SSNTDs : Current Status & Trends

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Solid State Nuclear Track Detectors (SSNTDs) find applications in many diverse fields: Nuclear Physics, Space Physics, Space Science. Geophysics, Archaeology, Nuclear Medicine & Biology, Reactor Physics, Radiation Physics and Dosimetry. Fleischer, Price & Walker initiated many new ideas and groups into SSNTD domain which includes all those materials (Minerals, Glasses and Plastics) which can record latent tracks due to passage of an ionizing particle. Track formation models have been proposed but the breakthrough came with the introduction of chemical etching for revelation of tracks.

URANIUM/RADON MEASUREMENT TECHNIQUES

Uranium estimation in soil

Fission track-etch technique has been used for uranium estimation in soil samples. In this technique the soil sample is pressed in the form of a pellet after properly drying and sieving. Lexan polycarbonate discs of the size of the pellet are pressed against both sides of pellet and packed in an aluminium capsule. The capsule is irradiated with a neutron fluence of 10^{16} n/cm^2 in CIRUS reactor at BARC. After irradiation the lexan discs are etched in 6.25 N NaOH solution at 70 ^{o}C for 40 min. Fission track density is measured using a microscope. The average value of uranium content is found by relation, C_{ppm}(sample)=[ρ (sample) / ρ (standard)] C_{ppm} (standard), where ρ represents the induced fission track density and C_{ppm} denotes the uranium content.

Uranium estimation in fossil bones

Elemental analysis in vertebrate fossil bones collected from various locations in the Siwalik Himalaya was carried out using XRF technique and uranium content was also determined by fission track-etch technique and alpha-autoradiography.

Uranium estimation in water

The experimental procedure for uranium estimation in water is based on fission track-etch technique. A known volume of water (two drops ~ .04 cm^3) of each sample was allowed to evaporate on Lexan plastic discs (1.3 cm diameter) in an air tight enclosure. Non-volatile constituents of water were left over the discs in the form of a thin film. The discs were packed in an aluminium capsule and sent for irradiation. After irradiation, Lexan discs were etched and total number of fission fragment tracks counted. The uranium content in water was determined using the following formula :

$C_w=(TM)/(V\ G\ N_A\ E\ \sigma\ \phi)$, where

T = Total number of tracks counted over the disc,

M = Atomic weight of uranium (238),

V = Volume of water drop (0.04 cm^3),

N_A = Avogadro number (6.023×10^{23}),

G = Geometry factor which is taken as unity,

E = Etching efficiency factor for Lexan plastic,

σ = Fission cross-section for ^{238}U (4.2×10^{-24}),

ϕ = Thermal neutron fluence (5×10^{15} n/cm^2).

Radon estimation in soil

Both track-etch technique and radon emanometry were used for radon estimation in soil-gas. In track-etch method, radon-thoron discriminator with cellulose nitrate (LR-115 type-II) film as track recorder was used. The discriminator was kept in the auger hole 60 cm deep for a period of 4 weeks. After retrieval, the detector film was etched in 2.5 N NaOH solution at 60 °C for 2 hr. Track density was measured by Carl Zeiss binocular microscope and radon was estimated by using the calibration factor of 1 track/mm^2/hr = 82.5×10^3 Bq/m^3.

In radon emanometry, the auger holes, each 60 cm in depth and 6 cm diameter were left covered for 24 hr. The soil-gas probe was fixed in the auger hole and connected to an alpha-detector in a close-circuit. The soil-gas was circulated through ZnS (Ag) coated chamber for 15 min. till the radon forms a uniform mixture with air. The detector was then isolated and radon alpha counts were recorded after 4 hr. when equilibrium was established between radon and its daughters. The alpha counts were converted to radon activity in Bq/m^3 using the calibration factor.

Radon estimation in water

Discrete sampling method for measurement of radon in water was used. 100 ml. of each sample was collected in radon-tight reagent bottles of one litre capacity and connected to a conical flask through a hand-operated rubber pump and a glass bulb containing $CaCl_2$ to absorb moisture. LR-115 type II detector foils were kept suspended in the conical flask for 15 days. The radon gas was transferred from the reagent bottle to the flask by bubbling water and sucking the gas with the help of the rubber pump. This close-circuit technique is quite effective in radon estimation in dry or wet air. The detector foils were etched in 2.5 N NaOH solution at 60 ^oC for 2 hr and scanned under microscope. Track density was converted to radon concentration in Bq/m^3 with a precision of 5-10%.

Radon estimation in indoor air

Both the track-etch technique and electronic counters have been used. Plastic foils, LR-115 type II, 2 cm^2 each were fixed on the glass slide with the help of scotch tape and suspended from the roofs of dwellings. After an exposure of one month, the detector foils were removed and etched in the laboratory. The measured track density was converted to radon concentration in indoor air by using a calibration factor. The electronic alpha counter using pulse ionization chamber is found to be most suitable for radon estimation in the environment. We have used Alpha-Guard PQ 2000, which is portable, direct reading and with a detection limit of 1 Bq/m^3.

