3\), A. Murtazaev\(^4\)

\(^1\)Khujand State University, 735700, Khujand, Tajikistan
\(^2\)CNRS - UMR 5569, Université de Montpellier II, Place Eugene Bataillon, F-34095 Montpellier Cedex 5, France
\(^3\)Joint Institute for Nuclear Research, LNP, JINR, Jolid Cuzie 6, 141980 Dubna, Moscow, Russia
murtaza@khj.td.silk.org

The definition of radon gas quantity in springs is of considerable interest both from the point of view concerning the isotope composition of water and the question relating to the information about the alteration of the geodynamics of the explored territory contained in radon. In order to study radon variations we were conducting observations in the course of months over Chashma spring situated in the lower part of the Mogol- Tau Hill, 10 km to the north-east of Khujand and many water wells of the Kuramin mountains. Chashma spring water has two river-beds: one of them flows to residential houses through the pipe, as for the second one it runs spontaneously along the formed course and falls into a specially done pit. We located the detectors of indices CR-39 and LR-115 in the middle of the pit and left them for 10 days. These procedure was being repeated during several months. We took concurrently water probes for the further analysis of mineral composition. The detectors were worked up with NaOH solution in a standard way; every time we found an average arithmetical number of alpha-particles tracks for the films mentioned. As a result of it we discovered the quantity of alpha- particle tracks cascilling from 20 up to 80 Bq/m\(^3\). The increase of the number of the particles is, to our mind, due to earthquakes, which are not infrequent in our region. We seem to believe that there is a correlation between the alteration of the microquantity of the particles and the anomalies taking place in the earthcrust.
Modelling the Length Distribution of Etched Tracks Taking Into Account Fragmentation Due To Partial Annealing
Raphaël Tisserand, Claude Dubois, Michel Rebetez, Manuel Grivet, Fabian A. Villa

Laboratoire de Microanalyses Nucleaires, U.F.R. Sciences et Techniques, Universite de Franche – COMTE, U.F.R. Sciences et Techniques, La Bouloie, 16 route de Gray, F-25030 Besançon Cedex, France
manuel.grivet@univ-fcomte.fr

Fission track length measurements on apatite minerals are of great interest in thermo-chronology studies. RBS analyses on Durango apatites irradiated by Krypton ions have previously shown the progressive amorphisation of tracks by annealing*. This study made for different irradiation energies corresponding to those of uranium fission fragments has been completed by TEM and AFM on etched tracks. In all cases, segmentation figures have been observed, that clearly necessitates to introduce fragmentation of latent tracks to model the length distribution of uranium etched fission tracks.

This presentation concerns the case of a homogeneous population of tracks with partial amorphisation. The next step will consist in considering multiple sub-populations of different amorphisation. This algorithm is a new aspect to be included in our model, which already takes into account diffusion and crystallography in the track etching process**.


Passive Technique Using SSNTDs for Estimation of Thorium to Uranium Ratio in Geological Rocks
Mohyi El-Din Kenawy1, Abdel-Fattah Hafez2, A.F. Said3

1Physics Department, Faculty of Women for Art, Science and Education, Ain Shams University, 18 El-Koroum Street, 12311 Doki, Cairo, Egypt
2 Faculty of Science, Physics Department, Alexandria University, 21511 Alexandria, Egypt
3Nuclear Materials Authority, Cairo, Egypt.
asugrl@asunet.shams.eun.eg

Uranium and thorium and their daughters are present in geological samples following,, their solidification. Their content in natural samples can vary depending on geological formation. The quantitative analysis of uranium in natural materials is almost difficult to determine unless the thorium to uranium ratio is known. The objective of this contribution is to investigate and demonstrate a method for estimation of thorium to uranium ratio in some geological rocks taken from uranium exploration mines in different galleries in eastern desert of Egypt. This method is applied using two different track etch detectors of different sensitivities for α-particle track registration i.e. CR-39 and LR-115.
Determination of Tectonic Uplift Rates and Geothermal Histories of Qinling Mountains in Central China by Fission Tracks

Bao-Liu Chen¹, Li Li¹, Li Guo¹, Yanchou Lu², Gongming Yin², Shi-Lun Guo¹

¹China Institute of Atomic Energy, P. O. Box 275 (104), Beijing 102413, China
²Institute of Geology, National Seismological Bureau of China, P. O. Box 9803, Beijing 100029, China

guosl@iris.ciae.ac.cn

Apatite and zircon minerals have been separated from the granites picked at 6 levels of elevation at Taibai Mountains and 6 levels at Hua Mountains in Qinling Mountain range in central China and dated by fission track techniques. The tectonic uplift rates in the range have been derived. The geothermal histories have been analysed. The climate changes caused by the uplifts in late Cenozoic period in China are discussed.

The Chemical Underground Parameters in Earthquake Process Preparation

Tatyana Tsvetkova¹, Igor Nevinsky¹, Michel M. Monnin², Victor Panyushkin¹, Vladimir P. Perelygin³

¹Research Center of Natural Radioactivity, 82,Frunze St.,set.Kholmsky,Abinsk District,Krasnodar region,353302,Russia
²Centre National de la Recherche Scientifique,URA-1359,F-34000 Montpellier,France
³Kuban State University, 350040,Krasnodar,Russia

mera@mail.kuban.su

Many years research of radon in soil and air in gallery "Sakhalin" on the depth 15-50 m in North Caucasus Krasnodar region was conducted. In automatic mode Rn-probe "CLLIPERTON" (France) was worked . Information was taken every hour. Solid state nuclear track detectors (SSNTDs) were operating in several points of gallery and exchanged every month. Data of Rn-concentration change before earthquake , mount collapse and storm are obtained. In 1999 periodical measuring of concentration of several chemical elements and combination in underground water began . Zn, Cu, Pb, Ni, Mn, Hg, Al, Fe, So₄, Co₂, and all was determined . Main polluting element in the region is Hg. Hg concentration change took place after several days of Rn concentration in soil increased. Other elements change also was observed andn to be connected with earthquakes preparation. The preliminary data are given.

Measurement of Radon Concentration Inside Uranium Exploration Mines in Egypt Using SSNTDs

Mohyi El-Din Kenawy¹, T.A.Sayyah², A. Morsy¹, T. D. Hegazy¹, A.F.Said²

¹Physics Department, Faculty of Women for Art, Science and Education, Ain Shams University, 18 El-Koroum Street, 12311 Doki, Cairo, Egypt
²Nuclear Materials Authority, Cairo, Egypt

asugrl@asunet.shams.eun.eg

CR-39 and LR-115 as a passive nuclear track etch detectors were used to measure radon concentration in various uranium exploration mines in different galleries in the eastern desert of Egypt. The nuclear track detectors were fixed at the inner bottom of a plastic can provided with microporous filter cover to eliminate aerosols. The cans were held upside down in different locations in these mines for about one-month, then normally processed and scanned for track density.
Unroofing History of the Sillai Patti Granite Gneiss, Pakistan: Constraints from Zircon Fission-Track Dating

N. U. Khattak, Aziz Qureshi, M. Akram, K. Mehmood, T. Iqbal

Radiation Physics Division, PINSTECH, P. O. Nilore, Islamabad, Pakistan

A group of alkaline igneous rocks is exposed in the north of the Peshawar Plain from Tarbela to Loe Shilman near the Pakistan-Afghanistan border. The alkaline rocks consist mainly of granites, syenites, gabbros, ijolites and carbonatites. The field relationships suggest that the Malakand granite is younger than the Sillai Patti granite gneisses. However, the fission-track systematics on zircon based on present work indicate that age of the Sillai Patti granite gneiss is less than absolute ages of the Malakand granite gneiss. Therefore, the zircon fission-track age of 24.4 ± 2.9 Ma from Sillai Patti granite gneiss, represents a time of post metamorphic denudation history of the area, when these rocks passed through the 210 °C isotherm, corresponding to a depth of about 6.7 km inside the earth’s crust from their present position if a paleogeothermal gradient of 30°C/km is assumed to have prevailed.

Our fission-track zircon age of 24.4 ± 2.9 Ma is closely similar to the average fission-track zircon age of 25.4 ± 0.7 Ma of Mansehra granites. The average uplift rates of the Mansehra and Sillai Patti granites have been computed to be 0.26 ± 0.01 mm/yr and 0.27 ± 0.03 mm/yr respectively on the basis of zircon fission-track ages for the period between 25 Ma and the present time. This indicates that the two complexes experienced similar average uplift rates during the last 25 Ma, or so.

Soil Radon Depth Dependence

Gilbert Jönsson

Department of Physics, Lund University, Box 118, S-221 00 Lund, Sweden
gilbert.jonsson@fysik.lth.se

At the planning and construction of new buildings the presence of radon in the ground must be taken into consideration. In order to determine the risk radon measurements in situ give a direct information of this risk and the classification of the ground with respect to the soil radon levels is possible (Jönsson 1995). As there is an increase of the radon level with increasing distance below ground surface at least in the range 0-2 m of depth this classification of the ground must refer to a certain depth, often one meter. The depth dependence of the soil radon level is discussed in several reports and sometimes in connection with ideas of the transport of the radon gas from deep layers (Fleischer et al., 1980; Kristiansson and Malmqvist, 1982; Monnin and Seidel, 1997). In this report data from measurements of radon gas in ground by plastic film is discussed and interpreted.

References:
Fission Track Technique in the Investigation of Trace Uranium Concentrations in Water
Bikram Bajwa, Hardev S. Virk

Department of Physics, Guru Nanak Dev University, Amritsar-143005, India.
bsbajwa@excite.com

Uranium in solution medium can be estimated by evaporating measured volumes on solid surfaces, irradiating with neutrons and then by etching and counting of fission tracks produced on the solids. In this paper, results of the uranium concentration measured in water samples collected from two major cities of Punjab, using the fission track technique, has been reported. The uranium concentration in the water samples of Amritsar city has been found to be varying from 3.17 ± 0.06 to 4.19 ± 0.07 ppb, while the uranium concentration in the Bathinda city has been found to be varying from 4.28 ± 0.07 to 16.61 ± 0.13 ppb, with one exception of the 1.21 ± 0.03 ppb which has been found to be present in one water sample collected from the NFL water works lake in the Bathinda city. The comparatively higher values observed in the water samples from Bathinda city may be attributed due to the utilization of the coal and flyash in the thermal power plant in this city.

Radon and Aerosol Flow Over Tectonic Fault Indicates Specific Signs of Earthquakes
V.A. Alekseev¹, M.O. Alekseeva¹, A.I. Grishin², G.G. Matvienko², Igor Nevinsky³, A.Yu. Reshetkin², V.S. Smirnov¹, Tatyana Tsvetkova³

¹Institute of Innovation and Thermonuclear Investigation (TRINITY), Troitsk, Moscow reg., Russia
²Institute of Atmospheric Optics SB RAS, Tomsk, Russia
³Research Center of Natural Radioactivity, set. Kholmsky, Krasnodar reg., Russia

In the Bugasski mud volcano region (the coastal zone of Tamanski peninsula, Caucasus), the radon distribution lengthwise and crosswise the Bugasski fault was measured by the SSNTD method with a network of detectors. The radon field variation was automatically recorded 24 hours at five-minute intervals (each detector was equipped with a scintillator of large area connected with microcomputer). Several earthquakes took place over the measurement period. On the eve of each earthquake the radon flow first increased and then fell, forming a sharp minimum at the moment of the event.

During several days the following parameters were measured: the aerosol flow dynamics (with the help of laser transmissometer), variations of atmospheric electric field, and the atmospheric conductivity. The triggering of future earthquake is seen particularly clearly from variation of the electric field and conductivity. So, on October 19, 1999 (M 4.4), about a day before the event, a specific augmentation of the electric field took place, which then again fell immediately before the earthquake. A characteristic decrease of the electric conductivity of the ground atmosphere was seen on the eve of the earthquake, which was then changed by its increase at the day of the event. This shows a priority of aerosols in determination of electric situation over tectonic fault.

The Determination of Radon and Thoron Concentrations in the Air by the Application of SSTD CR-39
Magdaléna Vicanová, Matej Durcık

Institute of Preventive and Clinical Medicine, Limbová 14, 833 01 Bratislava, Slovak Republic
vicanova@upkm.sk

One of the current problem of methods developed for the measurements of radon \(^{222}\text{Rn}\) and thoron \(^{220}\text{Rn}\) concentrations in the air could be the separation of radon from thoron. For the measurements of radon and thoron...
concentrations in karst caves areas there was proposed diffusion double chamber detector with solid state nuclear track detector CR-39 with discrimination of thoron by diffusion barrier. Paper diffusion barrier (thickness 0.15 mm) was used for detection of radon and thoron concentrations and polyethylene filters (thickness 0.01 and 0.05 mm) for discrimination of thoron and determination of radon concentrations were used. The experimental and theoretical efficiencies of discrimination of thoron concentrations by PE barriers with thickness of 0.01 mm and of 0.05 mm are 99% and 99.9%, respectively. The preliminary results of radon and thoron concentrations measurements in Slovak carst caves, will be also presented.

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Track-Thermoluminescence Parameters Relation in Lunar Olivine Crystals as Indicator of Their Exposure and Shock-Thermal History

Leonid Kashkarov, A.I. Ivliev, S.S. Assonov, A.S. Semenova

Vernadsky Institute Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow 117975, Russia.

ugeochem@geochem.home.chg.ru

Silicate crystals of lunar regolith during their complex radiation-thermal history accumulate VH-nuclei tracks and thermoluminescence (TL) [1,2]. With the aim of experimental check for possible relation between track and TL parameters in individual silicate crystals some track and TL characteristics in olivine grains from Luna-16 soil of 1603 sample were measured. Each crystal (about 0.2 mm size) was split into fragments, part of which used for track and another for TL investigations. Most of 20 investigated grains show track densities in the range \(\sim(5 \times 10^6\sim10^8) \text{ cm}^{-2}\) that correspond to our earlier results [3]. Yet track-length distribution in olivine examined was not uniform: most grains have normally distributed length of tracks with average value 6-8 \(\mu\text{m}\), and in four grains part (up to 60%) of tracks is 3-4 \(\mu\text{m}\) length. TL glow curves for all olivine grains show measurable intensity at temperature interval of 150-450 °C and TL-peak near 340-410°C. An additional low-temperature (near 250°C) broad peak is observed in olivine grains which demonstrate bimodal track-length distribution. Quantitative analysis of TL glow curves by our special program [4] allow us to evaluate the ratio of TL-intensity for low-and high-temperature peaks, which for olivine examined differ up to 3-fold quantity.

Obtained results indicate: (i) The use of a most sensitive track-annealing parameter – a shortening of the tracks in silicate grains gives essential data about their individual heating event(s). (ii) Just then the tracks produced after this event(s) will have unannealed length distribution. From this point of view observed in some crystals bimodal track-length distribution can be suggested a complex radiation-shock-thermal history for these separate grains. (iii) Precisely these grains demonstrate specific TL-emission spectrum, and we consider this fact as an indicator of the local shock-thermal occurence by the micrometeorite impact events.

The work was supported by Young scientist grant (S.Assonov) of Russian Academy of Sciences.

References:
1) Bhandari N. et al. (1972) Proc 3rd LSC,P.2811.
The Correlation Between Underground Radon Emanation and Ionosphere Anomalies Before Turkey Earthquakes of 1999
V.A. Alekseev¹, A. Malgin², M. Hernandez-Pajares³, V. Oraevsky⁴, Yu. Ruzhin⁴, O. Ryazhskaya², I. Shagimuratov⁴

¹Branch of Kurchatov Institute of Atomic Energy (TRINITI), Troitsk-town, Moscow region, Russia
²Institute for Nuclear research, Russian Academy of Sciences, Moscow, Russia
³Research Group of Astronomy and Geodesy, Barcelona, Spain
⁴IZMIRAN, Troitsk-town, Moscow region, Russia

The variations of a radon concentration were monitored underground with the 400-ton scintillation detector LVD (Large Volume Detector). The detector is located at the depth 1200 m near the Apennines great transversal fault. The vast surface area of the detector (about 600 m²) provided high statistic reliability of results obtained. Precursors type of ionosphere total electron content anomalies for two destructive earthquakes in Turkey (at 1999) is analyzed on base of TEC of GPS net. We found the ionosphere anomalies which well pronounced one-two days before the two well known Turkey earthquakes of 17th August of 1999 with magnitude more than M=7.0. For statistical purposes the number of these cases is negligible but for both earthquakes the ionosphere plasma TEC anomalies are very similar in form and dynamic. The correlation analysis of both radon and ionospheric data shown that the ionosphere anomalies in subionosphere points around the epicenters of earthquakes follow the underground radon field anomalies at the distance up to 1000 km from earthquake epicenter. This fact demonstrated the connection between ionospheric phenomena with tectonic deformations.

Preparation and Certification of Two Uranium Glass Reference Materials for Fission-Track Dating of Geological Samples
Michelle Derbyshire¹, Christopher Ingelbrecht¹, Frans De Corte², Peter Van den Haute¹, Jan Van Ham³

¹European Commission, Joint Research Centre, Institute for Reference Materials and Measurements, Retieseweg, 2440 Geel, Belgium
²Lab. Of Analytical Chemistry, Institute for Nuclear Sciences, University of Gent, Proeftuinstraat 86, B-9000 Gent, Belgium
³Geologisch Instituut, Universiteit Gent, Krijgslaan 281, 9000 Gent, Belgium
⁴Philips Display Components, BTG Special Products, Building TY, P.O. Box 218, 5600 MD Eindhoven, The Netherlands

michelle.derbyshire@irmm.jrc.be

In 1996, the European Commission issued the Nuclear Reference Material IRMM-540 for reactor neutron dosimetry in fission-track dating [1]. It consists of 13.9 mg kg⁻¹ (natural) uranium-doped glasses, distributed as sets of three discs (16mm diam. and 2 mm thick), including a specimen that was pre-irradiated (in contact with mica foil) with a certified thermal neutron fluence of 1.070×10¹⁹ m⁻². Because at present this material is going to be out of stock, and aiming at an increased applicability, two new reference glasses containing respectively 15 and 55 mg kg⁻¹ uranium (nominal concentrations) are now being produced. The 15 ppm U glass can be regarded as the successor of IRMM-540 while the new 55ppm glass allows irradiations with lower doses and should therefore be more suitable for dating higher uranium minerals such as zircon.

A new and more reproducible method was developed for the casting of uranium-doped glasses, avoiding micro-scale defects which would interfere with the measurement of track densities. Uranium homogeneity is verified by track density measurements on neutron irradiated samples and a long term ‘isochronous’ stability study is performed to investigate fission-track thermal stability. Uranium mass fractions will be certified by ICP/MS, EDXRF and TI/IDMS from six independent laboratories. The certified reference materials (CRMs) will be again made available as sets of three discs, including one disc (and a co-irradiated mica foil), irradiated with a certified neutron fluence.
Emanation Power of Radon and its Concentration in Rocks and Soil in Jordan
Khalid Abumurad, Mahmoud Attamimi

Department of Physics, Department of Earth and Environmental Science, Yarmouk University, Irbid 211-63, Jordan
abumurad@yu.edu.jo

The main source of radon in indoor and outdoor atmospheres is the top layer of the ground. The emanation of radon from the ground is associated with the presence of its immediate and ultimate precursor radium and uranium, respectively. Living in an atmosphere with elevated radon concentration presents a high lung cancer risk. This experiment was carried out to determine radon levels in different kinds of soil and bedrock. Seven stations were selected in the investigated district, which covers an area of about 2300 km² in the northern and western part of Jordan. Five holes were dug in each station at different depths (20, 40, 60, 80, 100 cm). Two to three time-integrated, plastic (CR-39) passive dosimeters were put in each hole. Ten days later, the dosimeters were collected and chemically etched. Some soil and rock samples from the study area were collected and analyzed for radioactive nuclides using γ-ray spectroscopy. However, the correspondence between radon levels in the soil gas and its precursor concentrations is not clear. However, radon level increases approximately exponentially with depth. In general, al-Hisa phosphate limestone showed the highest radon concentration while Amman silicified limestone showed the lowest concentration.

