Solid State Nuclear track Detectors (SSNTDs)

Dr / Basma Elbadry
Outline

- What’s the radiation
- Types of radiation
- Sources of radiation
- Radiation effect on body
- Radiation protection
- Solid State Nuclear track Detectors
What is "Radiation"?

Travels in Waves

High Speed Particles
Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions, but can excite the electron. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and ultraviolet.
ionizing radiation has higher energy than non-ionizing radiation; it possess enough energy to produce ions.

This process results in the formation of two charged particles or ions:

- molecule with a net positive charge
- free electron with a negative charge

Examples of ionizing radiation are alpha, Beta, neutron, gamma, and X-ray.
ALPHA PARTICLE
Alpha Radiation ($\alpha$)

- Helium nucleus (2 neutrons and 2 protons)
- heavy particles, Relatively slow
- Total charge of +2
- They travel short distances,
- Only a hazard when inhaled

Mass number changes by 4 and atomic number changes by 2

\[ \frac{A}{Z}X \rightarrow \frac{A-4}{Z-2}Y + \frac{4}{2} \alpha \]

(Note: $^{4}_2 \alpha = ^{4}_2 \text{He}$)
Beta Radiation ($\beta$)

- High speed electron or positron ejected from nucleus
- Light particles
- Relatively fast moving
- Total charge of -1 or +1

Atomic Mass Number remains constant

\[
\begin{align*}
A_Z^X & \rightarrow A_{Z+1}^Y + ^0_{-1}e + \bar{\nu} \\
A_Z^X & \rightarrow A_{Z-1}^Y + ^0_{+1}e + \nu
\end{align*}
\]

\[
\begin{align*}
1^n & \rightarrow 1^p + ^0_{-1}e + \bar{\nu} \\
1^p & \rightarrow 1^n + ^0_{+1}e + \nu
\end{align*}
\]
X-Rays and Gamma Rays

- Gamma rays are photons emitted from the nucleus, often as part of radioactive decay.

- X-rays are photons (electromagnetic radiations) emitted from electron orbits, such as when an excited orbital electron "falls" back to a lower energy orbit.

- Gamma rays typically have higher energy (Mev's) than X-rays (KeV's), but both are unlimited.

- No mass; Charge=0; Speed = C.
Neutrons

Apart from cosmic radiation, spontaneous fission is the only natural source of neutrons (n). A common source of neutrons is the nuclear reactor, in which the splitting of a uranium or plutonium nucleus is accompanied by the emission of neutrons. The production of nuclear power is based upon this principle. All other sources of neutrons depend on reactions where a nucleus is bombarded with a certain type of radiation (such as photon radiation or alpha radiation), and where the resulting effect on the nucleus is the emission of a neutron. Neutrons are able to penetrate tissues and organs of the human body when the radiation source is outside the body. Neutrons can also be hazardous if neutron-emitting nuclear substances are deposited inside the body. Neutron radiation is best shielded or absorbed by materials that contain hydrogen atoms, such as paraffin wax and plastics. This is because neutrons and hydrogen atoms have similar atomic weights and readily undergo collisions between each other.

- 1 AMU; Neutral Charge;

\[ ^1n + ^{235}\text{U} \Rightarrow ^{147}\text{La} + ^{87}\text{Br} + 2^1n \text{ (neutron induced fission)} \]

The stages in a nuclear fission event as described by the liquid-drop model.
Sources of Radiation
# Radiation from Natural Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>mrem/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic rays</td>
<td>28</td>
</tr>
<tr>
<td>The earth</td>
<td>26</td>
</tr>
<tr>
<td>Radon</td>
<td>200</td>
</tr>
<tr>
<td>The human body</td>
<td>25</td>
</tr>
<tr>
<td>Building materials</td>
<td>4</td>
</tr>
</tbody>
</table>
## Radiation from Manmade Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>mrem/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical</td>
<td>90</td>
</tr>
<tr>
<td>Fallout</td>
<td>5</td>
</tr>
<tr>
<td>Consumer products</td>
<td>1</td>
</tr>
<tr>
<td>Nuclear power</td>
<td>0.3</td>
</tr>
</tbody>
</table>
What could happen to the body when exposed to radiation?
Radiation exposure
Biological effects of radiation result from both direct and indirect action of radiation.

Direct damage is based on direct interaction between radiation particles and complex body cell molecules, (for example direct break-up of DNA molecules)

Indirect damage is more complex and depends heavily on the energy loss effects of radiation in the body tissue and the subsequent chemistry.
ACTION DIRECTE

PHOTON

ACTION INDIRECTE

PHOTON
Indirect damage

- **The physical stage (~10^{-16} s)**
  
  Photon or particle + H₂O → H₂O⁺ + e⁻

- **The physico-chemical stage (~10^{-6} s)**
  
  H₂O⁺ + H₂O → H₃O⁺ + OH⁻
  H₂O⁻ → H⁺ + OH⁻
  e⁻ + H₂O → H₂O⁻
  H₂O⁺ → OH⁻ + H⁺
  OH⁻ + OH⁻ → H₂O₂

- **The chemical stage (~s)**
  
  OH⁻, H⁻, H₂O₂ radical attacks DNA-molecule.

