Chapter 6 - Principles of Radiation Detectors

Radiation must be measured for several reasons
1) Safety of personnel. (film badges, TLD, survey meters)
2) Calibration of X-ray equipment. (ion chambers)
3) document patient exposures (diodes, TLD, monitor chamber)

All radiation detectors use the concepts of <u>ionization</u> and <u>excitation</u> to detect radiation

Review:

<u>Ionization:</u> incoming particle (photon, e^-, etc) interacts with an orbital electron and removes it from the atom, creating an ion pair

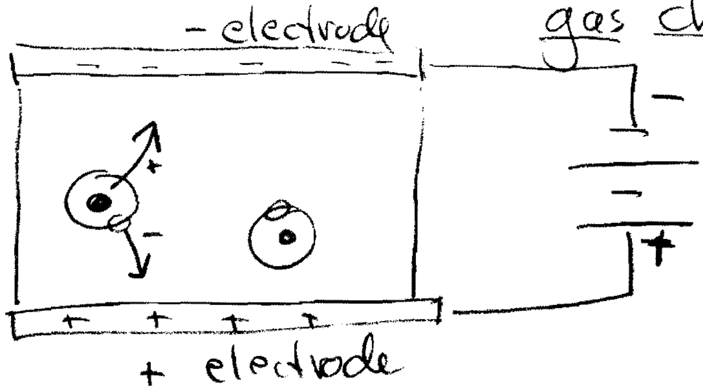
<u>Excitation:</u> incoming particle interacts with an orbital electron raising it to a higher energy state (or orbit)

(1) Gas Ionization Chambers:

There are different types of gas ion chambers.
a) ionization chambers
b) Geiger Mueller (GM) counters
c) proportional counters.

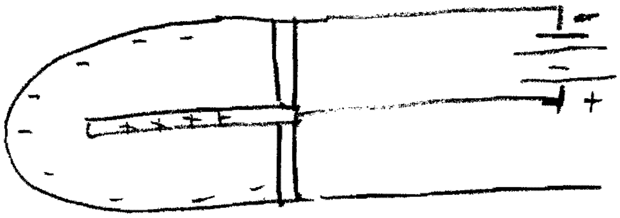
Each consists of the same parts:
a) Chamber of gas
b) electrodes
c) Voltage supply

gas chamber



OR

thimble Chamber

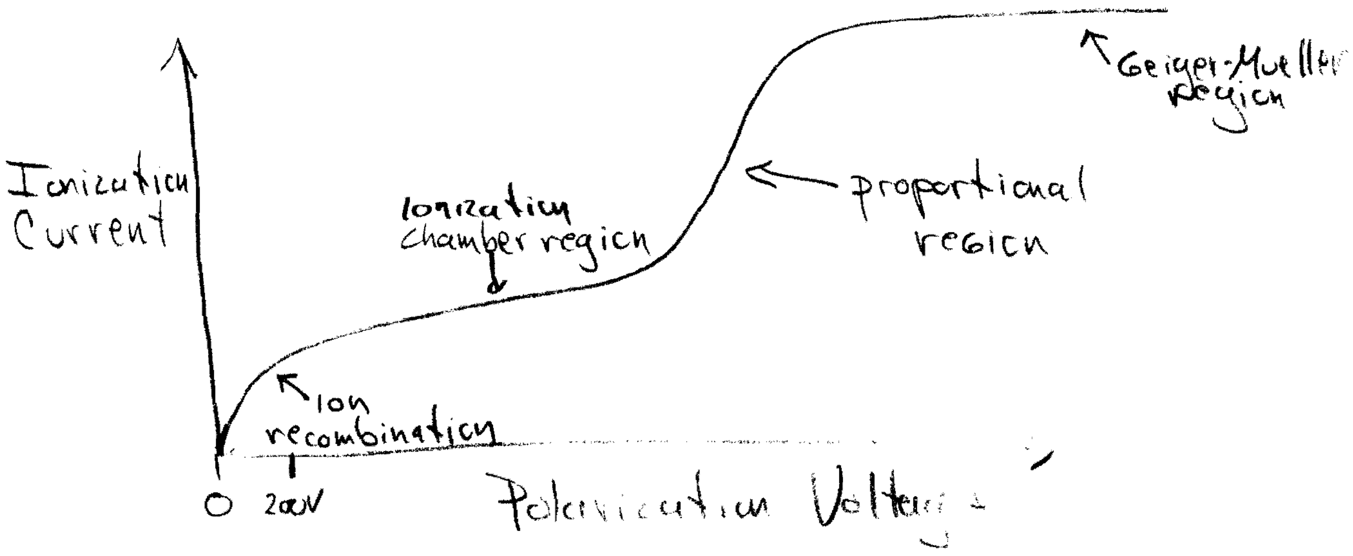


When radiation strikes the gas molecules within the chamber, the molecules become ionized:
The positive electrode attracts the freed electrons and the negative electrode attracts the positive ion.