Determination of Uranium Content of Egyptian Phosphate Ores by Passive and Active Detectors
A.F. Saad¹, T.M. Talaat¹, S.T. Atwa², Guillermo Espinosa³, Masami Fujii⁴
¹Physics Department, Faculty of Science, Zagazig University, Egypt
²Chemistry Department, Faculty of Science, Zagazig University, Benha-Branch, Egypt
³Instituto de Fisica UNAM, Apdo. Postal 20-364, 01000 Mexico, D.F.
⁴Faculty of Engineering, Aomori University, 2-3-1 Kobata, Aomori, Japan
fujii@aomori-u.ac.jp

Uranium contents of Egyptian phosphate ores were determined from measurements of radon emanated from the ore samples. In our method, neither direct contact of CR-39 track detectors to the samples nor thermal neutron activation process are required. The ore sample was loaded into an emanation container (Genitron Instruments GmbH) with volume of 50 l. The concentration of $^{222}$Rn in the emanation container is dependent on the amount of $^{238}$U. A small diffusion cup, carrying a CR-39 and covered with filter paper to avoid thoron, was fixed on the inner ceiling of the emanation container. A pulse ionization chamber, Alpha GUARD PQ-2000 (Genitron Instruments GmbH) was also connected to the emanation container. Thus, passive and active detectors were simultaneously used for the radon detection. The detection efficiency of CR-39 was calibrated with Alpha GUARD.

Preliminary measurements showed high concentrations of uranium in phosphate ores collected from different known sites in Egypt. The accuracy of our method and radon assessment of ore sites will be discussed at the conference.
Study of Radioactive Materials Content in Some Egyptian Rocks

Mohamed Mansy¹, A. Hussein², Hussein M. El-Samman³, M. El-Hawary⁴, A. R. El-Sersy¹, Mohammed El Fiki³

¹National institute for Standard, tersa streeet, El-Haram, Giza, Egypt.
²Department of physics, Faculty of Science, Qatar University Doha, Qatar.
³Department of physic, Faculty of Science, El-Menoufia University Shebin El-Koam Egypt.

In this work, radon emanation from some rock samples collected from Eastern desert of Egypt was determined using SSNTDs. The used track detectors were calibrated before in special Rn-chamber designed and constructed in our laboratory for this purpose. The uranium and radium content were also determined using high-resolution gamma spectrometer (Hyper pure Germanium detector) through 186-keV gamma line of $^{226}$Ra and 609-keV gamma line. of $^{214}$Bi. Calibration factor between the studied parameters using the two techniques was achieved. Using our simple and low coast method $^{226}$Ra, $^{238}$U and the emanated radon can be predicted in the row materials before its use in any industrial applications.

Uranium Analysis and Radon Exhalatron Studies in Geological Samples from Kulu Area, Himachal, Pradesh, India

Surinder Singh, Rajeev Malhotra, Jatinder Kumar

Department of Physics, Guru Nanak Dev University, Amritsar.

pcse@gndu.ernet.in; surinder51@yahoo.com

The track etch technique has been employed to estimate the concentration of uranium in the samples of soil, rocks, plants and water belonging to Kulu area of Himachal Pradesh, India. The radon exhalaton rate of soil, rock and plant samples is also determined. The anomalous uranium values have been found in soil (19.82 ppm), rock (24.72) plant (19.02 ppm) samples belonging to Balsari village of the district. The soil gas radon data obtained using radon emanometry is correlated with high uranium value recorded in soil, rock and plant samples of this area. The anomalous values obtained confirm the uranium mineralization reported earlier by Narayan Dass et. al (1979) and Udas and Mahadevan (1974) in the area.

Soil Radon Response Around an Active Volcano

Nuria Segovia, P. Peña, E. Tamez, M. Mena, C. Valdes

Instituto Nacional de Investigaciones Nucleares (ININ), Apdo. Postal 18-1027, Col. Escandon, 11801 Mexico D.F., Mexico

msa@nuclear.inin.mx

Soil radon behaviour related to the volcanic eruptive period 1998-1999 of Popocatepetl volcano has been studied as a function of the volcanic activity. Since the volcano is located 60 km from Mexico City, the risk associated with an explosive eruptive phase is high and an intense surveillance programme has been implemented. Previous studies in this particular volcano showed soil radon pulses preceeding the initial phase of the eruption. The radon survey was performed with LR 115 track detectors at a shallow depth and the effect of the soil moisture during the rainy season has been observed on the detectors response. In the present state of the volcanic activity the soil radon behaviour has shown more stability than in previous eruptive stages.
Determination of Effective Radium Content in Makkah Soil by CR-39 Nuclear Track Detectors

Asem Abdel-Naby

Alexandria University, Faculty of Education, Physics-Chemistry Department, Alexandria, Egypt
asem@uqu.edu.sa

CR-39 nuclear track detectors were used in air volume of several sealed cylindrical ? shaped plastic tubes can-technique for time integrated long term measurement of radon activity concentrations. Dried soil samples, collected from Makkah region, were used. The tubes 4 cm inner diameter and 20-180 cm in heights, were filled at the bottom with the dry soil samples up to different thickness (10-180 cm). The registration sensitivities of CR-39 nuclear track detectors in sealed tube, taking into consideration the plated-out activity on the walls, were discussed. The porosity of the soil samples, the diffusion length, the effective and real contents of radium-226 were estimated. The results showed that the sealed tube technique could be used as a useful tool the measurement of the radium concentration with reasonable accuracy.

Representative Indoor Radon Survey in Gyergyóremete, Romania

Sándor Csegzi¹, István Csige²

¹4300 Tirgu Mures, Str. Cornesti nr. 68/A, Romania
²Radon Group, Institute of Nuclear Research, H-4001 Debrecen POB 51, Hungary
Csige@moon.atomki.hu

Primary goal of the Gyergyóremete radon program was to pilot a representative indoor radon survey that can be done in other places of the country. Gyergyóremete was built on volcanic rock, where aligning of mineral water springs tells of the existence of geologic faulting. The 1992 census counted 2406 houses and 6550 residents of the village. Representativity of the sample was ensured by random pull of 120 houses from the stock (hypergeometric statistical model). Measurements were done in sleeping rooms at pillow level using etched track type Radamon radon detectors. Exposure lasted from January 1999 to July 1999.

From the results it can be stated with 3 ‰ certainty that the number of houses with radon concentration exceeding 200 Bqm⁻³ fall between 82 and 179. Mapping indoor radon levels resembles the fault location that is indicated by springs and exhibited by geological studies. Particular points of the program were the soulful and self-aware approach of the more than 30 schoolboys and girls participated, and that the program met with a warm response by the public.

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Radon Exhalation From Samples

C. Baixeras¹, B. Erlandsson², Lluis Font¹, Gilbert Jönsson²

¹Grup de Fisica de les Radiacions, Universitat Autònoma de Barcelona, E-08193 Bellaterra-Barcelona, Spain
²Physics Department, Lund University, Box 118, S-221 00 Lund, Sweden
gilbert.jonsson@fysik.lth.se

The soil or bedrock beneath a building, the building material and the house hold water are three sources of radon gas present in the indoor air. The ²²⁶Ra content of samples of these sources can be measured by gamma ray spectrometry. The exhalation of radon gas from the different types of material can be estimated to some extent if the content of ²²⁶Ra of a sample is known. The true emanation is however affected by various parameters, one of which
is the possibility for the gas to come out of the sample. There are several reports on measurements, where the exhalation of radon from different types of material is studied (For example Wilkening 1990; Karamdoust and Durrani 1991).

In this study we report the result from measurements of radon exhaling from samples of soil and bedrock frequent in the Lund region and in the Barcelona region. As soils have different grain size it is important to know the type of soil. The $^{226}$Ra content of a sample is measured with gamma ray spectrometry. The radon measurements are made by film in cans together with the samples according to technique developed for radon measurements in water samples (Erlandsson et al. 2000).

References:

A First Record of the Transantarctic Mountains Late Cretaceous Uplift-Denudation Phase in the Admiralty Block, Northern Victoria Land (NVL), Antarctica

Maria Laura Balestrieri$^1$, Giulio Bigazzi$^2$

$^1$Dipartimento di Scienze della Terra, Università di Firenze, Italy
$^2$CNR – Istituto di Geocronologia e Geochimica Isotopica, C. N. R., Area delle Ricerca, Via Alfieri, 1, I-56010 Ghezzano, Pisa, Italy

g.bigazzi@iggi.pi.cnr.it

The main topographic feature of NVL on the Pacific side of Antarctica are the Transantarctic Mountains characterized by a complex evolution through three distinct pulses of uplift-denudation (~125, ~90, ~50 Ma). We sampled two vertical profiles for fission-track analysis at Mt. Supernal and Mt. Montreuil. These two massifs, mainly composed of granitoids of the Devonian Admiralty Intrusives, face each other from the opposite sides of the Wilson and Bowers terranes boundary. From Mt. Supernal, four samples (3600-2300 m of altitude) were dated (ages between 148 and 65 Ma). At Mt. Montreuil nine samples (2680-1942 m) yielded ages between 99 and 70 Ma. The composite age-elevation profile of the two massifs and length distribution data reveals a pronounced break-in-slope at around 90 Ma and 3000 m. This is the first record of the Late Cretaceous uplift-denudation phase in this sector of NVL. At least 1000 m of denudation can be estimated.

Distribution of Uranium High Concentrations in Lake Baikal Sediments Using SSNTD-Method

Sergey Zhmodik, Anatoliy G. Mironov, V.A. Bobrov

United Institute of Geology, Geophysics and Mineralogy, SB RAS; Novosibirsk Geological Institute, SB RAS, Ulan-Ude, Russia

Uranium concentrations are generally low in water and sediments of Lake Baikal. However its higher concentration have been found in some horizons. For a long time, it failed to study the nature of U-distribution in such microlayers. But it became possible with using SSNTD-method by data of $\beta$-radiography. Preparations made of diatom aleurite-pelite silts and irradiated in a nuclear reactor by neutron flow $10^{16}$ n/cm$^2$ have been studied. Synthetic fluoraphlogopite etched in 20% HF-solution was used as a detector.

Study of U-distribution and its forms in the sediments showed the presence of regularly precipitated uranium and microclasts of U-containing minerals (apatite, zircon, etc). Forming the “stars” from fission trecks on the
radiographs. In the core of some columns at depth 1.1-1.6 m from sedimentary surface, we could discover a microlayer of diatom silt sediment (0.2-1.0 cm) enriched in uranium up to 60-80 ppm. Uranium content is 3-7 ppm in the hosted sediments. Within the microlayer, uranium is distributed quite regularly that testifies to its sedimentation from Baikal water. By composition, this layer corresponds to the diatom sediment enriched in phosphorite. Except uranium, more higher contents of Co (2.5 times), Fe (1.6), Ba (20), Sb (1.7) are observed here.

One to the fact that microlayer has been fixed in sediment of several columns, it can be concluded that U-enrichment is of an area character. Based on the rate of sedimentary formation in Lake Baikal (about 4 cm for 1000 years), sediments of this level formed 28-30 thousand years ago. Their origin can be connected both with uranium introduction in the lake in the period of interglacial getting warmer and its accumulation on geochemical reduced barrier.

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A Rapid Analysis of Radioisotope Concentrations in Sediments Using Gamma-Ray Spectrometry

Mahmoud K. Kullab1, A. M. Ismail1, Y. Abu-Rukah2

1Physics Department, 2Earth Sciences Department, Faculty of Science, Yarmouk University, 211-63 Irbid, Jordan

In this paper, we present the concentrations of the parent nuclides of the naturally occurring radioisotopes in sediments using γ-ray spectrometry. The nuclides' concentrations were found by either direct measurement of their activities, as in the case of 235U and 40K or through the measurements of the activities of their daughters with short half-lives, as in the case of 238U and 232Th. To achieve our goal, samples from Kufranja River basin in Jordan were analyzed by using a computerized γ-ray spectrometer with precise calibration of energy and efficiency. It turned out that the concentrations of radioisotopes in sediments of the studied area were below the standard limits.

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Fission Track Dating of Some Obsidians from Japan

Satoshi Koshimizu1, Kenji Tomura2, Genju Yamamoto3

1Yamanashi Institute of Environmental Sciences, Kamiyoshida, Fujiyoshida, Yamanashi 403-0005, Japan
2Institute for Atomic Energy, Rikkyo University, Nagasaka 2-5-1, Yokosuka 240-0101, Japan
3Yoshiwara Technical High School, Hina 2300, Fuji, Shizuoka 417-0847, Japan

Since the initial development of fission track dating, many minerals and glass material have been dated, primarily for zircon, apatite, sphene and obsidian (Flesicher et al., 1975; Gleadow, 1981). For the improvement of the accuracy of fission track dating systems, the use of age standards was recommended (Hurford, 1990). As geological sources of obsidian in Japan, nearly forty locations have been known (Kawano, 1950), and most of them in Hokkaido, central Honshu and Kyushu. These obsidians from about thirty sources were already dated by fission track method (Suzuki, 1970; Koshimizu, 1981). However, the most of these ages were obtained without age standards as well as thermal fading correction of their spontaneous tracks. In order to obtain the accurate ages of these obsidians, we performed the reinvestigation of fission track dating for obsidians from Japan using Moldavite as age standard, which is a tektite, has a reference age of 15.21 Ma and is widely accepted as a glass age standard.

Further, major and minor elements of these Japanes obsidians were determined by and X-ray fluorescences (XRF) spectrometer equipped with Rh tube. The calibration was performed using 16 rock standards of GSJ (Imai et al, 1995). The analytical errors of the calibration were enough small for the purpose of petrological investigations. Thus, we discussed on the relationship of the chemical composition and fission track ages for some obsidians from Japan.
Radon Exhalation and Radiometric Prospecting of Rocks Associated with CU-U Mineralisations

D. Sengupta\textsuperscript{2}, Rajeev Kumar\textsuperscript{1}, A.K. Singh\textsuperscript{1}, Rajendra Prasad\textsuperscript{1}

\textsuperscript{1}Dept. of Applied Physics, Z. H. College of Engg. & Tech., Aligarh Muslim University, Aligarh, U. P., India
\textsuperscript{2}Dept. of Geography and Geophysics, I.I.T. Kharagpur, W.B., India

The Singhbum thrust belt is 200 Km long arcuate belt in Bihar, eastern India. The huge mineral resources viz. Copper, Uranium, magnetite, apatite and molybdenite etc. make it significant from economic, geological and environmental point of view. Extensive studies of radiometric prospecting and assaying and radon exhalation have been carried out by us for the past five years from Dhubani in the east to Turmadih in the west of the Singhbum shear zone. Radon emanation measurements show reasonably high radon potential of the soil and rocks.

The presence of radioactive isotopes like uranium in the host rocks and the prevalence of confined atmosphere underground within the mines could result in enhanced concentration of radon gas and its progeny. In the present work rock samples from various locations both surface and subsurface were collected from Pathargora, Rakha and Bhatin region of Cu-U mines. LR115 type - II plastic track detector was fixed on top inside of the cylindrical can of 4.5 cm height and 7.0 cm diameter. Equal amount of each 100 µm grains size sample (100 gm) was placed at the base of the cans which were scaled for 90 days.

The radon activity or integrated radon exposure inside the can was obtained from the track density of the detector by using the calibration factor of 0.56 tracks cm\textsuperscript{-1} d\textsuperscript{-1} (Bq m\textsuperscript{3})\textsuperscript{-1} obtained from the earlier calibration experiment (Radiat. Prot. Environ. 20 (1997) 129) and the radon exhalation rate was obtained. A low level gamma ray spectrometer was used fro U estimation. Radon exhalation rates vary from 0.9 to 13.8 Bq. M\textsuperscript{2}. h\textsuperscript{-1} and U concentration from 10.7 to 1579.7 µg/g. Results will be discussed.
Cosmic Radiation Doses on Board of Concorde and Armenian Airlines

Anaïda Akopova¹, Jean-Noël Capdevielle², Anahit Melkonian¹, Stepan Tatikyan¹

¹Yerevan Physics Institute, Alikhanian Brother's 2, 375036 Yerevan - 36, Armenia
²College de France
akopova@lx2.yerphi.am

Charged particles and fast neutron fluxes on the board of aircrafts at the altitude 10-17 km were investigated. Absorbed and equivalent doses rates for the both components are estimated. As a detector a layers of nuclear photoemulsion BR and BY types with the threshold sensitivity 2 and 12 MeV/cm were used accordingly. It is shown, that the main contribution at the total dose (absorbed and equivalent as well) comes from the fast neutrons (about 75-85% of the total dose). In contrast to this, the major contribution to the total dose on the board of spacecrafts brings in by the charged particles. It is interesting to note, that the flight altitude have more essential influence on the neutrons flux and doses, then on the charged particles ones. So, the mean radiation dose from charged particles at the altitude 10-12 km and 17 km is 4.4 and 7.2 mSv/h respectively, while for the fast neutrons - (12-15) and (100-120). The energetic spectrum of the fast neutrons is investigated too. It is shown, that increasing of the flight altitude leads to the enriching of the flux by neutrons with energy 1-3 MeV.

On the Accuracy Problems When Dealing with Low Radon Levels: Report from an EU-Project

Lluis Font¹, C. Baixeras¹, Gilbert Jönsson², Wolfgang Enge³, Michel M. Monnin⁴, K. Freyer⁵, H.C. Treutler⁵, G. Schioccetti⁵, G. Cotellessa⁵

¹Grup de Física de les Radiacions, Universitat Autònoma de Barcelona, 08193 Bellaterra-Barcelona, Spain
²Physics Department, Lund University, 221 00 Lund, Sweden
³Institut für Experimentelle und Angewandte Physik der Universität Kiel, 24098 Kiel, Germany
⁴CNRS, Université Montpellier II, Institut des Sciences de la Terre, de l’Eau et de l’Espace, F-34095 Montpellier Cedex 5, France
⁵ENEA-CRE Casaccia roma, Dipartimento Ambiente, I-00100 Roma, Italy
ll.font@cc.uab.es

Within the frame of an European Union project, indoor radon concentration was measured in six inhabited houses from five different countries. The active (time-resolved) radon monitors PRASSI, ATMOS and ALPHAGUARD were used together with different Nuclear Track passive (time-integrated) detectors. Calibration and intercomparison of the different radon detector types are normally carried out exposing the detectors to high radon levels in the laboratory. This paper reports on the problems and advantages found when using the different types of detectors under real field conditions, specially when the radon concentrations were low. These problems and advantages have to be taken into account for a better interpretation of the data obtained with the different detectors in different countries.
Recent Enhancements to the Understanding of the Response of the NRPB Neutron Personal Dosemeter

Rick Tanner, David Bartlett, L G Hager

National Radiological Protection Board, Chilton, Didcot, Oxfordshire OX11 0RQ, United Kingdom
rick.tanner@nrpb.org.uk

Measurements of the response of the NRPB track-etch neutron personal dosemeter have been extended to cover the forward 2p in greater detail, but also to include measurements and calculations for the reverse 2p. These reverse angles are important when interpreting the response of the dosemeter in workplaces where the field has an isotropic component owing to either scattering or worker movement. In practice the directional distribution of the field will be influenced by both of these factors for all working environments, so a full characterization of the response requires a knowledge of the $H_p(10)$ response for rotational and full spherical isotropy.

It is difficult to determine experimentally the response of the dosemeter in the energy interval between the thermal region and the fast neutron threshold. The dosemeter must have a response to neutrons of these energies, through $^{14}\text{N}(n, p)^{14}\text{C}$ reactions with both the incident and backscattered neutrons. The use of the Monte Carlo code MCNP has allowed the response in this energy region to be evaluated, which substantially enhances the accuracy of interpreting the dosemeter response in the workplace.

Additional measurements have been made to determine the influence of the presence of a phantom on the response of the dosemeter. Previous determinations have used radionuclide sources, which do not give a strong indication of the dependence of this effect on the energy of the neutrons. In this work monoenergetic sources have been used to give a more detailed understanding of this effect. These measurements have been used to aid in the interpretation of detailed energy dependence of response measurements which were made free-in-air.

The measured and calculated response functions have been folded with a limited selection of workplace spectra to assess the implications for the dosemeter’s performance in the workplace. These workplace spectra are representative of the environments in which the dosemeter is worn, so the results have significant implications for the accuracy of dosimetry in those workplaces.

Methods of High-Sensitive Analysis of Actinides in Liquid Radioactive Waste

Alexander Dyakov, T.N. Perekhozheva, E.I. Zlokazova

Sverdlovsk Branch of Research and Development Institute of Power Engineering, Zarechny, Sverdlovsk region, 624051, Russia
dyakov@sfti.zar.rrs.ru

The method of determination of actinides in liquid and solid media, including the LRW of high mineral content and bottom sediments of LRW storage pools is based on the radiochemical separation of U, Np - Pu, Am - Cm on ion-exchange and extraction columns. An identification of radionuclides and determination of their content are performed using alpha-spectrometry. The targets for the alpha-spectrometry are prepared by electrolytical precipitation of actinides onto polished steel disks. A detection limit for actinides activity is 0.04 Bq in a sample.

