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RADIATION SENSORS : A REVIEW

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Abstract: The radiation sensors are used to sense the radiation itself (detect and quantify radiation from sources such as X-rays and from nuclear sources (α, β, and γ radiation). Ionization sensors, scintillation sensors and semiconductor radiation sensors are three basic types of radiation sensors. These are either detectors or sensor. These sensors are having wide range of applications such as in industries, agriculture, defense and medical fields. In this paper we have summarized different sensors with their applications.

Keywords: Sensor, radiation sensors, Ionization sensors, scintillation sensors, semiconductor radiation sensors, detectors.

1. INTRODUCTION

Sensors are sophisticated devices that are frequently used to detect and respond to electrical or optical signals. All radiation may be viewed as electromagnetic radiation. Many of the sensing strategies, may be viewed as radiation sensing. The conventional nomenclature will be as low frequency radiation "electromagnetic" (electromagnetic waves, electro-magnetic energy, etc.), high frequency radiation, (as in X-ray, α, β, γ or cosmic). Radioactive radiation can be viewed as something different than, say X-ray radiation or microwaves. It is often viewed as particle radiation. This approach is based on the duality of electromagnetic radiation, just as light can be viewed as electromagnetic or as particles – photons.

2. DETECTOR TYPES

There are three basic types of radiation sensor : Ionization sensors, scintillation sensors and semiconductor radiation sensors. Detailed information is as follows :

2.1 Ionization sensors

Ionizing (or ionising) radiation is radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them. Ionizing radiation comprises subatomic particles, ions or atoms moving at relativistic speeds, and electromagnetic waves on the short wavelength end of the electromagnetic spectrum. Gamma rays, X-rays, and the upper vacuum ultraviolet part of the ultraviolet spectrum are ionizing, whereas the lower ultraviolet, visible light (including laser light), infrared, microwaves, and radio waves are considered non-ionizing radiation. The boundary is not sharply defined, since different molecules and atoms ionize at different energies. Typical particles include alpha particles, beta particles and neutrons, as well as mesons that constitute cosmic rays.[1][2] Ionizing radiation arises from a variety of sources, such as bombardment of the Earth by cosmic rays, the decay of radioactive materials, matter at extremely high temperatures (e.g. plasma discharge or the corona of the Sun), or acceleration of charged particles by electromagnetic fields (e.g. lightning or supernova explosions). Ionizing radiation can also be generated by the production of high energy particles in X-ray tubes and particle accelerators. Ionizing radiation is invisible and not directly detectable by human senses, so radiation detection instruments such as Geiger counters are required. However, in some cases ionising radiation may lead to secondary emission of visible light upon interaction with matter, such as in Cherenkov radiation and radioluminescence. It is applied in a wide variety of fields such as medicine, research, manufacturing, construction, and many other areas, but presents a health hazard if proper measures against undesired exposure aren't followed. Exposure to ionizing radiation causes damage to living tissue, and can result in mutation, radiation sickness, cancer, and death.

Fig .1 *Diagram for G.M. Counter*

2.2 Scintillation sensors

A **scintillation counter** is an instrument for detecting and measuring ionizing radiation. It consists of a scintillator which generates photons of light in response to incident radiation, a sensitive photomultiplier tube which converts the light to an electrical signal, and the necessary electronics to process the photomultiplier tube output. The scintillator consists of a transparent crystal, usually a phosphor, plastic (usually containing anthracene) or organic liquid that fluoresces when struck by ionizing radiation. Cesium iodide (CsI) in crystalline form is used as the scintillator for the detection of protons and alpha particles. Sodium iodide (NaI) containing a small amount of thallium is used as a scintillator for the detection of gamma waves and Zinc Sulphide (ZnS) is widely used as a detector of alpha particles. Lithium iodide (LiI) is used as a neutron detector.

Table 1 Different Scintillator materials with their forms

Material	Form
NaI (Tl)	crystal
CsI (Na)	crystal
$CaWO_4$	crystal
ZnS (Ag)	powder
p-terphenyl in toluene	liquid
p-terphenyl in polystyrene	plastic

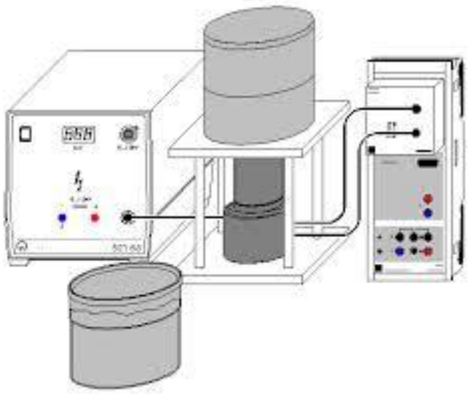

Fig .2. *Scintillation Detector with gamma ray spectometry assembly*

2.3 Semiconductor detector

Semiconductor detectors are especially pure crystals of silicon, germanium, or other semiconductor materials to which trace amounts of impurity atoms have been added so that they act as diodes. A diode is an electronic device with two terminals that permits a large electrical current to flow when a voltage is applied in one direction, but very little current when the voltage is applied in the opposite direction. When used to detect radiation, a voltage is applied in the direction in which little current flows. When an interaction occurs in the crystal, electrons are raised to an excited state, allowing a momentary pulse of electrical current to flow through the device. A semiconductor detector in ionising radiation detection physics is a device that uses a semiconductor (usually silicon or germanium) to measure the effect of incident charged particles or photons.