The electrons which are attracted to the positive electrode form a current, and this current is used to measure the amount of radiation present. (ionization current)

The Voltage which is applied is called the Polarization Voltage or the Bias Voltage.

The strength of the Polarization Voltage will determine how the chamber reacts to radiation.



At Ø Volts, there is no current since the electrodes don't attract the electrons. The ion pairs simply re-combine.

As the voltage increases above ~100V, nearly all of the ionized electrons reach the electrodes and are measured. This is the <u>Ionization Chamber region</u>.

In this region, detection is stable and reproduceable.

As the voltage increases further, another effect takes place:

each ionized electron that is attracted towards the electrode has sufficient energy to ionize another atom along the way - These are called Secondary Ionization Events.

Therefore for each ion pair created by the initial radiation, a much larger number of ion pairs are detected which is Proportional to the initial radiation.

(energy now high enough for photoelectric effect)

Since a small number of initial interactions can create a large number of detections, Proportional Counters are useful for detecting low doses.

Raising the voltage further brings us to the Geiger-Mueller (G-M) region.

Here a single ionization event will cause a near-simultaneous ionization of the entire gas.

The initial ionized electrons are accelerated towards the anode. The excite other atoms along the way. The excited atoms emit UV radiation when returning to ground state. This UV radiation excites more atoms & the process continues.

In essence, the entire gas is ionized with each single event.

G-M counters are good for detecting radiation, but not so good for measuring it.

Beyond the G-M region, the voltage is so high that the gas can be spontaneously ionized with no radiation event.

This is simply due to the high potential difference of the electrodes.

Ionization Chambers:

Types:

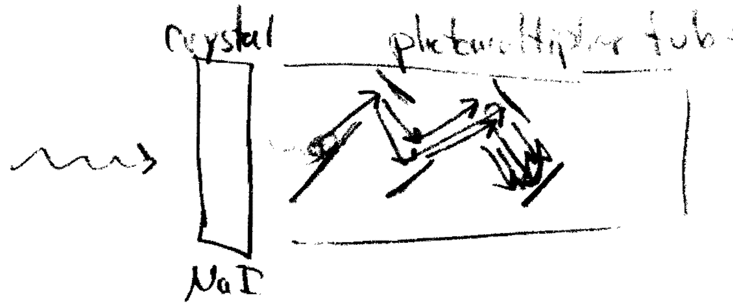
1) Thimble chamber
   - Farmer chambers
   - used for beam calibration

2) Moniter Chambers in Linear accelerators
   - used to measure the radiation output of the beam.

3) Portable ionization chambers
   - Cutie Pie
   - used for radiation surveys

Scintillation Detectors:

- Use a crystal detector instead of a gas.
  - Sodium Iodide (NaI)
  - Calcium Fluoride (CaF)
- photon excites or ionizes an atom of the crystal.
- characteristic radiation is given off.
- light goes into a photomultiplier tube, which amplifies the signal.



- Scintillation detectors are much more sensitive than G-M's

TLD's + Diodes

TLD's

Advantages: ① multiple sites at once
② small size allows placement in otherwise inaccessible areas

Disadvantages: ① need to wait for results
② high maintenance

Calibrating TLD:

- we need to determine what the light output of the TLD compared to (dose)

- we expose a TLD to a known amount of radiation and derive a Calibration Factor

Exposure Dose = 50 cGy
TLD reading = 32.4 nC

$$\text{Calibration Factor} = \frac{50\ cGy}{32.4\ nC} = 1.543\ \frac{cGy}{nC}$$

∴ when a patient TLD reads 83.2 nC the dose is:

$$(83.2\ nC)\left(1.543\ \frac{cGy}{nC}\right) = \underline{128.4\ cGy}$$

Diodes

Diodes are <u>Solid State</u> devices

- no bias voltage

<u>advantages</u>:

- instantaneous readings
- easy setup
- easy maintenance

Disadvantages:

- typically single site
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