The microconcentrations of the sum of the main fissile materials U-235 and Pu-239 are determined with the usage of plastic track detectors based on polyethylene-pyridine. Track detectors, placed directly into a liquid sample, are irradiated by thermal neutrons to a fluence of $(2 \cdot 10^{14}$ to $1 \cdot 10^{15})$ cm$^{-2}$ and then etched electrochemically. A detection limit for U-235 and Pu-239 is $3 \cdot 10^{-12}$ g/cm$^3$. 
Optimization of BN1 Screen Thickness for Thermal Neutrons Detection
Ammar A. Al-Sa’ad

Physics Dept., Science College, Basrah University, Ibn Al-Haitham Post Bureau, P.O.Box 42, Basrah, IRAQ

The thickness of a BN1 screen has been decreased from its original thickness to 105 µm in step of 5 µm. The track density and the optical density have been taken in each case for a CR-39 Plastic Track Etch Detector irradiated with Am-Be albedo neutrons and in contact with each sample of BN1 screen. Both the track density and the optical density were remain constant as the BN1 thickness decreased. At a determined value of the BN1 thickness the optical and track densities have been increased. The results have been discussed and concluded.

The BDT Bubble Neutron Detector For Personal Dosimetry
Filip Vanhavere, M. Coeck
SCK-CEN, Belgian Nuclear Research Centre, Boeretang 200, 2400 Mol, Belgium
fvanhave@sckcen.be

Twenty years after their discovery, the bubble detectors are progressing from a laboratory tool towards a workfield dosemeter used for neutron dosimetry. The high sensitivity, direct readability and near dose equivalent response make them at present the best alternative for personal neutron dosimetry. Most popular is the BD-PND bubble detector, available from Bubble Technology Industries. This detector has a threshold around 100 keV, so in neutron fields with an important thermal contribution, it is necessary to supplement the dose measurements with the BDT bubble detector. This one has a different chemical composition so that it measures mainly thermal neutrons.

Following a thorough study of the BD-PND detector we have investigated the characteristics of this BDT detector. We determined the energy dependence using mono-energetic neutrons and radionuclide sources and checked the influence of a phantom. Using thermal and $^{252}$Cf neutrons we also determined the angular dependence of the BDT. All these results learned us to what extent the BDT gives the personal dose equivalent $H_p(10)$. Another important point that we checked was the evolution of the sensitivity with time. Just as the BD-PND detectors, the response of the BDT detector is influenced by the temperature. Also here the temperature compensating system is the limiting factor in the use of these bubble detectors. We determined the change in temperature compensation with their age, again using both thermal and $^{252}$Cf neutrons.

All these tests lead to the conclusion that the BDT bubble detector is a good complement to the BD-PND detector for personal neutron dosimetry, but that care has to be taken when they are used in strongly thermalised neutron fields at high temperatures and large angles.

Methods for Monitoring of Neutron Fields Inside the Object Shelter Using SSNTD
Oleg A.Bondarenko¹, Yu.N.Onishchuk², V.M.Petryshyn¹, A.V.Dmitrienko³

¹Radiation Protection Institute, 53 Melnikov Street, Kiev 253050, Ukraine
²Kiev National Taras Shevchenko University, Physics Department, 2 Glushkov Prospect bldg. 11, Kiev 252022, Ukraine
³Object “Shelter”, Chernobyl NPP, State Enterprise NAEC, Ukraine
boa@rpi.kiev.ua

Transfer of the object Shelter (world wide known as the Sarcophagus) into an ecologically safe site is a vital task. The Sarcophagus is supposed to be a container of a large amount of high radioactive substance – a mixture of destroyed fuel and construction masses. Rising of such a hypothetical situation that may lead to spontaneous chain
reactions is not excluded. Additional evidence of this statement are experience of accident in Tokai Mura, Japan (September, 1999) and for this unexplained accidents (12.01.1996 and 12.09.1996) in some premises of the Sarcophagus when neutron detectors of active type recorded considerable neutron flux increment. Alternative way to increase the reliability of nuclear safety monitoring is considered in usage of passive type detectors on the basis of SSNTD for neutron flux monitoring. Registration of low level neutron fluxes is difficulty in the presence of high intensive gamma and beta fields for the purpose of monitoring of nuclear fissile materials. An exact allocation about 90 ton of fuel uranium is not determined by now. Usage of SSNTD as neutron detectors for searching of massive fuel agglomeration is discussed. Variants of detector facilities referred to the slow and fast neutron registration were debated. Capabilities of metallised sheets to prevent a radon penetration onto detector surface were tested.

LET Distributions Obtained by CR-39 Plates Onboard the Space Shuttle Missions STS-84, 89 and 91 and the Dose Equivalent Estimation by a Combination of Their Distributions and TLD-Data

Hiroko Tawara, Tadayoshi Doke1,2, Takayoshi Hayashi1, Atsushi Kyan3, Shunji Nagaoka2, Toru Nakano2, Shinpei Takahashi2, Kazuhiro Terazawa1 and Eiichi Yoshihira3

Radiation Science Center, High Energy Accelerator Research Organization, Ibaraki 305-0801, Japan
1 Advanced Research Institute for Science and Engineering, Waseda University, Tokyo 169-5888, Japan
2 Tsukuba Space Center, National Space Development Agency of Japan, Ibaraki 305-8505, Japan
3 Graduate School of Science and Engineering, Ibaraki University, Ibaraki 310-0056, Japan
hiroko.tawara@kek.jp

LET distributions have been measured by CR-39 plates with the Real time Radiation Monitoring Device (RRMD)-III in the Space Shuttle Missions STS-84, -89 and -91. Particle fluxes were obtained above 4 keV/µm by the CR-39 and corrected for the dip-angle dependency on track-formation sensitivity. Results were compared with those of GCR and of trapped protons measured by the RRMD-III. The fluxes were smaller than that for the total (GCR + trapped protons), but slightly larger than that for GCR. This fact can be explained by considering dominant radiation in the SAA region to be the trapped protons, and by the low track-formation sensitivity of the CR-39 for protons. We can estimate dose equivalents from the LET distributions and absorbed doses obtained by TLDs which have sensitivity in the lower LET region. The contribution of the trapped protons to the dose equivalents was estimated from the RRMD-III data.

The Diffusion and Deposition of the Gaseous and Solid Alpha Radionuclides Genetically Related in Air

Ana Danis1, Mariana Ciubotariu1, Ildiko Mocsy2, Vlad Tomulescu3

1“Horia HULUBEI” National Institute for Physics and Nuclear Engineering - IFIN-HH, Department 360,76900 Bucharest, Romania
2 Medical Centre and Health Services and Management, Str.Pasteur 6, C.P.93, 3400 Cluj Napoca, Romania
3 Institute of Public Health Bucharest, Str.Dr.Leonte 1-3.76256 Bucharest, Romania
danis@ifin.nipne.ro, vladytom@hotmail.com

The vertical gradient of volume concentrations for radon and its solid alpha descendants/aerosols were experimentally determined, in air, for the conditions corresponding to: an airtight chamber, a close chamber and an open chamber using: an airtight tubular laboratory chamber, a house celler and a lift well of an abandoned mine entrance, respectively. The used alpha track detector was the CR-39, Page England. Lamellae of such detectors of 10 x 35 x 1 mm dimensions were incorporated in an alpha monitoring devices, that were produced in our Laboratory. The devices were equipped/or not with a special filter for solid alpha radionuclides/aerosols stopping.

16 - 20 such alpha monitoring devices were placed along the chamber heights at different distanced, for a duration from a week up to 3 months, in function of volume radon concentrations. The temperature and humidity were
measured at beginning and the end of experiences, but for the airtight chamber the temperature was daily measured, outside the chamber.

The obtained experimental results led us to conclude on the height that would be more indicated to be used for alpha monitoring, in order to evaluate alpha exposure of the population in conditions corresponding to the three investigated chambers. Also, our studies put into evidence the influence of the relative humidity on the vertical volume concentration gradient of solid alpha radionuclides/aerosols by increasing of the heterogeneous nucleation processes.

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**A Comparison of Indoor Radon at the Centre and the Walls of Some Dwellings Using Passive Track Etch Technique**

Baldev Singh, Surinder Singh

Department of Physics, Guru Nanak Dev University, Amritsar 143005, India

The indoor radon measurements have been carried out in the dwellings of a few villages of Hamirpur Distt. Himachal Pradesh, India using Solid state nuclear track detectors in the bare mode. The radon values recorded at the centre of the room. It is observed that the radon concentration near the walls is more than that at the centre. The indoor radon value at the centre varies from 260.51 Aq m$^{-3}$ in NuKhel village to the indoor radon values lie in the range of action level (200-600 Bq m$^{-3}$) recommended by International Commission on Radiological Protection. The seasonal variation of indoor radon concentration in NuKhel is also discussed. It is found that the difference in the indoor radon concentration values recorded at the centre and at the walls is negligible in winter season. This may be due to fact that the room remains closed most of the times in winter.

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**National Program for Radon Exposure Protection in Uzbekistan**

Abdurashid Yafasov

Scientific Association "Akademasbob", Uzbekistan Academy of Sciences, Tashkent

bahramov@online.ru

Territory of Uzbekistan is of seismically active region. The greatest earthquake of 20th Century in Central Asia was erupted in the center of Tashkent City in 1966. A length of cracks formed due to the earthquake is about 35 km. There are also crack groups of 4.5 km long on the distance of 200-300 m from each other. A full length of rupture failures on the Tashkent city is over 500 km. A similar picture can be seen at the epicenter of Nazarbek earthquake of 1980 at the 12 km far from the Tashkent 1966 earthquake epicenter. Thus, geotectonics makes a considerable contribution to the abnormal behavior of radon in the majority of regions in Uzbekistan.

National Committee on Science and Technology of Uzbekistan has included a "RADON" program in the National Scientific Programs for 2000-2002 years. The primary goal of the "RADON" program is development and implementation of techniques to reduce radon exposure of population in Uzbekistan. The "RADON" project involves Republican and regional programs and includes the following aspects:

- Producing a national standard sample, development of radon measuring devices.
- Evaluation of radon level in air of planned and designed buildings.
- Effect of geotectonic anomalies on the formation of radon fields. Effect of microseismic activity on radon concentration variation in the environment.
- Possibility of predicting earthquakes on the base of radon behavior in soil gas and ground water, correlation with other methods of earthquake prediction.
- Radon mapping of the Uzbekistan territory. Classification of regions according to geotectonic and/or radiation anomalies.
Collaboration of Central Asia Republics on radon problem study with each other and International Organizations and Committee (AARST, USA, IAEA, and others).

The Central Asia region is a unique site for a study of natural radon sources as well as industrial pollution of air with radon gas and other alpha-active radionuclides. Fulfillment of the "Radon" program will enable solution of vitally important problem in Uzbekistan. In addition, study in this field will lead us to better understanding physics of radon.

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**Simultaneous Measurement of Equilibrium Factor F Between Radon and its Progeny and Thoron and its Progeny in Indoor Atmosphere Using Solid State Nuclear Track Detector**

R.C.Ramola¹, M.S.Negi¹, V.M.Choubey², T.V.Ramachandran³

¹Department of Physics, H.N.B. Garhwal University, Badshahi Thaul Campus, Tehri Garhwal - 249 199, India.
²Wadia Institute of Himalayan Geology, Dehradun - 248 001, India.
³Environmental Assessment Division, Bhabha Atomic Research Centre, Mumbai - 400 085, India.

hnbgurcr@ndb.vsnl.net.in

Radon, thoron and their progeny are present in indoor atmosphere as attached and unattached fractions. The rate of ventilation of house and plateout of radon/thoron daughters on the surfaces decide the extent of equilibrium between them. Since the daughter products are mainly responsible for the inhalation of the dose, the measurement of equilibrium factor, F, between radon/thoron and their progenies is desirable. It is therefore necessary to measure the equilibrium factor for different types of house construction, locations and seasons before projecting the dose from the measurements of radon and thoron. This paper presents the results of the measurement of F between radon, thoron and their progenies in the dwellings by using LR-115 type II plastic track detector. The exposures were made with a twin chamber dosimeter and 100 houses of different types, distributed at different locations have been surveyed in and around Tehri Garhwal region of Garhwal Himalayas, India. The measured equilibrium factor between radon and progeny varies from 0.90 to 0.014 while the same for thoron and progeny was found to vary from 0.87 to 0.001. The methods of measurement and results obtained are discussed in details.

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**Spatial Distribution of Radon and Thoron in a Stone-House in the Zemplén Mountain, Hungary**

Ilona Hunyadi¹, István Csige¹, Zoltán Dezsö², Zoltán Papp², Thomas Streil³

¹Institute of Nuclear Research of the Hung. Acad. Sci., H-4001 Debrecen, POB 51, Hungary
²Isotope Laboratory of Debrecen University, H-4010 Debrecen, POB 8.
³Sarad GmbH, Dorfplatz 1, D-01705 Pesterwitz/Dresden, Germany

hilona@moon.atomki.hu

During its 55 s half-life only a small amount of $^{220}\text{Rn}$ can emanate from rocks into air. Even at high $^{232}\text{Th}$ content of soil and building materials thoron was measurable only within some 10 cm distances of the walls and was relatively high at the joints of the adjacent walls in the cellar and living areas of a stone house. Radon and thoron were measured with doublets of an etched track type (Radamon) radon and thoron detector. In three series (1997 spring, summer and winter) around 160 measurements were done using nearly quarter year exposure time. $^{238}\text{U}$, $^{232}\text{Th}$, $^{226}\text{Ra}$ content of soil and building materials were measured with gamma-spectroscopic method.

Though thoron at the internal parts of living areas were hardly detectable, its significance comes from the fact that one of its decay product ($^{212}\text{Pb}$) has a half life of 10.6 hours. During this time this isotope and its alpha emitting decay products ($^{212}\text{Bi}$, $^{212}\text{Po}$) can distribute uniformly in the whole volume of the rooms. Exposure to thoron decay products hence may become as significant as to radon decay products. Concerning measurements this means that to estimate thoron exposure, thoron daughters need to be measured rather than thoron only. That significantly differs it from radon in which case radon exposure can be estimated quite accurately from the measurement of long period average radon activity concentration alone.

This work was partially supported by OTKA T 029306 and T 023181.
Exhalation Rate Study of Radon/Thoron in Some Building Materials

Navjeet Sharma, Hardev S. Virk
Department of Physics, Guru Nanak Dev University, Amritsar - 143005, India

Indoor radon/thoron have been recognised as one of the health hazards for mankind. Common building materials used for construction of houses, which are considered as major sources of these gases in indoor environment, have been studied for exhalation rate of radon/thoron. Can technique using plastic track detector LR-115 type-II has been used for measurement. Exhalation rates for radon and thoron have been found to be varying from a minimum value of 0.024 Bq m$^{-2}$ h$^{-1}$ and 29.4 Bq m$^{-2}$ h$^{-1}$ for cement plastered brick to a maximum value of 0.16 Bq m$^{-2}$ h$^{-1}$ and 692.2 Bq m$^{-2}$ h$^{-1}$ for unfired brick respectively. Exhalation rate for thoron has been found to be several times higher than that for radon. Measured exhalation rates for thoron indicate significant presence of thoron in indoor environment which is also supported by indoor measurements of thoron and its progeny.

Four Year Experiences with a Sandwich Track Etch Detector System Used for Reactor Beam- and Personnel Dosimetry

Jozsef Pálfalvi$^1$, Laszlo Sajó Bohus$^2$

$^1$Atomic Energy Research Institute, P.O. Box 49, H-1525 Budapest, Hungary
$^2$ Nuclear Physics Laboratory, University Simon Bolivar, P.O.Box 89000, 1080-A Caracas, Venezuela

The use of track etch detectors for neutron detection is an evergreen application. We have been working on this field for more than 20 years; developed and used neutron detection methods and an accident personnel dosimeter based on fission, (n,α) and recoil particle detection and LR115 and Lexan detector materials. To improve the system became urgent when the Biological Irradiation Facility started its operation at our research reactor in Budapest.

As the first step, a new method for the determination of the response function ($V_T$, track etch rate) of the CR-39 detector material was elaborated for alpha particles and protons. It was based on the formation of a new residual range ($R'$) concept, after the critical review of previous theories, in order to eliminate inconsistencies that might be found in the literature and to assign a real physical meaning to the residual range. An iterative computer code was developed to calculate the $V_T(R')$ function from measured quantities (track diameter, removed layer thickness). The method was verified by measurements using a proton accelerator and several radioactive alpha sources.

Parallel to the work mentioned, a sandwich type track etch detector of CR39 (TASTRAK) was developed utilizing neutron-proton recoil and (n,α) reactions. Applying gold filters with different thickness this system turns into a threshold detector above 100 keV neutron energy. Selecting appropriate filters a passive spectrometer can be composed on the surface of a single CR39 sheet. The number of filters can be optimized on cost and benefit base and also depending on the application. Incident thermal, epithermal, as well as, ‘albedo’ neutrons can be measured by applying boron converters with and without Cd shield.

All the theoretical and experimental investigations resulted in a new simple personnel dosimeter which was introduced into the routine personnel dosimetry service in 1998, and used parallel to the old system till now for comparison. Also several blind tests were performed in this way using different neutron spectra at our secondary standard neutron dosimetry laboratory. The results of the blind tests and the comparisons showed that the new system (having lower dose limit, easier and quicker evaluation) is more reliable and beneficial.

We will present our residual range concept together with the critical review of previous ones, the computer code which calculates the response function, the theory and construction of the gold filtered proton recoil detector and the performance of actual dosimeters being used by us for personnel and beam dosimetry purposes. A comparative
study on neutron dosimeters utilizing CR39 track etch detectors and published during the last ten years will be briefly presented, as well.

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Thorough Investigation of Radon in a School With Elevated Levels

Janja Vaupotic 1, Ilona Hunyadi2, Eszter Baradács2

1Institut “Jožef Stefan”, Jamova 39, SI-1001 Ljubljana, Slovenia
2Institute of Nuclear Research of the Hungarian Academy of Sciences, H-4001 Debrecen, POB 51, Hungary

As part of the nationwide indoor radon programme in Slovenia, instantaneous radon concentrations in air have been determined in 890 schools, using the alpha scintillation technique. Grab samples were collected during the winter in a ground floor classroom which was kept closed overnight. In 77 school buildings indoor radon concentrations exceeded 400 Bq m⁻³, with the highest value about 5 kBq m⁻³. The transport of radon over long distances in the karst region, which covers about 50% of the country, and the poor quality of the foundations of slab, are the two main factors responsible for high radon concentrations in about 70% of the buildings with high radon levels.

This paper reports the results of measurements carried out in the school with the highest radon concentrations. The school was built in 1885 on karst terrain. It is a two storey building with attic, with four rooms mostly occupied during the school hours: two classrooms on the ground floor and a kitchen and gym on the first floor, situated above the classrooms. The main part of the building does not have a basement - there is only a space below the staircase, which is separated and connected with doors to the corridors on the ground and first floors.

Transport of radon through the building was investigated using etched-track detectors and electrets for measurements of average indoor radon concentrations and AlphaGuard (Genitron), Sarad-EQF30xx (Sarad) and System-30 (Scintrex) monitors for continuous measurements of radon and radon decay products.

In the mainly occupied places of the building, average indoor radon concentrations in winter range from 3 to 5 kBq m⁻³. On the ground floor radon enters the classrooms through cracks in a poorly constructed concrete slab. In the air sucked from the crack below the parquet a radon concentration of 15 kBq m⁻³ was found. The highest radon concentration of about 30 kBq m⁻³ was, as expected, found in the poorly ventilated basement space. Since higher concentrations were found in the first floor rooms and in the staircase than in the classrooms in the ground floor, it seems that the main source of radon on the first floor is by direct transport from the basement through the staircase, when the doors from the staircase to the corridors are opened, rather than from the classrooms below. The building materials were excluded as an additional source of radon in the air because they were shown to contain low concentrations of uranium and radium.