- **The biological stage (min----years)**
  
  Resulting biological damage which can contribute to the destruction of the cell.
Cell Sensitivity

Somatic cells

Gonadal cells

Most sensitive cells:

Rapidly dividing cells
(Small intestines, bone marrow, hair, fetus)

Least sensitive cells:

Slowly dividing cells
(brain, nerves)
Biological Effects of Radiation

- Biological Effects of Radiation can be broken into two groups
- The First Group of biological effects are Stochastic Effects
- The Second Group of biological effects are Deterministic Effects
Deterministic Effects

• Deterministic Effects are those responses which increase in severity with increased dose

• For example; sunburn. The more you’re exposed to the sun, and the higher the ‘dose’ of sunlight you receive, the more severe the sunburn
Stochastic Effects

- Stochastic Effects are those effects which have an increased probability of occurrence with increased dose, but whose severity is unchanged.
- Example; skin cancer and sunlight. The probability of getting skin cancer increases with increasing exposure to the sun.
- Stochastic Effects are like a light switch; they are either present or not present.
Radiation Protection
Inverse Square Law

The radiation intensity, $I$, is proportional to one over the distance squared:

$$I \propto \frac{1}{D^2}$$

The source is assumed to be small compared to the distance.
Shielding

Material placed between yourself and the source will reduce your exposure to radiation.

The amount of reduction will depend upon the material and the radiation.

• Material density and thickness
• Radiation type: α, β, γ, or x-ray
• Radiation energy
TYPES OF RADIATION AND PENETRATION

α  Alpha
β  Beta
X  X-ray
γ  Gamma
n  Neutron

Paper  Thin plates made of wood, aluminum, etc.
       Lead, iron, and other thick metal plates
       Water, concrete, etc.
Time

Minimize the time spent in a radiation field
Containment

Purpose is to ensure that all work and non-work surfaces do not pose a risk to health

Radiation detection
Measurement of ionizing radiation is based on interactions of radiation with matter.

**Category of Detectors**

**Active detectors**
- Ionization chamber
- Geiger-Müller counters
- Proportional counter
- Scintillation detectors

**Passive detectors**
- Photographic emulsions
- Thermoluminescence TLD
- Solid State Nuclear Track Detectors
Solid-state nuclear track detectors

- A solid-state nuclear track detector or SSNTD (also known as an etched track detector) is a dielectric materials with specific resistivity (10⁶-10²⁰ ohm.cm).
- There are two types of these detectors.

**Organic detectors (Polymers):**

<table>
<thead>
<tr>
<th>CR_39</th>
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<tbody>
<tr>
<td>CN_85</td>
</tr>
<tr>
<td>Makrofol</td>
</tr>
<tr>
<td>Lexan</td>
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<tr>
<td>LR-115</td>
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</table>

**Inorganic detectors (Crystals and Glasses):**

<table>
<thead>
<tr>
<th>Muscovite mica</th>
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<tbody>
<tr>
<td>Phosphate glass</td>
</tr>
<tr>
<td>Quartiz</td>
</tr>
<tr>
<td>Tektile glass</td>
</tr>
<tr>
<td>Soda lime glass</td>
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</table>
The basic principles of SSNTD technique

When a heavily ionizing charged particles passes through such insulating solids, it leaves a narrow trail of damage about 50 Å in diameter along its path. This is called latent track that may be observed either directly by transmission electron microscope [TEM] provided that the detector is thick enough, viz. some μm across or under ordinary optical microscope after suitable enlargement by etching the medium.

Track formation in SSNTDs mainly depends upon

1. Total energy loss rate ($-dE/dX$)
2. Angle of incidence of the ion with respect to the detector surface.
**Track revelation by chemical etching**

- The rate of chemical attack along trails of radiation damage is called track etch rate $V_T$, and that along undamaged bulk material is called bulk etch rate $V_B$. The shape of the tracks depend upon the ratio of the track etch rate to the bulk etch rate. The activation energy for the damage region is higher as compared to that of remaining bulk material. Therefore $V_T/V_B > 1$ and thus the etchant produces a conical etch pit having a cone angle.

- For etched tracks to appear, there is a certain critical angle $\theta_c$, the angle between the plane of material and the direction of particles below which tracks will not be registered by chemical etching although the condition $V_T > V_B$ is satisfied.

  ➢ The size and shape of these tracks yield information about the mass, charge, energy and direction of motion of the particles.
If the particles enter the surface at normal incidence, the pits are circular; otherwise the ellipticity and orientation of the elliptical pit mouth indicate the direction of incidence.
Chemical Etching depends on

- chemical solution type
- concentration of chemical solution
- temperature of chemical solution
- time of etching
Track Evaluation Methods

Manual (Ocular) Counting:

- After the chemical etching of a detector, the tracks of particle can be easily scanned by an optical microscope using ordinary magnification. The tracks can be easily distinguished from the background scratches etc. in the detector. Optical microscopy has been found to be highly useful and convenient for obtaining track parameters and densities, although the counting through a microscope is a cumbersome process.

- Track densities are expressed either in relative terms or in absolute terms [tracks cm\(^{-2}\)] which is converted after calibrating into a dose.

- There are also spark counting and automatic track evaluation.
The reasons for the widespread use of SSNTD

They are inexpensive, convenient to use and quite robust.
They can be obtained in any size, from very small to very large (small detectors can be used to measure particle fluxes in odd locations while large detectors are used to record very rare events in cosmic ray studies).
The registered tracks are a permanent record of the phenomenon under investigation. In particular, they remain unaffected by changes in atmospheric conditions such as temperature, pressure, humidity etc.
They are insensitive to visible light. Their development or etching is simple and rapid and does not require dark room facilities.
They can be used as threshold detectors, e.g. glasses and certain plastics record fission fragment tracks but do not record alpha particle tracks.
The charge and energy discrimination of these detectors has been found to be better than that of nuclear emulsions.
They do not need any electronic/electric
Earthquake prediction
Geological uses (Uranium exploration)
Radon dosimeter
Neutron dosimeter
Medical and Biological studies
environmental Sciences
Nanotechnology
Thank you for your attention

Any Questions?