A) Silicon detector

Most silicon particle detectors work, in principle, by doping narrow (usually around 100 micrometers wide) strips of silicon to turn them into diodes, which are then reverse biased. As charged particles pass through these strips, they cause small ionization currents that can be detected and measured. Arranging thousands of these detectors around a collision point in a particle accelerator can yield an accurate picture of what paths particles take. Silicon detectors have a much higher resolution in tracking charged particles than older technologies such as cloud chambers or wire chambers. The drawback is that silicon detectors are much more expensive than these older technologies and require sophisticated cooling to reduce leakage currents (noise source). They also suffer degradation over time from radiation.

Fig. 3. *Silicon Lithium Detector*

B) Diamond detector

Diamond detectors have a high radiation hardness and very low drift currents. At present they are much more expensive and more difficult to manufacture.

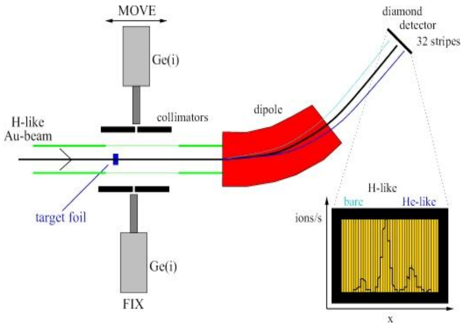

Fig .4 *Pollycrystalline Diamond Detector*

C) Germanium detector

Germanium detectors are mostly used for gamma spectroscopy in nuclear physics. While silicon detectors cannot be thicker than a few millimeters, germanium can have a depleted, sensitive thickness of centimeters, and therefore can be used as a total absorption detector for gamma rays up to few MeV.

Fig. 5. *High-Purity Germanium Detector*

These detectors are also called high-purity germanium detectors (HPGe) or hyperpure germanium detectors. Before current purification techniques were refined, germanium crystals could not be produced with purity sufficient to enable their use as spectroscopy detectors. Impurities in the crystals trap electrons and holes, ruining the performance of the detectors. Consequently germanium crystals were doped with lithium ions (Ge(Li)), in order to produce an intrinsic region in which the electrons and holes would be able to reach the contacts and produce a signal.

3. APPLICATIONS OF DIFFERENT SENSORS

3.1 Medical Field

The semiconductor radiation detectors are applied in all fields of radiation medicine nuclear medicine, radiology and radiation therapy. Developent of research on radiation semiconductor detector based instrumentation for high energy physics (HEP) experiments has produced an essential boost in medical imaging instrumentation where silicon pixilated and strip detectors compete effectively with photomultipliers. These devices are applied to SPECT, PET, CT, digital mammography and dosimetry instrumentation. Silicon detectors are useful in medicine with applications in diagnostic, medical imaging and cancer treatment. Radiation therapy is one of the part of radiation medicine associated with cancer treatment. [3][4]

Ion chambers are widely used as hand held radiation survey meters to check radiation dose levels.

Gas detectors are usually single pixel detectors measuring only the average dose rate over the gas volume or the number of interacting photons as explained above, but they can be made spatially resolving by having many crossed wires in a wire chamber.Scintillation counter are found in thyroid probes, well counters, gamma cameras, and positron emission tomography (PET) systems.

3.2 Industries

Industrial radioactive contamination monitors, either hand-held for area or personal surveys or installed for personnel monitoring require a large detection area to ensure efficient and rapid coverage of monitored surfaces. For this the scintillation counter with a large area scintillator window and integrated photomultiplier tube is suited and finds wide application in the field of radioactive contamination monitoring of personnel and the environment.

The rate of combustion of lubricating oil in operating engines has been followed by means of tritium-labeled lube oil and tritium-counting of samples of exhaust water. [5]

3.3 Agricultural Field

Radiation sensors are useful to detect level of fertilisers in soil by which plants get required nutrients and yield will increase and also growth of crops will be normal. [6]

3.4 Defense

The SDG is developing Germanium detectors for nuclear safeguard applications.Other potential applications include environmental remediation, well logging, medical diagnostics. Silicon detectors are used in astrophysics, nuclear physics, national security, gamma-ray astronomy, uclear non-proliferation, and x-ray spectroscopy for material analysis.

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