Annual effective doses were estimated for the pupils and the teachers according to ICRP 65. They ranged from 3.7 to 5.2 mSv. The complete annual effective dose for pupils and teachers obtained by exposing etched-track detectors in their homes, will be presented.
Use of SSNTD in Study of Relation of Indoor Radon and Building Fabric

Wei Lu¹, Yunjiang Yao², Fang Zhang³, Baoxiang Yang³, Bo Zhang², Xixin Ja³

¹Tianjing Institute of Geology and Mineral Resources, No 4, 8th Road, Dazhigu, Tianjing 300170, China
²Jingwang Limited Company, Fenghuang County of Hunan Province, China
³Tianjin Building Materials General Group Corporation, No. 223 Er Ma Road Nankai, Tianjin 300100, China

weilu@public.tpt.tj.cn

Some indoor radon level seems lower than another rooms in the same building though it lies on geological fault, where is a high level of radon in soil. Changing the structure of building can effect the rise and fall of indoor radon level. such as, frontage, the structure of wall and ground, the ventilate and drainage as well as the strictness of face of wall in order to prevent radon exudation and so on. nucleo-physical scientist and building scientist associated determine many radon level in soil and indoor by SSNTD in order to look for a structure preferably for lower radon level. The study was done for 6 buildings by Water Park in Tianjin, China.

The Effect of High Voltage Power Lines on Radon Concentration in Soil

Riad Shweikani, Ghassan Raja, M. Takeyedinc

Atomic Energy Commission of Syria, Damascus, P.O. Box 6091, Syria

Many studies were conducted to find out if there is any correlation between lung cancer and childhood leukemia with radon exposure. In addition, studies were carried out on the correlation between the exposure of magnetic and electric fields with health hazards. But very few studies, if any, were conducted to find the correlation between the magnetic and electric fields and radon exposure. In this work, the effects of electric and magnetic field produced by the high voltage power lines (220 kV and 440 kV) on the soil radon concentration were studied. Passive measurements were used to measure radon in soil, while instruments from Holaday Industries were used for measuring the electric and magnetic fields.

The measurements were performed through two profiles. The first profile was under two parallel 230 kV power lines and the other one was under one 440 kV power line. Passive radon detectors were buried in soil at about 50 cm depth through a line crossing perpendicular to the direction of the lines. The distance between the detectors were 3 m under the power lines itself and 6 m elsewhere. Measurements of radon in soil were repeated twice to confirm the results.

The results showed that for measurements performed under 230 kV, there is a clear correlation between radon in soil and magnetic field, while on the other hand, the correlation with electric field was not clear. In the case of 440 kV lines, it appears that radon concentration is affected positively with magnetic field and negatively with electric field. This behaviour was explained through the physics of radon emanation from the soil grains and the physical properties of both magnetic and electric fields produced by power lines.
Indoor Radon Measurements and Methodologies in Latin American Countries

A. Canoba\textsuperscript{1}, F.O. Lopez\textsuperscript{1}, M.I. Arnaud\textsuperscript{1}, A.A. Oliveira\textsuperscript{1}, R.S. Neman\textsuperscript{2}, J.C. Hadler\textsuperscript{3}, P. J. Iunes\textsuperscript{2}, S.R. Paulo\textsuperscript{2}, A.M. Osorio\textsuperscript{3}, R. Aparecido\textsuperscript{3}, C. Rodriguez\textsuperscript{5}, V. Moreno\textsuperscript{4}, R. Vasquez\textsuperscript{4}, Guillermo Espinosa\textsuperscript{5}, J.I. Golzarri\textsuperscript{7}, T. Martinez\textsuperscript{6}, M. Navarrete\textsuperscript{6}, Nuria Segovia\textsuperscript{7}, P. Pena\textsuperscript{7}, E. Tamez\textsuperscript{7}, Patricia Pereyra\textsuperscript{8}, Maria Elena Lopez Herrera\textsuperscript{8}, Laszlo Sajo Bohus\textsuperscript{9}

\textsuperscript{1}Autoridad Reguladora Nuclear. Av. Libertadores 8250. Buenos Aires, Argentina
\textsuperscript{2}Instituto de Física, UNICAMP, 13083-970, Campinas, SP, BRAZIL.
\textsuperscript{3}Universidad Estadual Paulista, Sao Pablo. BRAZIL.
\textsuperscript{4}Comisión Ecuatoriana de Energía Atómica, PO Box 17-01-2517, Quito, ECUADOR.
\textsuperscript{5}Instituto de Física, UNAM. Apdo. Postal 20-364. 01000, México, D.F., MEXICO.
\textsuperscript{6}Facultad de Química, UNAM. Edificio D, Ciudad Universitaria, México, D.F. MEXICO.
\textsuperscript{7}ININ. Apdo. Postal 18-1027, 11801 México, D.F., MEXICO.
\textsuperscript{8}Pontificia Universidad Católica de Perú. Apdo. Postal 1761, Lima 100, PERU.
\textsuperscript{9}Universidad Simón Bolivar. P.O. Box 89000, Caracas, VENEZUELA.

According to the current international guidelines concerning environmental problems, it is necessary to evaluate and to know the indoor radon levels, specially since most of the natural radiation dose to man comes from the radon gas and its progeny. Several countries have established National Institutions and National Programs in charge of the study of radon and its connection with lung cancer risk and public health.

The aim of this work is to present the indoor radon measurements for the different Regions of Latin America (LA) in the following countries: Argentina, Brazil, Ecuador, Mexico, Peru and Venezuela; including the detection methods used. This study shows that the passive radon devices based on alpha particle Nuclear Track Methodology (NTM) is one of the more generalized method in LA for long term indoor radon measurements. CR-39, LR-115 and Makrofol being the more commonly used detector materials. The participating institutions and the radon level measurements in the different countries are presented in this contribution.

Keywords: Indoor Radon; Detection Methodologies; Latin American Countries.

Hot Particle Dosimetry at Nuclear Power Plants

M. Bakali, Francisco Fernández

Grup de Física de les Radiacions. Departament de Física, Universitat Autònoma de Barcelona, E- 08193 Bellaterra, Spain

Calibration and data analysis for a multicomponent thermoluminescence dosemeter are described. Measurements of directional dose equivalent of beta radiation and effective beta energy were carried out in the working environment of a Nuclear Power Plant (Vandellos II). The effective beta energy is most frequently between 150 and 500 keV. The new code VARSKIN MOD 2 was used to calculate the skin dose equivalent $H_s(0,07)$ and the gamma dose equivalent $H(10)$ corresponding to the encountered hot particles. A comparison between the calculated results and experimental values is presented.
Determination of Radon Exhalation from Building Materials Using Active and Passive Detectors

Mohammed Al-Jarallah¹, Falah Abu-Jarad², Fazal-Ur-Rehman²

¹Dept. of Physics, King Fahd University of Petroleum & Minerals, KFUPM Box 77, Dhahran 31261, Saudi-Arabia
²Centre for Applied Physical Sciences, King Fahd University of Petroleum & Minerals, P.O. Box 2020, Dhahran 31261, Saudi-Arabia

mibrahim@kfupm.edu.sa

Measurement of radon exhalations for selected samples of construction materials were carried out using active and passive detectors. These samples were granites, marbles and ceramics. In the active method, AlphaGUARD gas analyzer with emanation container was used while in the passive method, PM-355 nuclear track detectors with the can technique was applied. The results of the two measurements will be presented and the comparison between the two methods will be discussed.

A Development of Plastic Track Detector Method to Solve Safety Problems of Nuclear Reactors

Alexander Dyakov, T.N. Perekhozheva, E.I. Zlokovazova

Sverdlovsk branch of Research and Development Institute of Power Engineering, Zarechny, Sverdlovsk region, 624051, Russia

dyakov@sfi.zar.erp.ru

The twenty–year experience in the development and application of the plastic track detector (PTD) method for solving the problems of radiation, nuclear and ecological safety of nuclear reactors is reported. The “wet” variant of the PTD method is applied for the investigation of the mechanism of uranium mass transfer in the first circuit of the IVV–2M nuclear research reactor. The detection limit for U–235 found by the ‘wet’ variant of the PTD method is $3 \times 10^{-12}$ g/cm$^3$. In order to determine a uranium concentration in the first circuit of the VVER–1000 type power reactor as well as in original natural waters, the method, combining the PTD with the thin layer inorganic sorbents, was developed. The detection limit for natural uranium is $3 \times 10^{-12}$ g/cm$^3$ and that for plutonium activity is $1.5 \times 10^{-3}$ Bq/cm$^3$. A concentration of fissile materials in liquid radioactive waste is determined after the radiochemical separation of actinides.

Indoor Radon Level in Dwellings of Rajshahi City in Bangladesh Using Passive Solid State Nuclear Track Detector Technique

Alok Srivastava¹, M.R.Zaman², Kamal K.Dwivedi³, T.V.Ramachandran⁴

¹Department of Chemistry, Panjab University, Chandigarh-160014, India
²Department of Applied Chemistry, Rajshahi University, Rajshahi-6205, Bangladesh
³Arunachal University, Itanagar-791111, India
⁴Environmental Assessment Division, Bhabha Atomic Research Centre, Mumbai-400085, India

tvr@apsara.barc.ernet.in

The indoor radon level in some dwellings of Rajshahi city in Bangladesh has been determined using the passive solid state nuclear track technique using Lr-115 (Type II) solid state nuclear track detectors. Though large scale measurements on radon exposure have been carried out in advanced countries due to increasing concern about its detrimental effects on the health of general population there have been relatively very few studies in this area in developing countries.
A modest attempt has been made by initiating measurement on the indoor radon level in some dwellings of Rajshahi with a view to extend the present work to other regions of Bangladesh. The equilibrium radon concentration in the dwellings selected for this work ranged from 8 to 14 Bq per cubic metre which suggests that the indoor radon level in dwellings of Rajshahi are within the limits prescribed by the International Commission for Radiation Protection. Further an attempt has also been made to correlate the observed indoor radon levels with the seasonal variation and the living conditions of the inhabitants.

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Radon Levels in Dwellings in Tomsk and Correlation with Influence Factors

Valentina Iakovleva, Vladimir Karataev

Tomsk Polytechnical University, 30 Lenin avenue, 634034 Tomsk, Russia

jak@interact.phtd.tpu.edu.ru

The research of radon contents in dwellings began since 1997 in Radiation Control Laboratory of Tomsk Polytechnic University. Indoor concentration of $^{222}$Rn was determined in over 300 homes using etched track detectors and radon radiometer RRA-03 (Russia). Diurnal and seasonal variations at some locations were observed in order to determine correction factors. The link between indoor level of $^{222}$Rn, number of storeys, type of building materials has been investigated. The local geology for revealing influence on indoor radon levels was examined also. Surface soils are presented basically loamy soils with the average radium content 25 Bq/kg, which correspond to surface radon exhalation about 35 mBq/m$^2$ s (only diffusion transport). This can not be cause of elevated indoor radon levels. But there are more then 150 springs (and fontanels) in Tomsk that indicates presence of fractures. Our study showed that some buildings situated in these places have indoor levels more then 200 Bq/m$^2$.

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Radon and Its Progeny Concentrations in Dwellings: Influences of Geological and Housing Factors

Abdul Khan

Department of Physics, Aligarh Muslim University, Aligarh-202002, India

pht04ajk@amu.up.nic.in; j.abdul@mailcity.com

$^{222}$Rn is a radioactive gas emitted during the decay of $^{238}$U. Inhalation of radon and its radioactive decay products have been associated with the induction of lung cancer not only in underground mines but also in family dwellings. A large number of radon measurements inside the dwellings of Europe and North America revealed that many dwellings have more radon levels than expected. This paper describes the results of research undertaken in about 600 dwellings of different provinces in India in which one of the objective was to evaluate the influence of geological and housing parameters on radon levels. Radon and its decay products were measured with LR115 type-II detectors in bare mode. Geological parameters of rocks and soils were determined from various sources (e.g. geological maps etc.) and housing characteristics were documented with a questionnaire.

The results show that the indoor radon concentrations depend both on geological factors as well as housing characteristics. The geometric mean (GM) values of the radon concentrations for Kohima, Palampur-Baijnath and Dehradun dwellings were 88 Bq m$^{-3}$, 134 Bq m$^{-3}$ and 57 Bq m$^{-3}$ with geometrical standard deviations (GSD) 1.7, 2.3 and 1.7 respectively. The GM radon concentrations in the 300 dwellings of Lucknow and Kanpur cities were found to be 25 Bq m$^{-2}$ and 25 Bq m$^{-2}$ with GSD of 2.2 and 2.6 respectively. Total potential alpha energy (TPAE) concentrations due to radon progeny were measured in 143 dwellings of Rajasthan province. The GM values of TPAE concentrations in the three towns were found to be $1.9 \times 10^{-7}$ J m$^{-3}$, $1.2 \times 10^{-7}$ J m$^{-3}$ and $1.7 \times 10^{-7}$ J m$^{-3}$ with a GSD of 2.2, 2.2 and 2.5 respectively. These results illustrate the difficulties in predicting radon and its progeny concentrations in homes.
Experience of Belarus in the Study of Radon Impact on the Health of Population in Zones of Tectonic Breaks
Michail ?linin

Institute for Problems of Natural Resources Use and Ecology of National Academy of Sciences of Belarus, 10 Staroborisovsky trakt, 220114 Minsk, Republic of Belarus
ipnrue@ns.ecology.ac.by

The problem of studying radon for the Republic of Belarus has a special urgency, since about the quarter of its territory is contaminated with Chernobyl radionuclides. According to the aerospace map of tectonic breaks in order to study radon cities were marked, damaged by the Chernobyl catastrophe. The detailed radon-monitoring in Rechitsa, located on tectonic breaks, has shown that there are about 34 areas with increased contents of radon in the air. The studies to investigate radon effluents were continued in Baranovichi, Zhlobin, ?ozyr and ?insk . As a search sign to find such places the tectonic breaks, composition of crystalline and sedimentary rocks, the depth of underground water were used. The studies were executed with equipment ???-500 and radon-monitor "Alpha GUARD PQ 2000". It has been stated that in separate basement premiseses concentrations of radon reached 700, on the 1-st floors - 250 and on street floors - 150 - 250 Bq/m$^3$. The compiled radon-dangerous maps were used to undertake the preventive actions and to adjust general plans of building up of these cities.

Indoor Radon Measurements in Dwellings of Kulu Area, Himachal Pradesh, Using Solid State NuclearTrack Detectors
Surinder Singh, Rajeev Malhotra, Jatinder Kumar

Department of Physics, Guru Nanak Dev University, Amritsar 143005, India
pcse@gndu.ernet.in; surinder51@yahoo.com

The results for indoor radon measurement carried out in the dwellings of Kulu area, Himachal Pradesh, India using LR-115 plastic track detectors in the bare mode are reported. The average indoor radon concentration in the villages surveyed varies from 156.11 Bqm$^{-3}$ for Kasol village to 635.42 Bqm$^{-3}$ in Balsari Village. In 78% of the houses the radon concentration is below the upper limit of the recommended action level (<600 Bqm$^{-3}$) and 27% of the houses are having radon concentration above the recommended values (7600 Bqm$^{-3}$). The annual exposure, the annual effective dose and life time fatality risk are calculated for each village according to the guidelines given by the International Commission on Radiological Protection (ICRP, 1993). The data seasonal variations of indoor radon and the gamma activity recorded in the area is also discussed.

New Can Technique for Measuring Radon and Its Daughters in Makkah Tunnels
Asem Abdel-Naby

Alexandria University, Faculty of Education, Physics-Chemistry Department, Egypt
asem@uqu.edu.sa

A new passive radon and its daughters detector based on a cylindrical metal can of radius 51 mm and height 100mm with such a device has been proposed earlier by Somogyi, the device houses 3 detectors of CR-39,one exposed to the ambient air and two in different positions inside the cylinder. The detectors used to detect radon and its daughters. The detectors allow $^{222}$Rn, $^{218}$Po and $^{214}$Po concentrations to be determined separately. This device was applied to measure the radon and its daughters in Makkah Tunnels and the holy city of Makkah.
Indoor Radon Levels Measurements in Mexico City

Guillermo Espinosa¹, Richard Gammage²

¹Instituto de Física, UNAM. Apdo. Postal 20-364, 01000 México, D.F.
²Oak Ridge National Laboratory, Oak PO Box 2008, Oak Ridge, TN 37831, USA

espinosa@fenix.ifisic.uc.unam.mx

Mexico City, also called Federal District, with almost 22 million inhabitants, is one of the most populated sites, taking into account the metropolitan area of the Valley of Mexico. Due to its geographical position, the Federal District presents very peculiar factors for the study of indoor radon: a) The city is located more than 2,200 meters above sea level.; b) Mexico City is considered as a high seismicity zone, with an average of more than seven (from three to five Richter scale intensity) earthquakes per day; c) The construction materials of houses and buildings are in general concrete, clay bricks and gypsum, natural emitters of radon; and d) there is a high population density.

This work presents the Indoor Radon Levels Measurements, in each one of the 16 political zones of the Federal District and in the 17 urban municipalities of the neighboring state of Mexico. Although the entire metropolitan area has a regular climate with small fluctuations, the types of construction are quite diverse: from large high buildings to small rooms inhabited by several families. In this study, we selected an Indoor Radon Passive Close-End Cup device, with CR-39, 600 µm thick polycarbonate (Lantrack®) as Nuclear Track Detector. The track development is done in one chemical-etching step, and the detectors were read by a Digital Image Analysis System (DIAS).

The results are interesting taking into consideration that the measurements span three years, in periods of three months of integration time, and cover at least fifty sites in each zone or municipality. These data in association with other measurements of contaminants in Mexico City, such ozone, suspended microparticles, lead and sulfur, will serve to have a better idea of the health problems of the population of the Metropolitan Zone.

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Keywords: Indoor Radon, CR-39, Mexico City.

Radon and Its Progeny Concentrations in Dwellings: Influences of Geological and Housing Factors

Abdul Khan

Department of Physics, Aligarh Muslim University, Aligarh-202002, India

pht04ajk@amu.up.nic.in; j.abdul@mailcity.com

²²²Rn is a radioactive gas emitted during the decay of ²³⁸U. Inhalation of radon and its radioactive decay products have been associated with the induction of lung cancer not only in underground mines but also in family dwellings. A large number of radon measurements inside the dwellings of Europe and North America revealed that many dwellings have more radon levels than expected. This paper describes the results of research undertaken in about 600 dwellings of different provinces in India in which one of the objective was to evaluate the influence of geological and housing parameters on radon levels. Radon and its decay products were measured with LR-115 type-II detectors in bare mode. Geological parameters of rocks and soils were determined from various sources (e.g. geological maps etc.) and housing characteristics were documented with a questionnaire.

The results show that the indoor radon concentrations depend both on geological factors as well as housing characteristics. The geometric mean (GM) values of the radon concentrations for Kohima, Palampur-Baijnath and Dehradun dwellings were 88 Bq m⁻³, 134 Bq m⁻³ and 57 Bq m⁻³ with geometrical standard deviations (GSD) 1.7, 2.3 and 1.7 respectively. The GM radon concentrations in the 300 dwellings of Lucknow and Kanpur cities were found to be 25 Bq m⁻³ and 25 Bq m⁻³ with GSD of 2.2 and 2.6 respectively. Total potential alpha energy (TPAE) concentrations due to radon progeny were measured in 143 dwellings of Rajasthan province. The GM values of
TPAE concentrations in the three towns were found to be $1.9 \times 10^{-7}$ J m$^{-3}$, $1.2 \times 10^{-7}$ J m$^{-3}$ and $1.7 \times 10^{-7}$ J m$^{-3}$ with a GSD of 2.2, 2.2 and 2.5 respectively. These results illustrate the difficulties in predicting radon and its progeny concentrations in homes.

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**Experimental Determination of LR-115 Detector Efficiency for Exposure to Alpha Particles**

Daniele Marocco, Francesco Bochicchio

Laboratorio di Fisica, Istituto Superiore di Sanita, Viale Regina Elena 299, I-00161 Roma, Italy

bochicchio@iss.infn.it

A radon dosemeter with two LR-115 detectors, designed by Tommasino, is widely used by Italian and other laboratories. A simple model was developed to calculate its sensitivity, in order to optimise some parameters (Bagnoli et al. 1999). The model assumes a constant response to alpha particles with energy within the range $E_{\text{min}} - E_{\text{max}}$ and with angle of incidence less than the critical angle $\theta_c$. The values preliminarily adopted for $E_{\text{min}}$, $E_{\text{max}}$ and $\theta_c$ were taken from the literature, however they were not obtained with both our etching procedure and track counting technique (spark-counter), which affect significantly the sensitivity. Therefore, an experimental apparatus was set up to measure the efficiency of LR-115 detectors exposed to alpha particles with different energy and angle of incidence, using Am-241 as source of alpha particles and air in a pressure-controlled chamber to degrade their energy. The preliminary results will be presented.