SSNTD APPLICATIONS

(a) Nuclear Physics : (i) Nuclear Fission

(ii) Transuranium Elements

(iii)Heavy Ion Reactions

(iv) Nuclera Lifetimes (10^{-16}-10^{-19}s)

(v) Excitation function for (p,α) reaction

(b) Trace Element Analysis : Micromapping of U, Th, Ra and B

(c) Radiation Dosimetry : (i) Thermal and fast neutron dosimertry

(ii) Personnel and area dosimetry

(d) Geochronology : F.T. Dating of rocks & minerals, tektites, meteorites and moon rocks. Thermal history and uplift rates. Ocean bottom spreading.

(e) Solid State Physics : Defect identification, channeling and blocking.

(f) Solar Physics & Cosmic Rays : Nature of solar nuclei, Energy & composition of cosmic rays, Cosmic ray exposure ages.

(g) Miscellaneous : (i) Uranium Exploration

(ii) Earthquake Forecasting

(iii) Oil Exploration

(iv) Nuclear Medicine and Biology

(v) Environmental Pollution

(vi) Reactor Fuel Development

(vii) Metallurgy

(viii) Materials Science

(ix) Radwaste Disposal

(x) Cluster Radioactivity

(xi) Fragmentation of Relativistic Heavy Nuclei

(xii) Ultra Heavy Cosmic Rays

Research Highlights of SSNTD Group at G.N.D.University, Amritsar

(a) Fission Track Age of Himalayas, Pegmatites, Iron & Copper Ores, Tektites, Volcanic Eruptions, Ocean - Bottom spreading and Meteorites.

(b) U-Estimation in Minerals, Water, Plants, Juices, Toothpastes, Fertilizers, Siwalik Fossil Bones, etc.

(c) Intercalibration of Glass Dosimeters for Neutron Dosimetry.

(d) ‘Single Activation Energy Model’ of Heavy Ion Annealing of Radiation Damage in SSNTDs.

(e) Uranium uptake in Plants and Discovery of U-Anomalies/Indicator Plants for U- Exploration in Lower Himalayas.

(f) Radon as a Precursor for Earthquake Prediction Studies.

(g) A Model for Correlation of Radon Anomalies with Magnitude of Earthquakes.

(h) National Survey for Radiation Dose Measurement in Punjab and Himachal Pradesh due to Indoor Radon Concentration.

(i) Radon/Helium Exploration in Thermal Springs.

(j) Range – Energy Measurements in SSNTDs.

(k) Preparation and Applications of Micro-filters.

(l) Heavy Ion Modification of Polymeric Materials.

Table 1: MATERIALS CHEMICALLY ANALYZED BY TRACK METHODS

URANIUM in	**LITHIUM** in
Aerosols	Steel
Archaeological materials	
Bivalves	**BORON**
Bones	in
Coal	Beagles
Coffee	Germanium
Condiments	Glass
Drugs	Metallic glasses
Flyash	Plants
Fossils	Plutonium
Human tissues	Rocks
Kidney stones	Silica

Liquid-solid systems	Steels
Meteorites	
Milk	**NITROGEN**
Minerals	in
Mouse liver	Polymers
Ores	Si_3N_3
Packaging materials	Steels
Plants	
Rocks	**POLONIUM**
Seeds	in
Silicon	Cigarette filters
Soils	
Spices	**THORIUM**
Teeth	in
Tektites	Meteorites
Urine	
Water	

For Data Tables, Pl. refer to Book by Fleischer RL, Price PB and Walker RM: Nuclear Tracks in Solids: Principles and Applications, University of California Press, Berkley, 1975.

Table 2: Examples of Solid State Nuclear Track Detectors (SSNTDs)

Type	Detector Material	General Etching Conditions	Lightest Detectable Particle	Critical Angle θ_c
Minerals crystals	Olivine	KOH_{aq}, 160 ^{0}C, 10 min.	Fe	
	Zircon	10% HF, 23 ^{0}C, 30 sec.	Ca	
	Quartz	85% H_3PO_4, 500 ^{0}C, 1 min.	Ar (100 MeV)	
	Mica	KOH Soln., 210 ^{0}C, 10 min	Ne (20 MeV)	$4^0 30'$
		48% HF, 23 ^{0}C, 1- 40 min.		
Glasses	Sodalime glass	48% HF, 23 ^{0}C, 5 sec	Ne (20 MeV)	
	Phosphate Glass	48% HF, 23 ^{0}C, 10 sec	F (20 MeV)	$\sim 50^0$

Plastics	Poly Carbonate Plastics (Lexan, Makrofol, Mylar) Cellulose Nitrate (Daicell, LR-115, CA-80-15) CR-39 (Allyl diglycol polycarbonate	6 N NaOH, 60 ^{0}C, 60 min. 3-6 N NaOH, 50 ^{0}C, 40 min. 6 N NaOH, 70 ^{0}C, 1-4 hr.	He (0.3 MeV) H (0.5 MeV) H (1.0 MeV)	~2-3^{0} ~4-8^{0} -