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**Fast Neutron and ?-Ray Dosimetry with Imaging Plates**

Aziz Boukhair$^1$, Céline Heilmann$^1$, A. Pape$^1$, Guy Portal$^2$

$^1$ Institut de Recherches Subatomiques, Université Louis Pasteur, Chimie Nucleaire, 23 rue du Loess - BP 28, F-67037 Strasbourg Cedex 2, France

$^2$ CEA/DAM, Bruyères le Châtel 91680, France

celine.heilmann@IReS.in2p3.fr

An Imaging Plate (IP) is a passive integrating detector capable of medium-term storage of ionizing energy. A visible laser scan ($\lambda = 633\text{nm}$) can then be used to liberate a number of visible photons proportional to the amount of energy trapped. An IP is sensitive to all ionizing particles of any energy whatsoever, and to photons. It is linear in response over 4-5 decades. We have studied the response of IP to neutrons emitted by a Pu-Be source in a differential measurement that corrects for the $\gamma$-ray component from the neutron source. The dose threshold for fast neutrons, as well as for $^{60}$Co $\gamma$-rays, could thus be determined.
Determination of Uranium Isotopic Composition in Soil Hot Particles from the Chernobyl Vicinity

Sergei Boulyga\textsuperscript{1,2}, J.S. Becker\textsuperscript{1}, H.-J. Dietze\textsuperscript{1}

\textsuperscript{1} Central Department for Analytical Chemistry, Research Centre Juelich, D-52425 Juelich
\textsuperscript{2} Radiation Physics and Chemistry Problems Institute, 220109 Sosny, Minsk, Belarus
s.boulyga@fz-juelich.de

Environmental contamination with spent uranium is possible during reprocessing of spent nuclear fuel from nuclear reactors or during accidents with nuclear devices and nuclear power plants (NPP). Investigation of the radionuclides leaching from the nuclear fuel particles in soil is important for monitoring and forecasting radio-ecological situation in the contaminated regions. To this end the analytical methods are required for the direct determination of spent reactor uranium in soil particles in addition to radioanalytical methods for plutonium and americium measurement.

The aim of this work was the development of a rapid and sensitive analytical procedure for uranium isotopic ratio measurement in extremely small samples based on nuclear track radiography and inductively coupled plasma mass spectrometry. The \( ^{236}\text{U} \) isotope was used as an environmental monitor for the spent fuel because it is produced in nuclear reactors via the \( ^{235}\text{U}(n,\gamma)^{236}\text{U} \) reaction.

Nuclear track radiography was used for identification of particles having high specific activity in a multitude of soil samples. A double focusing sector field mass spectrometer “Element” (Finnigan MAT) with microconcentric nebulizer attached to a desolvation unit was applied for uranium isotopic ratio measurements. With this experimental arrangement uranium isotopic composition was analysed in individual soil particles collected in the vicinity of the Chernobyl NPP. The minimal detectable \( ^{236}\text{U}/^{238}\text{U} \) ratio was about \( 10^{-7} \). The paper presents both the results of method development and experimental measurements of uranium isotopes with extremely differing abundance in environmental microsamples.

Simulating Radon Daughters Diffusion Through the Air and Their Depletion on Material Surfaces

S. R. Paulo\textsuperscript{1}, Rodrigo Neman\textsuperscript{2}, P. J. Iunes\textsuperscript{2}, Julio Cesar Hadler Neto\textsuperscript{2}

\textsuperscript{1} Departamento de Física, Departamento de Ciências Exatas e da Terra, Universidade Federal do Mato Grosso, UFMT, 78060-900, Cuiaba, MT, Brazil
\textsuperscript{2} Instituto de Física “Gleb Wataghin”, Universidade Estadual de Campinas, UNICAMP, 13083-970, Campinas, SP, Brazil.

In recent decades, much has been learned about the nature of radon and radon daughters (RD) contamination. Nevertheless, the RD plate-out phenomenon is still not well understood due to environmental conditions, mathematical and detection limitations. When nuclear track detectors are employed to assess the radiation levels of alpha activity, a problem takes place: the selfplate-out effect caused by detector’s surface disturbs the spatial distribution of the surrounding RD and the activity measured is not the real activity present in the air. In this work we simulate the RD diffusion inside a region where a detector, with shape and size chose, is exposed. The influence of the detector’s size and shape on the RD spatial distribution and on the depletion rate is shown to be in accordance with experimental data.
A Non-Destructive Method of Pu Determination in Specimens

Julia Bondar

Ukraine State Scientific Center of Environmental Radiogeochemistry, Academy of Science of Ukraina, 252680 Kiev, Ukraine
center@radgeo.freenet.kiev.ua

At present the man-made transuranium elements created as a result of nuclear weapons tests or due to accidents on nuclear power plants are widely distributed on the surface of the Earth. Plutonium is the most widespread element among TSE and is represented as alpha- and beta-emitter. Although the average concentration of plutonium is about 10-13 g/g in the environment, it is considerably higher in the contaminated regions. The appearance of plutonium in the geo- and biosphere is a relatively new problem in trace analysis, so its geobiochemical behaviour in the environment has been studied insufficiently at present.

The investigation of the plutonium content with the radiochemical separation and alpha-spectrometry is rather difficult. Besides, as a result of a chemical treatment the information on its microdistribution in the specimen is lost. We are proposed a non-destructive method of Pu determination in solids, allowing to avoid these difficulties. It is based on $^{239}$Pu determination in specimens using combined neutron and gamma-activation analysis. This method can be used for the quick, high-sensitive and inexpensive Pu estimation in the areas heavily damaged due to radioactive fall-out. The sensitivity of proposed method lies between $10^{-9}$-$10^{-11}$ g/g. Some modifying of this method made it possible to identify “hot” particles of the Chernobyl area.

Neutron, Gamma and Roentgen Fluorescent Activation Analysis of Hair of Children, Suffering from Bronchial Asthma

O.A. Alekseeva$^1$, S.F. Gundorina$^2$, M.V. Frontasjeva$^2$, M.V. Gustova$^2$, A.G. Belov$^2$, Vladimir P.Perelygin$^2$, O.S. Zaverioukha$^3$

$^1$Chair of Childhood Diseases, Russian University of Peoples Friendship 142022, Moscow, Russia
$^2$Joint Institute for Nuclear Research, 141980, Dubna, Russia
$^3$Tomsk Polytechnical University, 634034, Tomsk, Russia
pergam@cv.jinr.dubna.ru

The aim of present study was the multiparametric investigation of dangerous microelements containing in the hair of children under school and primary school age in the town Troitsk, Moscow Region, including 12 children ill with bronchial asthma and 11 control group persons. The hair specie with weight 10-40 mg were analyzed with application of epithermal neutron activation analysis conducted at experimental installation REGATA and neutron source unique Pulsed Fast Reactor IBR-2 with application of combined gamma-neutron irradiation at Microtron MT-25 and Roentgen Fluorescence Analysis device of JINR.

The data or element contains in hair were obtained with solid state track detectors and semiconductor electronic spectrometers. The solid state track detectors provide the determination of U, Th, Bi and Be elements at the level of sensitivity up to $10^{-3}$-$10^{-5}$. These data were compared with more representative information about dangerous microelements concentration obtained with NAA and RFA analysis. The obtained concentrations of most elements vary in a wide range, which is in agreement with the know data. The highest degree of element dispersion was observed for U, Th, Pb, I, Br, Sb, Co, K and Be (the variations coefficient were higher than 100-200%).

The preliminary analysis of results shows, that in the clinical picture there is some proved correlation between an increased content of some element in hair and symptoms of their accumulation in the organism of ill children, whose revealing is a basic of examination. These experiments shall be continued in the future on the more representative basis.
Determination of Uranium Concentration in Human Hair by (n, f) Radiography

Y.S. Chung\textsuperscript{1}, Zinaida En\textsuperscript{2}, S.Y. Cho\textsuperscript{3}

\textsuperscript{1}HANARO-Center, KAERI, Integrated Safety Assessment Team, P.O. Box 105, Yusong, Taejon 305-600, Republic of Korea
\textsuperscript{2}Institute of Nuclear Physics, Uzbekistan Academy of Sciences, Ulugbek, Tashkent 702 132, Uzbekistan
\textsuperscript{3}College of Health Science, Yonsei University, #234, Maeji, Hungob, Wonju, Kangwondo, 222-710, Korea
zinaen@suniup.tashkent.su

Hair is considered to be an appropriate indicator of internal contamination with heavy metals. At the same time, hair can also serve an indicator of external pollution. A fission fragment track detection technique was applied to determine uranium concentration in human hair. Hair samples were collected from two groups of people - a) from people not dealing with uranium directly, b) from heavy duty work employees. The samples analyzed were compiled into two sets - unwashed and washed with acetone and distilled water.

Irradiation was performed in the pneumatic irradiation tube NAA1 at the HANARO reactor, KAERI with a thermal neutron flux $\sim 1.7 \times 10^{13} \text{ cm}^{-2} \text{ sec}^{-1}$ with a Cd ratio $\sim 200$ for 10 min. Lexan plastic was used for the detection of fission fragments from the $^{235}\text{U}(n, f)$-reaction.

Concentration of $^{235}\text{U}$ for the first people group was varied from $<1$ to 35 ppb. Radiographs of heavy duty work samples contained high dense "hot spots" along a single hair. After washing, external contamination was shown to be not removed totally. There was significant amount of fission fragment stars in the washed sample radiographs. Insoluble uranium compounds were not washed out completely. The f-radiography technique, having high sensitivity, and capable of getting information on uranium content at each point of a single hair, is an excellent tool for controlling uranium contamination.

Dosimetric and Microdosimetric Characteristics of High Energy Proton Beams

František Spurný\textsuperscript{1}, Valeriy Bamblevski\textsuperscript{2}, Alexander Molokanov\textsuperscript{2}, B. Vlcek\textsuperscript{1}

\textsuperscript{1}Department of Radiation Dosimetry, Nuclear Physics Institute, Czech Academy of Sciences, Na Truhlárce 39/64, CZ- 180 86 Praha 8, Czech Republic
\textsuperscript{2}Joint Institute of Nuclear Research, P.O.Box 79, 141980 Dubna, Moscow region, Russia
spurny@ujf.cas.cz

High energy ($\lambda > 50$ MeV) protons can be considered, when their ionization losses stopping power is taken into account as the radiation with low ($< 5$ keV/µm) linear energy transfer (LET). However, their energy is already sufficient to create through the nuclear reactions in an irradiated matter secondary particles with much higher LET. This phenomenon can modify characteristics of the energy transfer process due to these particles, it should be taken into account when such particles are used for radiobiology studies and/or for radiotherapy.

The importance of these secondary particles was studied experimentally by means of the LET spectrometer based on a chemically etched track detector, in which the tracks of primary protons are not revealed. The studies were performed in proton beams available at the Joint Institute of Nuclear Research (JINR) at Dubna, Russia, with protons of energies between $\sim 80$ MeV and 1 GeV. The microdosimetric distribution of secondary particles mentioned are presented and compared, the contribution of them to primary proton ionization losses absorbed dose is estimated. This contribution increases relatively with the proton energy, the importance of this phenomenon to some applications is discussed.
On the TH Internal Contamination by Ingestion Using the Fission Track Method

Mariana Ciubotariu

“Horia Hulubei” National Institute for Nuclear Physics and Engineering, P.O.Box MG-6, 76900 Bucharest
mciubo@ifin.nipne.ro

We have been studying the internal contamination with fissionable elements. After uranium, the thorium was used by us in such studies. In this paper, the Th biodistribution, retention and elimination in the Three Wistar-London breed rats were internal contaminated using a Th solution. Each of them has received a same quantity corresponding to a Th Annual Limit Intake. The rats were sacrificed at different time intervals after contamination. Immediately after sacrifice, their vital organs were sampled and calcined. In order to determine Th contents the samples were analysed by the fission track method. The obtained results led us to conclude on the Th biodistribution, its retention and elimination by rats. A comparison between the U internal contamination and that one using Th put into evidence some interesting differences.

Photon and Neutron Dose Distribution for Head and Neck Cancer Treatment Using TLD Dosimetry

H.I. Farag\textsuperscript{1}, F. Ahmad\textsuperscript{2}, A.A. Hamed\textsuperscript{3}, S.A. Gaafar\textsuperscript{4}, H. Salwa\textsuperscript{2}, Hoda Eissa\textsuperscript{2}, Mohammed El Fiki\textsuperscript{2}

\textsuperscript{1}National Cancer institute, Cairo.
\textsuperscript{2}National Institute for standards, Tersa Str., El Haram, El Giza P.O. Box 136, Giza, 12211, Egypt
\textsuperscript{3}National Center for Nuclear Safety and radiation Control, Egypt
\textsuperscript{4}Biophysics Department, Faculty of Science, Cairo University, Giza, Egypt

Radiotherapy is a strong modality for cancer treatment. We could use a very, precede radiation technology to achieve the best radiation dose and quality. Linear accelerator of dual mode photon and electron in addition to simulators and physical planning systems were used. For the determination of homogeneity dose distribution of head and neck cancer, we used Thermoluminescence Dosimetry (TLD) and a software program for in vitro assessment in Alderson Rando Therapy Phantom (ART). We did not notice a large difference in homogeneity obtained by both methods that reflect the accuracy in obtaining and applying the treatment protocols. TLD is suitable for measuring doses administered to the head and neck, which makes it possible to have an early prediction of systematic errors. These errors may occur during the treatment of the patients, in addition to several sources of absorbed dose outside the treatment volume, also we detect neutron doses during photon treatment. To avoid their effects for patients and workers, we announce to take care during treatment protocols.

Chances of Lung Cancer Due to Radon Exposure in al-Mazar Area, Jordan

Khalid Abumurad

Physics Department, Yarmouk University, P.O. Box 566, Irbid 21163, Jordan
abumurad@yu.edu.jo

Radon (\textsuperscript{222}Rn) levels were determined in al-Mazar area, northern part of Jordan. Passive diffusion dosimeters (using CR-39) were used in indoors in different seasons. CR-39 plastic films were chemically etched in a solution 30\% KOH @ 70\degree C for nine hours. The average radon concentration during summer season was about 64 Bq/m\textsuperscript{3} (~1.7 pCi/l which correspond to 0.009 WL for equilibrium factor, F=0.5), while in winter season was about 98 Bq/m\textsuperscript{3}. However, overall radon average in al-Mazar is comparable to the radon average in other Jordanian cities. Furthermore, the radon average concentration during the year was about 81 Bq/m\textsuperscript{3} (~2.2 pCi/l which correspond to about 0.01WL). According to these findings, the chance of dying from lung cancer due to exposure, over the lifetime, to 0.01 WL of radon level is about 0.09\%.
Radionuclides in the Lung Tissue of Oncologic Patients in Altai Region

E.Kovalev¹, A.V.Lepilov², Albert M.Marenny¹, Y.N.Shoikhet², Svetlana P.Tret'yakova³, P.A.Vlasov⁴

¹Research Center of Spacecraft Radiation Safety, 123182 Moscow, Russia;
²Altai Medical Institute, 656099 Barnaul, Russia
³Flerov Laboratory of Nuclear Reactions, JINR, 141980 Dubna, Russia;
⁴Institute of Biophysics, 123182 Moscow, Russia
tsvetl@sungraph.jinr.ru

Investigations of the radionuclide effect which have been performed using a lung cut off affected by an oncology disease are presented. Fine biological preparations have been deposited onto polymer backings and covered with the dielectrical detectors (CR-39 and Melinex) for performing the radiographic investigations. CR-39 for alpha radiography and Melinex was used for neutron radiography. The coordinates of the radionuclide dislocations and their activity have been determined. The radiation effect on the cell level of tissue has been analyzed.

Determination of Stopping Power in Histological Samples Using Proton Beam

Marko Giacomelli¹, Jure Skvarc¹, Radomir Ilic¹,²

¹Institut “Jožef Stefan”, Jamova 39, 1000 Ljubljana, Slovenia
²Faculty of Civil Engineering, University of Maribor, Smetanova 17, 2000 Maribor, Slovenia

70 µm thick sliced mice samples used in boron neutron capture therapy research are commonly frozen-dried and unremovably mounted on a glue tape. Such preparation entirely alters tissue density and makes it impossible to correctly determine the ranges of alpha particles from $^{10}$B(n,α)$^{7}$Li reaction. Proton radiography can be successfully used for density determination of these histological samples. The technique is based on the measurement of different energy losses in different tissues. A thin layer of histological sample stuck to an etched track detector is exposed to a monoenergetic proton beam over entire area. Regions of the radiographic image are analysed and range of protons in particular tissue is determined. Computer simulation was made in order to estimate the efficiency and sensitivity of this technique. Some typical values of tissue density and elemental composition were taken from SRIM program database. The applicability of this technique is illustrated and ranges of alpha-particles in histological sample of tumor bearing mouse are determined using proton ranges as a reference.

An Indoor Radon Survey for Lung Diseases Epidemiology

F. Franco-Marina¹, Nuria Segovia²*, L. Godinez³, Letitia Tavaera², Arturo Lopez², A. Chavez², P. Peña²

¹INER, Tlalpan, Mexico D.F., Mexico
³IGUNAM, Ciudad Universitaria, 04510 Mexico D.F., Mexico
msa@nuclear.inin.mx

Lung cancer is an important cause of malignant neoplasms in Mexico City. In the scope of an epidemiologic study of the disease, an indoor radon survey was performed together with the determination of several additional parameters.

The radon survey was performed in 500 houses using LR-115 track detectors in a cup array. The exposure time in the dwellings was around three months. Those dwellings having the highest values in the radon concentration were cross-checked with short term Honeywell automatic radon detectors in order to assess the anomalous values.
The results indicate a radon concentration arithmetic mean of 145 Bq m$^{-3}$ while the geometric mean was 26 Bq m$^{-3}$; the higher data frequency correspond to values lower than 25 Bq m$^{-3}$. The distribution of the radon concentration is discussed as a function of several local characteristics.

### Transport of The U-Oxides Through the Ground

Radovan Antanasijevic, Ivan Anicin$^1$, Radomir Banjanac, Vladimir Udovicic

Institute of Physics, Pregrevica 118, 11080 Belgrade, Yugoslavia

$^1$Faculty of Physics, University of Belgrade, 11000 Belgrade, Yugoslavia

udovicic@atom.phy.bg.ac.yu

The migration of the U-Oxides, originate from the combustion of the metallic U, through the ground was investigated. The measurements of the U concentration at the different depth in the ground, were performed by the neutron-induced fission using NTD (mica muscovite). The samples were exposed with the neutrons from the RB-reactor in the Nuclear Institute Vinca. At the same time, the U concentration of the samples was obtained with the X-spectroscopic method.

### Morphological Changes in Living Cell Cultures on Exposition by Alpha-Particles Studied by Optical and Atomic Force Microscopy

D. Selmeczi$^1$, B. Szabó$^1$, L. Sajo Bohus$^2$, Noemi Rozlosnik$^1$

$^1$Department of Atomic Physics, Eötvös University, Pazmany P. setany 1/A, H-1117 Budapest, Hungary

$^2$Universidad Simon Bolivar, Dep. de Fisica, Caracas, Venezuela

noemi@esr.elte.hu

The shape of the cells and the released material (traces) from migrating adherent cells depends on the cell type, the surface coating of the culture plate, the extracellular matrix, and some other parameters. In our studies we investigated the effect of low dose (2-3 particle/cell/hour) alpha-exposure on cell cultures. Chicken fibroblast cell and 3T3 cell-line were grown on a 20 µm thick, chemically modified polypropylene foil and exposed by alpha-particles of an $^{241}$Am source through the foil. The alpha-dose was measured by CR-39 track-dosimeter and. The morphological changes of the cells and the traces were investigated by phase-contrast optical microscopy and by atomic force microscopy in low force contact mode. The static traces give information about the the dynamics of cell migration and about the damage of the extracellular matrix.

### Alpha Damage and Repair in a Biological Monitor

LetitiaTavera, M. Breña, M. Pérez, J. Serment, Miguel Balcázar

Instituto Nacional de Investigaciones Nucleares, Apartado Postal 181027, México D F 11801, México

mtd@nuclear.inin.mx

Living organisms have the capability to repair genetic damage induced by either physical or chemical agents, these repair mechanisms are only partially understood. The bacterium *Escherichia coli* is especially suitable for repair studies, since mutants defective in several repair genes are readily available. Nine of such mutants were employed to study their response to radiation emitted by an americium alpha source. A special device kept the irradiation geometry unchanged, a surface barrier detector monitored particle flux and CR39 detectors determined particle distribution.

Survival plots are correlated with the theoretical number of alpha particles needed to induce lethal damages as a function of several defective repair or protective genes. The results show that approximately 8 alphas, with a LET of
128 keV/µm and a dose rate of 2.37 cGy/s, cause a lethal event in wild type E. coli and that this number decreases according to the impaired or defective gene.

**Neutron Capture Autoradiography for a Study on Boron Neutron Capture Therapy**

Koichi Ogura¹, Hironobu Yanagie², Ayako Yamazaki¹, Masazumi Eriguchi³, Toshio Matsumoto³, Kazuo Maruyama⁴, Hisao Kobayashi⁵

¹College of Industrial Technology, Nihon University, 2-11-1, Izumi-cho, Narashino, Chiba 275-0005, Japan
²Department of Surgery, Institute of Medical Science, University of Tokyo, 4-6-1, Shiroganedai, Minato-ku, Tokyo 108, Japan
³Metabolism and Pharmacokinetics group, Omiya Research Laboratory, Nikken Chemicals Co. Ltd., 1-346 Kitabukuro-cho, Omiya 33, Japan
⁴School of Pharmaceutical Sciences, Teikyo University, 1091-1 Suarashi, Sagamiko, Tsukui-gun, Kanagawa 199-0195, Japan
⁵Institute of Atomic Energy, Rikkyo University, 2-5-1, Nagasaka, Yokosuka, Kanagawa 240-01, Japan

ogura@mmm.cit.nihon-u.ac.jp

The tumor cell destruction in boron neutron-capture therapy (BNCT) is due to the $^{10}\text{B}(n,\alpha)^{7}\text{Li}$ reaction. It is theoretically possible to kill tumor cells without affecting adjacent normal cells, if sufficient $^{10}\text{B}$ atoms can be selectively accumulated in tumor cells. Therefore, one of extremely important concerns in BNCT is the confirmation of the effective $^{10}\text{B}$ delivery system. In order to investigate the effective $^{10}\text{B}$ carrier, we applied CR-39 plastic track detectors to neutron capture auto-radiographic (NCAR) measurements of $^{10}\text{B}$-biodistributions in sliced whole-body samples of tumor bearing mice after intravenous injection of $^{10}\text{B}$-solutions. CR-39 can record the energetic heavy charged particles generating from the $^{10}\text{B}(n,\alpha)^{7}\text{Li}$ reaction, as well as neutron-induced protons, such as originated from $^{14}\text{N}(n,p)^{14}\text{C}$ reaction, which disturb alpha-autoradiographic imaging as background tracks. In order to selectively desensitize and eliminate undesirable proton tracks, we applied PEW (15wt% KOH+65wt% C₂H₅OH+20wt% H₂O) solution to the etching of CR-39 and succeeded to develop the alpha-autoradiographic images of good quality. The quality of NCAR images on CR-39 etched in PEW solution will be compared with the images on CR-39 etched in NaOH solution. In addition, the quality of NCAR images obtained by the cold neutron beam will be also discussed comparing with its obtained by the thermal neutron irradiation.

**Effect of the Environmental Conditions on Radon Gas and Progeny Concentrations in the Granitic U-Exploration Galleries, Eastern Desert, Egypt**

A.A. Abdel-Monem¹, Hoda Eissa², A. I. Abdel-Hafez², S.A. El-Fiki³, Y.A. Abdul-Razek¹, Anas El-Naggar⁴

¹Nuclear Materials Authority, Cairo, Egypt
²National Institute for Standards, Tersa Str., El Haram, El Giza P.O. Box 136, Giza 12211, Egypt
³Physics Dept., Faculty of Science, Ain Shams University 18 El-Koroum Street, 12311 Doki, Cairo, Egypt
⁴Nuclear Safety and Regulatory Center, EAEA, Cairo, Egypt

Measurements at different times of the year of Rn-gas and progeny concentrations in the U-exploration galleries dug into the granitic masses of Gabal Qattar, Gabal Al Missikat and Gabal Al Aradiya, Eastern Desert, Egypt, were carried out using active and passive techniques. The active technique was achieved using EDA-RDA-200 alpha counter. The passive technique was achieved using the SSNTTD: CR-39, MK, CN-85 and LR-115. The measurements were carried out at 10 monitoring stations in each gallery and their locations were chosen to represent different environmental conditions such as: the wall rock fracture densities, tunnel air temperature and ventilation conditions.

Measurements carried out by passive techniques are more informative and representative of the stations. Data on Rn-gas and progeny concentrations in the same galleries during winter time, indicates that the measurements
obtained by active method are significantly lower than those obtained by passive method by a factor of 10 for Qattar-I, -12 for Al Missikat, and -7 for Al Aradiya galleries. The seasonal temperature variation affects the measured Rn-gas concentrations SSNTD such that the ranges of the averages of the spring time: 4.33-9.75 kBq/m$^3$ (Qattar-I), 4.29-24.99 kBq/m$^3$ (Al Missikat) and 3.54-9.1 kBq/m$^3$ (Al Aradiya) are higher by a factor of -2 compared with the measurements during the winter time where the ranges or the averages are, 2,12-5.13 kBq/m$^3$ (Qattar), 2.34-12.95 kBq/m$^3$, (Al Missikat) and 2.28-4.97 kBq/m$^3$ (Al Aradiya).

The equilibrium factor averages at the ventilated stations are 0.45 (Qattar, 2 stations), 0.5 (Al Missikat, 4 stations) and 0.57 (Al Aradiya, 7 stations). On the other hand, the stations isolated from the ventilation path show equilibrium factors: 0.9 (Qattar, 8 stations), 0.89 (Al Missikat, 6 stations) and 0.93 (Al Aradiya, 3 stations).

The effect of the fracture densities indicates that the stations near or within the fracture zones have higher Rn-gas and progeny concentrations as follows: 8.1 kBq/m$^3$ (Qattar, 6 stations), 10.1 kBq/m$^3$ (Al Missikat, 4 stations) and 5.85 kBq/m$^3$ (Al Aradiya, 6 stations). This is compared with the lower values for the stations in the less fractured areas, 5.14 kBq/m$^3$ (Qattar, 4 stations), 7.54 kBq/m$^3$ (Al Missikat, 5 stations) and 4.59 kBq/m$^3$ (Al Aradiya, 4 stations).

Key Words: Radon/Passive/Active/Rock Fracturing/Granite

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Ambient and Seasonal Effects on the Radiation Protection Measurements in U-Exploratory Tunnels Using SSNTDs at Al-Allouga Mine, Sinai, Egypt

Hoda Eissa¹, A. A. Abdel-Monem², A. I. Abdel-Hafez², F. H. Abdel-Kader³, S. F. Hassn², Anas El-Naggar⁴

¹National Institute for Standards, Tersa Str., El Haram, El Giza P.O. Box 136, Giza, 12211, Egypt
²Nuclear Materials, Authority, Cairo, Egypt
³Physics Department, Faculty of Science, Cairo University, Egypt
⁴Atomic Energy Authority, Cairo, Egypt

The investigated pails of Al-Allouga U-exploratory tunnel network totals 670m deriven into silty sandstones and shales The cross-section of the tunnels are about 2x2m and 28 stations were chosen reflecting the different environmental conditions. Measurements of Rn-gas concentrations and working levels (WL) were carried out at these stations during winter, spring, summer and fall time using SSNTD: CR-39, MK, CN-85 and LR-115.

The data sets show that the averages of Rn-gas concentrations at the ventilated stations are larger during fall and winter times (28-66 pCi/l) than those of spring and summer times (26-46 pCi/l). Also, at the non-ventilated stations the same pattern is observed where during fall and winter (458-610 pCI/l) are larger compared with spring and summer (409-516 pCi/l). The (WL) ranges at the ventilated stations are also higher during fall and winter (0.07-0.314) relative to spring and summer (0.144-0.257), whereas at the non-ventilated stations the ranges are (4.123-5.624) and (3.669-5.497) respectively.

These patterns have been attributed to the effect of higher humidity and ground water seepage rates in the tunnels during fall and winter especially at the non-ventilated stations. Also, the type of SSNTD used has some effect.
Determination of Boron Concentration in Korean Total Diet by \((n, \alpha)\) Radiography

Y.S. Chung\textsuperscript{1}, Zinaida En\textsuperscript{2}, S.Y. Cho\textsuperscript{3}

\textsuperscript{1}HANARO-Center, KAERI, Yusong, Taejon, 305-600, Korea
\textsuperscript{2}Institute of Nuclear Physics, Uzbekistan Academy of Sciences, Ulugbek, Tashkent 702 132, Uzbekistan
\textsuperscript{3}College of Health Science, Yonsei University, #234, Maeji, Hungob, Wonju, Kangwondo, 222-710, Korea

Korean Total Diet (TD) was produced as a reference food material and consists of over 30 food components eaten by average Korean person. This was under the project of Korean reference materials for nutrition. Boron is considered to be an important element for human health. However, excessive amount of it has a poison effect, although a critical level has not been determined definitely yet. \(^{10}\text{B}(n, \alpha)^{7}\text{Li} - \) radiography technique was applied for a boron determination study. The TD sample was ground to 100 mesh, dried and pressed into tablets with a specific gravity of ~1.2 g/cm\(^3\). Irradiation was performed in the HANARO reactor irradiation tube NAA1 (KAERI), neutron fluence was ~10\(^{14}\) cm\(^{-2}\). CR-39 TASTRAK plastic was used for the detection of the \(^{10}\text{B}(n, \alpha)^{7}\text{Li}\) reaction products. Due to high concentration of hydrogen and nitrogen in biological sample, there were significant amounts of tracks related to those elements in the radiographs. Track-size distribution analysis was applied to correctly distinguish the tracks related to boron from others, that was important for quantitative analysis. In spite of fine grinding and careful mixing before making tablets, the boron distribution in the sample was not uniform. Boron concentration profile along the sample diameter and average boron concentration have been determined.

Radon Measurements In Moroccan Waters by Etched Track Detectors

Bassam Aharmim\textsuperscript{1}, H. Marah\textsuperscript{2}, A. Sabir\textsuperscript{1}

\textsuperscript{1}Applied Nuclear Physics Laboratory, Faculty of Sciences, Kenitra Ibn tofail University, BP-133, Kenitra 14000, Morocco
\textsuperscript{2}CNESTEN, Rabat, Morocco

baharmim@yahoo.fr, marah@cnesten.org.ma

A method for measuring radon concentration in water has been developed. It consists in bubbling air through water and subsequent measurement of the dissolved radon concentration by the solid state nuclear track detectors "SSNTD" technique. An analytical model is used to determine the transfer coefficient of radon from the water to detecting volume. This is used in conjunction with a theoretical VT variable track etch velocity model, and a geometrical Monte Carlo simulation to calculate the calibration coefficient of the apparatus which allow us to convert the recorded a counts in Bq/l. Using this numerical simulation, it is possible to design a sensitive and accurate device with parameters such that the a track densities may be optimised to a chosen radon concentration range. Validation of the modelling will be presented in the form of comparisons between predicted and experimentally determined sensitivities of apparatus with CR-39 and LR-115 SSNTD. Results from radon measurements made using this technique in Moroccan waters will be presented and discussed.
In Vivo and in Vitro Radiation Dose Measurements in Radioiodine Therapy of Thyroid Cancer

H.I. Farag¹, F. Ahmad², Mohammed EL-Fiki², S.A. Gaafar³, Noha-Emad², Hoda Eissa²

¹National Cancer Institute, Cairo University
²National Institute for Standards, Tersa Str., El Haram, El Giza P.O. Box 136, Giza, 12211, Egypt
³Biophysics Department, Faculty of Science, Cairo University, Giza, Egypt

Accurate measurements of radiation dose are necessary, if radiation treatment with radioiodine (I-131) is to be used effectively at an early phase of disease. The importance of dosimetric studies is to improve the therapy technique.

In Vivo measurements of I-131 absorbed dose by using thermoluminescent dosimeters (LiF-700) were performed. This work was undertaken on 50 patients with differentiated thyroid cancer, who received I-131 for ablation of post surgical thyroid remnants at unit of nuclear medicine of Egypt National Cancer Institute, Cairo University. The results indicate the validity of in Vivo measurements of I-131 concentration for each individual human tumor sites.

In Vitro measurements of I-131 absorbed dose were performed on ART phantom and dose distribution were plotted by the help of computer. Using this data we could roughly estimate the brain absorbed dose, which was found to be 2.478 (mGy/mCi.hr) cm³ for 26 mCi I-131 per 22 hour. Good agreement was found between in vivo and in vitro measurements of I-131 concentration. Then we can predict the absorbed dose at any site in-patients preferring only to physical means.
Neutron Autoradiography – Working-out Method and Application in Investigations of Paintings

Antoni Kalicki¹, Ewa Panczyk¹, Luzia Rowinska¹, Bozena Sartowska¹, Lech Walis¹, Krzysztof Pytel¹, Beatrycze Pytel¹, Alina Koziel¹, Ludwik Dabgowski¹, Małgorzata Wierchnicka², Leonard Strzalkowski², Tadeusz Ostrowski², Maria Ligeza³

¹Institute of Nuclear Chemistry and Technology, 16 Dorodna St., 03-195 Warsaw, Poland
²Institute of Atomic Energy, 05-400 Otwock-Swierk, Poland
³Academy of Art, 31-108 Cracow, Poland
bsarto@orange.ichtj.waw.pl

Non destructive testing methods are very important in investigations of paintings. The main purpose of this work was to worked-out method, build special stand and test chosen precious works of painting art using neutron autoradiography. Neutron induced autoradiography were carried out at MARIA research reactor in Poland. The painting was exposed to the thermal neutrons. Then the radionuclides emitting beta particles and gamma rays were formed from some of elements existing in the pigments. Beta particles were detected during successive exposure to a series of X-ray medical sensitive films. Obtained image - blackening the films depends on half-lives of activated elements.

Series of test paintings were investigated and according obtained results optimum parameters have been selected: neutron irradiation conditions and autoradiographs exposure conditions. Then six paintings from the Venetian XIV–XVIII century school (from National Museum in Warsaw) were investigated using neutron autoradiography and analysed by physicists, art-restorers and historians of art.
Surfaces of the samples of z-, a- and m-orientations were tested by AFM. It was found that the surface damage structure strongly depends on the irradiation ions mass and energy and on the crystallographic orientation of the target surface. Different surface structural modifications such as craters (abrupt depressions), islands and chaotic degradation were observed in top 5 nm layer of irradiated samples. Most sufficient damage was found on the m-orientation sample. This effect was related to the highest packing density of O-atoms in m-direction. For the quantitative assessment of the damage the surface fractal dimension parameter was used.

The electron microscopy of high resolution technique was applied for investigation of real atomic structure of irradiated crystals. It was found that the symmetry of destructed area around the track corresponds with the symmetry of crystal lattice.

Radiography Techniques for Studying Elemental Distributions
Elena Flitsiyan
Dept. of Physics, University of Central Florida, FL 32816-2385 Orlando, USA
esf@physics.ucf.edu

For advantageous decision of urgent problems in various areas of physics, chemistry, geology, metallurgy, biology, agriculture and other branches of science and technology, it is necessary to obtain the information about the spatial element distributions and their local concentration in additional to an average content. The radiography method is developed for the investigation of ionizing radiation sources distribution on the sample surface by means of a two-dimensional image, produced in a photoemulsion or dielectric track detector. The sensitivity of the elaborated techniques is within a range of $10^{-2} - 10^{-7} \, \text{g/mm}^2$ and resolution from 0.01 to 100µm. Statistical analysis and computer processing of the radiographic images have allowed us to solve the two main tasks of the radiography methodology: determination of the true distributions of ionizing radiation sources of the sample surface and the quantitative estimation of the local content of different chemical elements within a given accuracy.

A complex of radiographic techniques based on the registration of secondary radiation of the neutron activated nuclei, instantaneous products of the nuclear reactions and fission fragments of transuranium elements has been developed. The elaborated methods were used to solve a set of problems in geology and geochemistry, as well as for analysis of technological and environmental samples. A theoretical model of image formation and series of typical examples of using the elaborated radiographic techniques to solve some practical problems in geology and geochemistry, in microelectronics and in environment study are described.

Thus, the radiographic investigation of lead and zinc distributions in scales of rock was turn off. The lead determination was attainable by radiation with the accelerated ions $^{16}\text{O}$. The fission fragments of lead nuclei was registered during the radiation by polymer track detector. The radiography of zinc was executed by activation the scale by thermal neutrons. The methods sensitivity is $10^{-4}$-$10^{-7} \, \text{g/mm}^2$ for lead and $10^{-6} \, \text{g/mm}^2$ for zinc. The space resolution is 7-10µm for lead and 50-70 µm for zinc.

The radiographic method for study of gold and boron distributions in products of microelectronic was elaborated. The gold distribution was obtained after resonant neutron irradiation. The boron distribution was obtained during the irradiation by using the $\alpha$-particles from the (n,$\alpha$) reaction at the $^{10}\text{B}$. The conducted investigation of the plant had show, that using the radiography method it is possible to reveal the regions of heavy metal pollution of environment.
In-situ Studies of Point Defect Creation CsI Scintillators Under 8.63 MeV/amu 86Kr Ion Irradiation at 15-300 K

Anatolij Popov, E. Balanzat

1Institute of Solid State Physics, University of Latvia, 8 Kengaraga str., LV-1063, Riga, Latvia
2Institute of Physical and Chemical Research, RIKEN, Hirosawa 2-1, Wako, Saitama 351, Japan

CsI and CsI-tl crystals are known as a very effective scintillator materials due to their widespread use in particle detectors. In this report we present the results of in situ luminescence and optical absorption studies in scintillator crystals CsI and CsI-Tl, submitted to very dense electronic excitations induced by $^{86}$Kr ions (8.63 MeV/amu) at 15-300 K are reported. The main results can be summarized as follows:

- Under irradiation we have observed a prominent F center absorption band. The production efficiency (eV/center) of F centers is to be 2.5x10$^7$ eV/center. Such a quite high value defines the appropriate radiation hardness of CsI scintillators.
- We calculate Rabin-Klick parameters for alkali halides with CsCl-type structure to analyze Rabin-Klick diagram [1] for whole list of alkali halides.
- The luminescence spectra induced by Kr ion were compared with that obtained by irradiation with X ray. We have found that luminescence spectra of both pure CsI and CsI:Tl induced by ions differ from that obtained with X-ray.
- In the course of the study in situ luminescence under dense heavy ion irradiation, in addition to already known emission bands due to singlet and triplet self-trapped excitons (STE) [1] and Tl ions [3], we have observed new luminescence band at 230 nm interpreted as luminescence of metastable monohalide STE. Its temperature quenching is well correlated with the thermal development of the dihalide STE emission bands. Similar emission in KBr, RbBr, KCl and NaCl has been recently by A.Lushchik et al [2].
- We have shown that point defects created by heavy ions manifested themselves in luminescence ageing. Furthermore this effect is different for different luminescence bands.


Digital Autoradiography: Possibilities and Applications

Delara S. Gafitullina

Institute of Nuclear Physics of Uzbek Academy of Sciences, Ulugbek, Tashkent 702132, Uzbekistan
crystal@suninp.tashkent.su

In this report the possibilities and applications of digital autoradiography are described to obtain the fine structure of chemical element distributions in the different samples. For advantageous decision of urgent problems in various areas of material science, biology, agriculture, environment and other branches of science it is necessary to obtain the information about the spatial element distributions and their local concentration in additional to an average content. The main problem of autoradiographic analysis: the suppression of the background and betterment of linear solvability, was investigated by using of pattern recognition for interpretation of autoradiographic pictures.

The theoretical models of an origin of a noise in autoradiographic features and the suppression of the of the background by using digital image processing are studying. The possibilities of digital autoradiography for investigations of fine structure of the spatial element distributions in different samples (crystals, plants, water inhabitants etc) are shown.
Determination of Boron Distribution in Semiconductors, Alloys and Plants Using SSNTD

Makhtuba Kadirova, N. Jumaev, Yu. E. Simakhin, M.M. Usmanova

Institute of Nuclear Physics, Uzbekistan Academy of Sciences, Ulugbek, Tashkent 702132, Uzbekistan

kadyrova@suninp.tashkent.su

Boron is used in semiconductor electronics for creation a p-n junction, also for ion implantation and thermodiffusion in the Cd$_x$Hg$_{1-x}$Te, SiC and Si structures, application as a doping element in steel and Al-, Cu-, Ni-, Mo-Re- and W-Re- alloys for improvement of their mechanical strength. Boron is one of the vital microelements for the majority of plants, but the superfluous contents of boron in soil lead to disturbance of plants natural growth or in separate cases to their perish. Therefore it is useful to know the local boron concentration and its micro distribution in investigated solids and plants.

The techniques to study of boron surface distribution in photodiode matrix structures and some leave of plants, behavior of boron in polycrystalline beta-silicon carbide, processes of construction steels strengthening by boron laser doping, to determine local boron concentration and its micro distribution in single crystal silicon carbide, silicon structures and in the Mo-Re- and W-Re- alloys have been developed.

A boron distribution determination technique is based on the detection of $^{10}$B(n,$\alpha$)$^{7}$Li reaction products by cellulose nitrate (basis of cinemafilm, type A-2). After irradiation of a detector-sample system with thermal neutrons of WWR-CM reactor the boron concentration defined by density of the etched pits appearing on the film surface after etching in 6N NaOH solution at 40°C for 35 min.

The Radiography System Models for Evaluation the Radionuclides Transport in Rocks

Elena Flitsiyan$^1$, Karl-Heinz Hellmuth$^2$

$^1$Physics Department, University of Central Florida, Orlando, FL 32816-2385, USA  
$^2$Finnish Center for Radiation and Nuclear Safety, Helsinki, Finland

esf@physics.ucf.edu

Understanding of the transport and retardation properties of the host rocks for a deep geologic nuclear waste repository requires use of variety of complementary methods for characterization the rock matrix. Quantitative radiography method for investigation of rock samples has been developed by use of $^3$H – and $^{14}$C-labeled polymethylmetacrelate (PMMA) as well as using neutron activation of thin rock sections. The elaborated technique supplemented by SEM analysis has been shown to provide valuable information of rock properties.

The radiographic system was studied experimentally and theoretically. The estimation of different radiography systems and treatment the radiography images analysis functions allowing correlation of mineralogic-petrographical and porosity information. The method could achieve a resolution down to 10 and 20 µm for $^3$H and $^{14}$C, respectively, and 50-70 µm for activated sections. Possible candidates for intact, low-porous rock standard materials were studied and the measurement of their transport properties discussed.
Deposition of Radon Decay Products on Metals in Contact
Igor Lengar¹, Jure Skvarc¹, Radomir Ilic¹, ²

¹Institut “Jožef Stefan”, Jamova 39, 1000 Ljubljana, Slovenia
²Faculty of Civil Engineering, University of Maribor, Smetanova 17, 2000 Maribor
igor.lengar@ijs.si

Deposition of radon decay products on surfaces depends on geometrical factors such as proximity of other objects, as well as on local electrical fields. We investigate deposition of radon progeny on two different metals in contact. As an example metal pairs Ag-Al and Fe-Al were taken. The density of alpha particle tracks, emitted by $^{218}\text{Po}$ and $^{214}\text{Po}$, deposited on metals was measured at different proximities of a conducting wall. We show that even small contact potentials can cause a significant difference in deposition rates of radon decay products.

Determination of Chemical Homogeneity of Historical Glassware Using Autoradiography of Potassium Natural Radioactivity
Bozena Sartowska, Jerzy Kunicki-Goldfinger

Institute of Nuclear Chemistry and Technology, 16 Dorodna St., 03-195 Warsaw, Poland
bsarto@orange.ichtj.waw.pl

We know some elements with the radioactive long-live isotope. That isotope often is the component of natural existing element. Autoradiography allowed us to detect natural radioactivity of elements. The main purpose of that work was to determine content of potassium in the tested glassware. Natural radioactivity of the isotope $^{40}\text{K}$ has been applied. Using autoradiography we can carry out non-destructive and non-sampling investigations of the historical glassware.

The broken stem of a 18th century goblet, made of colourless, high quality glass has been analysed. The results of chemical analysis of samples taken from different points of the stem showed large differences in elemental composition. Our experiment consisted of two parts: examination of model glasses with calibration of the method and examination of broken stem.

Obtained results showed us large inhomogeneity of the glass. Differences in $\text{K}_2\text{O}$ concentration were in the range 13-20%. It means that chemical inhomogeneity of historic glasses cannot be omitted during investigations that require sampling.

Neutron Field Mapping by CR39 for Radiography and Other Applications
Jozsef Pálfalvi, Márton Balaskó

Department of Health Physics, Atomic Energy Research Institute, P. O. Box 49, H-1525 Budapest, Hungary
palfalvi@sunserv.kfki.hu

In many applications of neutron radiation – like neutron radiography, radio-adaptation experiments triggered by low dose, other biological investigations, BNCT or calibration of personnel dosimeters- it is very important to know the structure of the neutron filed. In most of the cases listed above only proton recoil track detectors can be applied to study the spatial and energy distribution of neutrons, since they have small dimensions, good proton sensitivity and they do not disturb the radiation field. At the Atomic Energy Research Institution (AERI) there is a secondary standard neutron irradiation facility for dosimetry as well as a research reactor where three horizontal channels are used for industrial and biological experiments. In the latter cases the irradiation cavities outside of the bulk shielding of the reactor core must be well isolated to avoid the over exposure of the staff. The reflection from the shields and
other structural materials may significantly but unfavorably modify the radiation field. In the same time the beam or field qualities must be controllable and well known. To fulfil these requirements a neutron telescope based on the n-p elastic scattering interaction was constructed. It can determine the angular and energy distribution, as well as the directional flux of neutrons in a radiation field.

The telescope consist of a polyethylene proton radiator with variable thickness, thin gold foils for degrading proton energy and forming a diaphragm and several layers of thin and a thick CR39 detectors. The elements are supported by a thin plastic frame in such a way that their distance from each other can be easily changed. The orientation of the detector can be adjusted in the radiation field. A geometrical model was elaborated to make relationship between the measurable track parameters and the incident angle as well as the energy of protons and the neutrons. The proton tracks parameters are investigated by an image analyzer and based on the model the results are evaluated by a computer code developed for the purpose. The system was calibrated by using monoenergetic protons and neutrons up to 10 MeV.

In general, the energy and angular distribution of the incident neutrons should be known only in a small volume or on the surface of the object to be irradiated, this makes it possible to perform enough measurements with acceptable effort for a given case.

We will present the theoretical aspects and the construction of the telescope as well as few examples for the utilization: the determination of the neutron flux and the dose when cell cultures are irradiated at the Biological Irradiation Facility of our research reactor and the field mapping work performed at the neutron radiography unit.

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**Radiography by Soft X-Rays from Plasma Focus Device**

Radovan Antanasijevic, Dušan Joksimovic, Jovan Vukovic

Institute of Physics, Pregrevica 118, 11080 Belgrade, Yugoslavia

jbvukovic@phy.bg.ac.yu

The plasma focus device (PFD) as the source of soft X-rays (SX) was used for the radiography. The chamber of PFD was filled with the different gases as active media (H, D, He, N, Ar). The dependence of the SX maximum energy and filling gases was determined using X-ray film. Radiography by the SX of the hard and soft bioobjects was detected. Our PFD is also potential device for use as the SX microscope: contact or scanning. Two problems were considered: interaction of the SX with nuclear tracks in solids (NTS) as the specimen (the contrast) and interaction of the SX with detector for visualization (SX resist, a type of the NTS).
A High-Frequency Plasma Discharge Effect on Track Membranes

Serguei N. Dmitriev1, Lyubov Kravets1, V. V. Sleptsov2, V. M. Elinson2

1Joint Institute for Nuclear Research, Flerov Laboratory of Nuclear Reactions, St. Vekslera 14-17, 141980 Dubna, Russia
2Tsiolkovsky Moscow State Aviation Technological University, 121552 Moscow, Russia
kravets@nrsun.jinr.dubna.su, sasha@kurts.msk.ru

Effect of a plasma discharge on track membranes (TM) from poly(ethylene) terephthalate, polycarbonate and polypropylene have been investigated. One side of the membranes treated to a plasma. Studied was an influence of the composition of the plasma-forming gas, the parameters and the duration of the discharge on the structure and the properties of the TM resulting at high-frequency plasma discharge (13.56 MHz) treatment. It has been figured out that the gas-discharge etch of a polymeric matrix, its hyrdophilization and generation of radicals in the surface layer of the membranes are the main processes when treating the track membranes by a non-polymerizing (inorganic) gas plasma. We show that the gas-discharge etching of TM in the plasma causes decreasing a mass part of the low-molecular products in the membrane as well as changing a relief of the surface layer and the shape of the TM pores. The latter is the basis for creation of asymmetric TM1. The observed process of hydrophilization of the TM surface on exposure to a gas-discharge is related to a formation of functional carboxylic groups2. Their appearance is caused by oxidation of the end-groups due to effect of the active plasma particles here the chemical bonds break down. The formation of radicals in the TM surface layer allows one to make the grafting of monomers to their surface.

The treatment of the membranes with the plasma of organic compounds results in a deposition on their surface of a thin polymeric film. Depending on the duration of the plasma treatment, one can obtain TM for microfiltration, ultrafiltration and reverse osmosis. In the last case, a thin semipermeable layer that fully covering the pores, is deposited on the TM surface. The possibility of adjusting the width of the polymerized layer and the wide range of organic compounds for producing the membranes of this type make this method very promising. New properties of the surface of the composite materials produced this way, mainly depend on a type of the chemical compound used. For example, when using carbohydrates as a plasma-forming gas, a thin polymeric chemically stable diamond-like film is formed on the surface exposed to plasma of does not possess functional groups. This provides a way for producing hydrophobic composite membranes possessing a mechanical and chemical strength3. While depositing the polymeric film from the discharge to hexamethyldisizane, the membranes having bactericide properties are generated. The a positive or negative charge appearing due to the introduction of the functional groups is one more thing allowing one to regulate the membranes’ characteristics. In the last case, the use of n-vinylpyrrolidone as a plasma-forming gas serves as a basis for creation of hydrophilic composite membranes. The use of allyl alcohol as a plasma-forming gas allows one to improve hydrodynamic characteristics of the track membranes3. When a polymeric film is deposited on the TM surface from the discharge in butylamine, bipolar membranes are formed which have two layers with different electric conductivity.

References:
Synthesis of Temperature and pH-Sensitive Gels and Its Application to Ion-Track Filters
Masaru Yoshida, Yasunari Maekawa, Ryoichi Katakai, Reimar Spohr, Pavel Apel

Department of Material Development, Takasaki Radiation Chemistry Research Establishment, Japan Atomic Energy Research Institute, 1233 Watanuki-machi, takasaki, Gunma 370-1292, Japan
katsu@taka.jaeri.go.jp

Temperature- and pH-sensitive gels were synthesized by radiation-induced polymerization of acryloyl-L-proline methyl ester with acrylic acid, finding out experimental conditions required for highly selective separation of metal ions. This made it possible under the regulation of such factors as hydrophobicity, carboxylate ion, porosity, and pore geometry, depending strongly on a slight change of temperature or pH. We intended this gel for application to ion-track filters with pore sizes of micron-scale to nano-scale by the radiation grafting technique.

Improved Design of Electrolysis Cell for Galvanic Replication and Synthesis of Nano/Microstructures and Devices
Shiv Chakarvarti

Department of Applied Physics, Regional Engineering College, Kurukshetra-136 119 India.
phy@reck.ernet.in

Template synthesis is one of the most simple and versatile techniques for generation and synthesis of nano/microstructures, sensors and devices and is based upon electrodeposition of the desired material within the etched pores as templates of the Nuclear Track Filters (NTFs). There are various types and designs of such cells available [1-3] but for certain inherent limitations e.g., absence of proper and convenient temperature control and stirring, ease of handling, interfacing with microprocessors and PC etc. Some designs [4] include an outer jacket with facility of hot water circulation have been used for maintaining the temperature which proves to be a time consuming process besides one can not change the temperature in short span, if so required, during the process of electrodeposition.

In this work, an improved design of electrolysis cell is described which incorporates the provision for variable stirring, fast temperature change and control, low thermal capacity of the cell (thereby reducing time for bringing in temperature changes) and ease of handling, using variable speed DC small motor, small immersion heater besides an optional facility of interfacing with microprocessor, PC.

References:

Pore Shape Control in Nanoporous Particle Track Etched Membrane Production
Etienne Ferain, Roger Legras

Unité de Physique et de Chimie des Hauts Polymères – Université Catholique de Louvain, Croix du Sud 1, B-1348 Louvain-la-Neuve, Belgium
ferain@poly.ucl.ac.be

Optimal template synthesis of nanoscale materials by filling the porosity of track etched membranes requires membranes with controlled and predictable pore size and geometry. In this work, we mainly show that the use of appropriate polycarbonate film lead to the production of track etched membrane with smooth and cylindrical pores.
(down to 15 nm), instead of the rough and "toothpick" shaped pores obtained in commercial polycarbonate track etched membrane. An explanation of this "toothpick" pore shape is also proposed.

Some related published works:

Response of Fast Neutron Dosimeter Based on $^{12}$C(n, 3α) Reaction and Cr-39
Svetlana P. Tretyakova¹, Alexander Golovchenko¹, Marlies Luszik-Bhadra², Mehran Katouzi³, Radomir Ilic⁴, Jure Skvarc³, G.Zorin¹

¹Joint Institute of Nuclear Research (FLNR, JINR), St. Vekslera 14-17, 141980 Dubna, Russia
²Physikalisch-Technische Bundesanstalt 100, 38116 Braunschweig, Germany
³Institut “Jožef Stefan”, Jamova 39, 1001 ljubljana, Slovenia
⁴Faculty of Civil Engineering, Smetanova 17, 2000 Maribor, Slovenia
tsvetl@sungraph.jinr.ru

Fast neutron interactions with carbon, oxygen are of interest for many studies and applications such as, for example, determining the release of energy to tissue or tissue-equivalent materials, radiation damage effects in reactor materials containing carbon, neutron transport calculations, and an understanding and quantitative description of neutron detectors or neutron dosimeters. Response of fast neutrons (8 – 19 MeV) dosimeter based on the registration of triple alpha tracks in CR-39 detector via $^{12}$C(n, 3α) reaction was measured. The response for carbon radiator was found to be $10^{-4}$ to $10^{-5}$ triple tracks/neutron depending on the neutron energy.

Spallation Neutron Production from Heavy Targets by Proton Irradiation
Maria Zamani-Valasiadou¹, Reinhard Brandt², Monique Debeauvais³, J.-C. Adloff³, Boris Kulakov⁴, Misha I. Krivopustov³

¹Aristotle University of Thessaloniki. Physics Department, Nuclear Physics Division, Thessaloniki 54006, Greece
²Kernchemie, FB 15, Philippus-Universität, D-35032 Marburg, Germany
³Centre de Recherche Nucléaires, SADVI, B.P. 20, F-67037 Strasbourg Cedex, France
⁴Joint Institute for Nuclear Research (FLNR, JINR), St. Vekslera 14-17, 141980 Dubna, Moscow Region, Russia
⁵Joint Institute for Nuclear Research, LNP, JINR, Jolid Cuzie 6, 141 980 Dubna, Moscow, Russia
zamani@physics.auth.gr

Spallation neutron production from Pb U/Pb and Hg targets was studied when irradiated by protons of 0.5 to 7.4 GeV. The target was of cylindrical form of 8 cm diameter and 20 cm height. This cylinder were enveloped by 6 cm parafin moderator. Thermal and fast neutron distributions were taken along the moderator surface. It was found that thermal neutron fluxes are increasing function of the target mass and of the beam energy. A similar behavior shows also fast neutron distribution. Thermal neutron fluxes were higher from those of fast neutrons in all experimental conditions studied. As neutron detector CR39 and Macrofol are used in combination with 10B and 235-U converters for thermal neutrons. For fast neutron measurements both sides of CR39 detection system were covered by 1 mm Cd foils. Additional information for fast neutrons is taken from proton recoils on CR39 detector. Fissions of 238-U by fast neutrons were also measured on Macrofol detectors.
Reactor Fission Rate Measurement for Miniature Neutron Source Reactor (MNSR) by Solid State Nuclear Track Detector

Yong-Qian Shi, Yi-Guo Li

China Institute of Atomic Energy, P.O.Box 275(75), Beijing 102413, Republic of China

mnsr@mipsa.ciae.ac.cn

The paper describes the reactor fission rate measurement principle and method by solid state nuclear track detector (SSNTD). The fission rate measurement result for miniature neutron source reactor was gotten by this method. Finally, the reactor power is given in combination with other reactor parameters. This method has advantage over other physics methods and avoids the approximate suppose of some author in fission rate measurement.

Key words: Reactor fission rate, Reactor power, Solid state nuclear track detector

Synthesis of Tapered Micro-Tipped Metallic Field Emission Electrodes

Shiv Chakarvarti¹, Vijay Kumar²

¹Department of Applied Physics, Regional Engineering College, Kurukshetra- 136 119 India.
²Department of Physics, Haryana Engineering College, Jagadhri, India.

phy@reck.ernet.in

Nano/microtipped metallic electrodes can find their myriad applications in many important fields viz., field emission electrodes (cold cathodes) as energy saving devices, as STM tips and related areas including nano/microtechnology etc. The technique of template synthesis is one of the simple methods for obtaining such structures. Vetter et al. (1991); Chakarvarti and Vetter (1991, 1998) have reported the fabrication of such ensembles. We describe here another version of the technique used by Vetter et al. (1991) primarily for obtaining "endoscopic" view into the track channels in a Nuclear Track Filter (NTF) and obtaining at the same time tapered metallic needles as true replica of the channels so contained in the NTF. Makrofol KG (polycarbonate) NTFs (10 µm thickness, irradiated with U-238 ions of specific energy 11 MeV/n and a flux of 10⁶/cm² at the UNILAC at Darmstadt, Germany) were floated on the surface of 6N NAOH at room temperature (20°C) so that the etchant can penetrate only through one surface and therefore produce tapered etched channels. In order to ascertain the termination of the etching, a fine copper wire was implanted over the top surface with the help of copper self-adhesive conducting tape and the resistance between the top surface and the lower surface in contact with the etchant was monitored with high impedance digital multimeter. As soon as the dc resistance dropped from almost infinite value to some finite value, the breakthrough of the NTF was achieved and the channels so produced were conical or tapered. Copper was electrodeposited using template synthesis and SEM pictures were obtained revealing conical or tapered microtipped needles.

References:
Modification of Polymer Track Membranes by Radiation-Induced Graft Polymerization

Nadeshda I. Shtanko, V.Ya. Kabanov, Pavel Apel

1Flerov Laboratory of Nuclear Reactions, JINR, Dubna 141980, Moscow region, Russia
2Shubnikov Institute of Crystallography, Russian Academy of Science, Leninsky prosp. 59, 117333 Moscow, Russia
shtanko@nrsun.jinr.dubna.su

In this communication our results on the modification of poly(ethylene terephthalate) (PET) and polypropylene (PP) track membranes (TM) are presented. Modified membranes have been prepared by radiation-induced graft polymerization of 2-methyl-5-vinylpyridine (2M5VP) and N-isopropylacrylamide (NIPAAM) from liquid phase. The properties of grafted PET and PP TM have been studied. It was shown that the rate of grafting and the limiting grafting value linearly increase with the increasing of the pore diameter. The gas and hydrodynamic pore diameters of the modified membranes were determined. A track membrane modified by grafting with 2M5VP shows a sharp increase in the water flow rate with the increasing grafting yield, and the maximum water flow rate corresponds to the maximum hydrofilicity on evidence of water contact angles. Thermosensitive track membranes were prepared by radiation-induced grafting with NIPAAM. The phase transition temperature of the grafted gel was measured by conductometric method. The transport properties of the grafted TM were determined. The structure of the grafted membranes have been investigated by scanning electron and atomic force microscopy.

Ion Track Filters: Some Applications in Science and Technology

S. Amrita Kaur, Gurpartap Randhawa, Hardev S. Virk

1Department of Physics, R.R. Bawa D.A.V. College, Batala, India
2Department of Physics, Khalsa College, Amritsar, India
3Department of Physics, Guru Nanak Dev University, Amritsar, India
gurpartaps@yahoo.com

Ion track filters (ITFs) are produced by physico-chemical treatments to thin films of polymers and mica irradiated by heavy ions. These ion track filters have many applications in the fields of science and technology. In the present investigation, some applications of ITFs, like microhydrodynamical flow studies, conduction of bacteria and blood cells, development of metal and metal-semiconductor microstructures, etc. are reported. The developed ion track filters from polycarbonate films have been used to filter bacteria of various types in water. It is observed that the electric conduction through these filters depends upon the concentration of contaminants and pore diameter of filters. Filtration experiments were carried out using both single and multi-pore filters. We describe an electrochemical template method for the synthesis of microstructures and microtubules of desired material viz., metal and polymer within the etched pores of Makrofol-KG, Kapton and PVDF. The developed microstructures and replicas were scanned by SEM for morphological studies.

The Effects of Energy & Dose Rate on the Tl Response of a GE - Doped Optical Fibre

Youssef Abdulla, D. A. Bradley, Y. M. Amin, B. H. Khoo

1University of Malaya, OR 204 Block “c” Ehsan Ria condo (11/2), 50603 Kuala Lumpur, Malaysia
2School of physics, University of Exeter, Exeter EX4 4QL, U.K
3Physics Department, University Hospital, University of Malaya, 50603 Kuala Lumpur, Malaysia
shafter40@hotmail.com

We have studies the thermoluminescent dosimeteric (TLD) characteristics of gamma-photon beam irradiated germanium doped silica fibre. Using fibres of one- centimeter length and mass 0.3 mg, we have investigated light output versus irradiation energy and the effect of dose rate and dose. Pronounced energy dependence has been found.
for irradiated fibres, the light output being close to a factor of 2.5 greater for 10 MeV photon irradiations when compared with results for 100Kv photon irradiations (the latter being emitted by superficial X-ray therapy). Dose rate effects have not been observed over the dose-rate range 0.01 to 0.10 Gy/sec. For particular sources of irradiation we note dose linearity over the range 0.02 Gy in to excess of 100 Gy.

The Track Membranes Porous Structure and Selective Properties Investigation

Pavel Apel1, V.V.Berezkin1, A.N.Nechaev1, Dmitri Zagorski2, T.V.Tsiganova1, N.V. Mitrofanova, B.V.Mchedlishvili1

1Shubnikov Institute of Crystallography RAS, Leninsky prosp. 59, Moscow, 117333, Russia
2Flerov Laboratory of Nuclear Reactions of Joint Institute of Nuclear Research, Russia

track@imb.imb.ac.ru

The polyethyleneterephtalate track membranes (PETP TM) pore diameter D was studied by the bubble point (BP), hydrodynamics (HD) and scanning electron microscopy (SEM) methods. The data, determined with these methods, differed one from other and relation $D_{SEM} > D_{HD} > D_{BP}$ was found in any cases. The double cone shape pore was supposed to explain this result. This shape may be consequence of definite value of track etching rate along the track axis. This results in difference of etching times at film external surfaces and inside it so etchant don’t permeates in track instantly. So the pore diameters at external membrane surfaces must be greater than the one is inside membrane. The $D_{BP}$ value is calculated with the largest pressure value corresponding to air bubble formation inside pore. So $D_{BP}$ is the least pore diameter, i.e. the diameter of the neck placed at half of pore length. The relation between the $D_{SEM}$, $D_{HD}$ and $D_{BP}$ was written in frame of the double cone shape base:

$$3 \cdot (D_{SEM}/D_{HD})^4 \cdot \beta^3 - \beta^2 - \beta - 1 = 0$$

here $\beta = D_{BP}/D_{SEM}$.

This equation was used to calculate $D_{BP}$ value of TM samples with $D_{HD}$ and $D_{SEM}$ values, measured in experiments. The results of calculations were consist with values, determined with “bubble point” method. These TM samples were used to investigate the relation of TM selectivity $\varphi$ and ratio of particle size – to pore diameter $\lambda = d/D$, (here d- particle size). The polystirol latex particles with diameter of 0.3 $\mu$m were used. It was shown, that function $\varphi(\lambda)$ depends on method of the TM pore diameter determination.

The main conclusion is the value $D_{BP}$ must be used to determine the TM relationship $\varphi(\lambda)$, needed for TM selectivity predictions in filtration processes.

Keywords: track membrane, pore structure, selectivity.

Separation of Emulsions Using MICA Filters

S. N. Husaini, Ehsan-Ullah Khan, F. Malik, Imtinan Qureshi, M. Sajid, S. Karim

Radiation Physics Division, PINSTECH, P.O. Nilore, Islamabad, Pakistan

ehsan.pins@dgcc.org.pk

Nuclear Track Micro Filters (NTMF) are produced by the bombardment of heavy ions on various Solid State Nuclear Track Detectors (SSNTDs) with subsequent etching in the appropriate etchant. The number, size and shapes of the pores in these filters are controlled by the beam flux and etching conditions. These filters have been extensively employed in aerosol research, bio-medical and chemical sciences, environmental studies and in blood scanning. In industrial and radiochemical processes there exists a problem for complete separation of emulsions into their constituent phases. Previously NTMF made of Kapton have been employed for the separation of TBT-HNO$_3$ emulsion. In the present paper we report the successful separation of emulsions of various strongly mixed immiscible liquid phases using mica NTMF.
Radiation Resistance of Track Etched Membranes
Marek Buczkowski, Bozena Sartowska, Danuta Wawszczak, Wojciech Starosta
Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland
mbucz@orange.ichtj.waw.pl

Track etched membranes (TEM) obtained by irradiation of polymer films using heavy ions and subsequent etching of latent tracks can be applied in many fields among others in biomedicine. It is important to know radiation resistance of TEM because of wide use of radiation sterilization in case of biomedical devices. Tensile properties of TEM made of PET and PC films with thickness 10 µm after electron irradiation at different doses are known from literature. Nowadays TEM are being manufactured from thicker PET film (20 µm) and polyethylene naphthalate (PEN) as a new polymer material is proposed for TEM. It seems to be important to get data about radiation resistance of new kinds of TEM. Samples of polymer films made of PET and PEN with thickness 19 - 25 µm and TEM made of such materials have been irradiated using 10 MeV electron beam with doses up to 500 kGy. Tensile properties and SEM photographs of samples after irradiation are given.

Neutron Measurements for a Polyhedral Room
V. Pérez-Medina, Miguel Balcázar, A. Tejeda, M.E. Camacho, Letitia Tavera
Instituto Nacional de Investigaciones Nucleares, Apartado Postal 18 1027, México D. F. 11801, México
mbguclear.inin.mx

A small-polyhedral neutron-calibration room build at the Nuclear Center of México shows, in spite of its small dimensions, low neutron reflection component. Confirmation is obtained by analyzing the $^{252}$Cf neutron spectra by means of SAIPS code containing SAND-II as neutron spectrum unfolding. The Hunt and Eisenhauer method is used for neutron scattering determination and for neutron beam characterization. The scattered room component S of 0.15 $m^2$ experimentally obtained using Bonner spheres of several diameters (m) 0.05, 0.76, 0.13, 0.20, 0.25, 0.31, 0.35, 0.46, and the resulting unfolding spectrum show good results. The background outside the calibration room assessed by means of CR39 detectors show acceptable levels.

Monitoring Fast Neutron Flux Inside Spent Reactor Fuel by CR-39 Detector
Tam Cong Nguyen, Laszlo Lakosi
Institute of Isotope and Surface Chemistry, Hungarian Academy of Sciences, P.O.Box 77, H-1525 Budapest, Hungary
tam@alpha0.iki.kfki.hu

Upon spent reactor fuel assay by track etch method, fast neutrons arrive at the detector from all directions in a huge gamma field. The density of tracks, shape-selected by using 0.5 MeV energy discrimination to reduce the number of disturbing events, depend strongly both on direction of incidence and gamma dose. A model case was studied using Cf-252 sources, whose neutron spectrum is similar to that of spent fuel, in a high gamma field obtained by Co-60 irradiation. Based on the calibration performed in this way, neutron flux inside fuel assemblies was found to be $10^2$ – $10^6$ n/cm$^2$ s, depending on burnup and cooling time. The effect of adjacent assemblies can decrease substantially, if the detector surface is perpendicular to the axis of the fuel assembly.
Measurement of Fast Neutron Fission Factor for Heavy Water Zero Power Reactor by
Solid State Nuclear Track Detector
Yong-Qian Shi, Yi-Guo Li

China Institute of Atomic Energy, P.O.Box 275(96), Beijing 102413, Republic of China
mnsr@mipsa.ciae.ac.cn

The paper describes the principle, experimental method and result of the measurement of fast neutron fission factor for heavy water zero power reactor by solid state nuclear track detector. A comparison between the experimental and theoretical results shows they were in reasonable agreement.

Key words: Solid state nuclear track detector, Fast neutron fission factor

Telescopic Metallic Microstructure Synthesis Using Piled Nuclear Track Filters
Shiv Chakarvarti

Department of Applied Physics, Regional Engineering College, Kurukshetra- 136 119, India
phy@reck.ernet.in

The technique of Template Synthesis is akin to that of synthesizing components through the process of replication. The so generated structures can be both homogeneous or heterogeneous short, squat fibrils, long needle-like fibrils, tubules, tapered conical (single or double cones) elements etc., depending upon the pore dimensions, shape and geometries. Moreover, there can be a complete control over the aspect ratio of such elemental components. Both metallic and nonmetallic, cylindrical as well as tubules, have been synthesized and reported [1, 2]. In such processes, usually one polymeric Nuclear Track Filter (NTF) having desired type of templates in the form of etched pores is used. Reported here in this work is the use of piled (two or more) etched (micro-sized cylindrical pores) Makrofol polycarbonate (60 µm thickness) NTFs, placed one upon another, with a large possibility of overlapping of co-axial cylindrical pores (dia about 1 to 2 µm) of different sizes in two respective NTFs. The probability of overlapping increases with large pore densities. Metal copper was deposited using an electrodeposition cell and SEM of the synthesized structures yielded "telescopic" structures. This opens up of a possibility of generating large sized such telescopic structures using multilayered or piled NTFs for their possible applications as micro-wave antenna.

References:

Investigation of Beam Uniformity in Industrial ElectronAccelerator
Farhood Ziaie¹,², Hossein Afarideh¹,², S. M. Hadji-Saeid²,³

¹Nuclear Research Center for Agriculture & Medicine, P. O. Box 31585-4395, Karaj, Iran
²Amir Kabir University of Technology, Physic Department, P. O. Box 15875-4413, Tehran, Iran
³Radiation Processing & Research Center, P. O. Box 89175-389, Yazd, Iran
ziaie@123iran.com

In this paper the performances of an industrial electron beam processing has been investigated by measuring of two-dimensional dose distribution in electron beam profile and also the three dimensional dose distribution in large volume of absorbing materials with densities 0.5 and 1 gr/cm³, which are wood and polyethylene respectively. On the other hand the mentioned measurement also are performed for x-ray (Bremsstruholung) beam that were converted...
by interaction of electron with a high power x-ray target. The experiments have been performed by using several types of film dosimeters such as PVB, CTA, GAFCHROMIC, and FWT. These dosimeters are used for beam profile measurement and precise dose evaluation. The obtained results clearly show that the electron beam emerging out from scanning horn has a good uniformity along the electron beam profile.

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**Beam Acceleration in Plasma Focus Device**

Radovan Antanasijevic, Radomir Banjanac, Aleksandar Dragic, Zvonko Maric, Jovica Stanojevic, Vladimir Udovicic

Institute of Physics, Pregrevica 118, 11080 Belgrade, Yugoslavia

udovicic@atom.phy.bg.ac.yu

The proton beam emission from the small 8 kJ Plasma Focus device operated with the H\textsubscript{2} filling, was analyzed. Maximum energy, the spatial distribution and yield were obtained using NTD. The fast protons were registered with the energy up to 500 keV using the absorbers with the different thickness.

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**Comparison and Limitations of Three Different Bulk Etch Rate Measurement Methods as a Function of High Gamma Absorbed Doses in Nuclear Track Detectors**

Fazal-ur-Rehman\textsuperscript{1}, Falah Abu-Jarad\textsuperscript{1}, Mohammed Al-Jarallah\textsuperscript{2}

\textsuperscript{1}Centre for Applied Physical Sciences, King Fahd University of Petroleum & Minerals, P.O. Box 2020, Dhahran 31261, Saudi-Arabia

\textsuperscript{2}Department of Physics, King Fahd University of Petroleum & Minerals, KFUPM, Box 77, Dhahran 31261, Saudi-Arabia

fazalr@kfupm.edu.sa

Samples of Nuclear Track Detectors (PM-355) were exposed to high gamma doses from 1×10\textsuperscript{5} Gray (10 MRad) up to 1.2×10\textsuperscript{6} Gray (120 MRad) at an incremental dose of 1×10\textsuperscript{5} Gray (10 MRad). The gamma source was a 9.03 PBq (244 KCi) Co-60 source used for sterilization of medical syringes. The bulk etch rate (V\textsubscript{b}) was measured for various high gamma doses by three different methods: 1- thickness change method; 2- mass change method; 3- fission track diametric method [1]. The study gives a comparison and limitations of these three methods used for bulk etch rate measurements in the detectors as a function of high gamma doses. The track etch rate (V\textsubscript{t}) and the sensitivity (V) of the detector were also measured using the fission track diametric method.

It was observed that V\textsubscript{b} increases with the increase of the gamma absorbed dose at a fixed etching time in each bulk etch measuring method. The bulk etch rate decreases exponentially with the etching time at a fixed gamma absorbed dose in all three methods. The thickness and mass change methods have successfully been applied to measure V\textsubscript{b} at higher gamma doses up to 1.2×10\textsuperscript{6} Gray (120 MRad). The bulk etch rate determined by the mass and thickness change method was almost the same at a certain gamma dose and etching time whereas it was quite low in the case of the fission fragment track diametric method due to its limitations at higher doses [2]. Also in this method it was not possible to measure the fission fragment track diameters at higher doses due to the quick disappearance of the fission tracks and therefore the V\textsubscript{b} could not be estimated at higher gamma doses.

References:


Sensitivity Coefficient of the System "Metal Uranium Thick Foil - SSNTD" for Neutron Registration

Igor V. Zhuk

Institute of Power Engineering Problems, 220109 Minsk, Sosny, Belarus
lab3@sosny.bas-net.by

When measuring neutron and physical characteristics of nuclear plants, registration of densities of neutron fluxes by the method of solid state nuclear track detectors “thin” sources of fission fragments are mainly used, for which the thickness (d) is considerably less than the average range of fission fragments (R). Efficiencies of fission fragments registration for “thin” sources are well known for various types of SSNTD. Sometimes it's preferably to use "thick" fissionable foils, for which the relationship d>>R is executed, because they don't require their preliminary calibration relative to each other. "Thick" foils are also more effective than "thin" ones for measurements in neutron fields with small neutron fluxes.

There were determined the sensitivity coefficients for a number of solid state nuclear track detectors, such as polycarbonate film, lavsan, natural mica, artificial mica and cover glass for microscopes. They equal (1.18±0.04; 1.15±0.04; 1.06±0.03; 0.99±0.03; 0.59±0.02)x10^{-5} track/neutr.barn (2σ) correspondingly.

Neutron Irradiation Calibration for FTD by Fission Products from U_3O_8 Powder

Arturo López¹, F. Aguilar¹, Miguel Balcázar¹, J. Solé²

¹Instituto Nacional de Investigaciones Nucleares, Apdo. Postal 18-1027, 11801 México D.F., México
²Instituto de Geología, UNAM., Apartado postal 70-296, 04510 México D. F., México
mtd@nuclear.inin.mx

The Triga Mark III research reactor at the Nuclear Centre of México has a central thimble facility for fission track dating of 0.025 m in diameter and 0.35 m long. The neutron flux along the vertical axis was calibrated by assessing the fission products from twelve samples of U_3O_8 powder placed 0.025 m apart along the vertical axis. The amount of secreted fission yield is calculated using an ORIGIN code. A comparison with neutron activation analysis on gold foils at the central part of the thimble gave a difference less than 3%. All γ-spectrometry measurements were performed using a low background GeHP detector. The neutron profile along the thimble was also compared with that obtained for age standars evaluated by ^{40}Ar/^{39}Ar dating method. The knowledge of neutron flux distribution along the vertical irradiation facility permits to improve the irradiation efficiency.

Comparison of Experimental and Calculated Response of CR-39 to Neutron Spectra of Am-Be and 252Cf Source

Karel Turek¹, Gábor Dajkó²

¹Nuclear Physics Institute of the Czech Academy of Sciences, Dept. of Radiation Dosimetry, Na Truhlářce 39/64, CZ-180 86 Praha 8, Czech Republic
²Institute of Nuclear Research of the Hungarian Academy of Sciences, Bem tér 18/C, 4001 Debrecen, POB 51, Hungary
turek@ujf.cas.cz

Previously obtained experimental values of response of CR-39 track-etch detector to monoenergetic neutrons were used to fit the response as a function of energy. Responses to broad energy neutron spectra calculated using this fit were compared to corresponding experimental values to prove the choice of fitting functions. The comparison was carried out for 2 different electrochemical etching conditions and for both bare and shielded (Fe, resp. paraffin) Am-
Be and $^{252}$Cf neutron sources. Good agreement was found for bare sources, some deviations in shielded fields can be explained as a conclusion of a difference between the real neutron spectra in experiment and these used for calculations.

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**Alpha Responses of Polycarbonates, LR-115 and CR-39 Detectors for Measuring $^{226}$Ra in Microprecipitate Filters for Large-Scale Environmental Monitoring**

Mehdi Sohrabi, M. Taheri

National Radiation Protection Department, Atomic Energy Organization of Iran, P. O. Box 14155-4494, Tehran, Islamic Republic of Iran

m.sohrabi@iaea.org; msohrabi@cic.aku.ac.ir

A method has recently been introduced by us for radioactivity determination of $^{226}$Ra in environmental samples and in particular water for large-scale environmental monitoring. The method is based on detection of alpha particles from $^{226}$Ra and $^{222}$Rn under equilibrium in microprecipitates on a filter by a solid state nuclear track detector (SSNTD). Microprecipitates are prepared on a filter of special pore size, for maximum precipitation efficiency, from environmental samples by the collection of radium with lead as Pb/RaSO$_4$. Then radium is co-precipitated by a barium carrier leaving a thin film forming microprecipitate on the filter. The state of equilibrium of $^{226}$Ra with $^{222}$Rn was verified systematically by alpha spectrometry up to reaching an equilibrium. Due to wide energy ranges of alpha particles from $^{226}$Ra and $^{222}$Rn daughters up to 7.69 MeV from $^{214}$Po, the responses of each detector are quite different from those of another detector. In our original study, alpha particles from $^{226}$Ra and $^{222}$Rn were detected by polycarbonate (PC) when electrochemically etched (ECE). For provision of more detection possibilities, higher efficiency, lower minimum detection limit (MDL), lower exposure time, etc., the responses of LR-115 and CR-39 detectors when chemically etched (CE) were also investigated. The characteristic responses of each detector were studied under the relevant ECE or CE conditions. The optimum distances where the detectors provide the highest responses were determined to be 2.5, 1.5, and 0.5 cm for the PC, LR-115 and CR-39 respectively. Using a standard $^{226}$Ra solution in water for preparation of microprecipitates, the calibration response and the MDL of each detector were determined and compared. In particular, since the alpha counting time can be relatively long, the MDL is relatively lower than that of other existing methods and even than that of the emanation method which has the lowest MDL of 2 mBq l$^{-1}$. Based on some preliminary estimates, for an exposure time of 30 days, MDLs of 1.2, 0.12, and 0.13 mBq l$^{-1}$ were estimated for the PC, LR-115 and CR-39 detectors respectively. Due to the passive and simple nature of the method developed, activity of $^{226}$Ra in large number of environmental samples (e.g. 100) can be almost simultaneously determined with relatively limited equipment, high efficiency, very low MDL, etc. In this paper, some results on the above are presented, compared and discussed.
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