Module 5 Unit 4
Radiation Sensors

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Types of Radiation

- Ionizing
  Alpha, beta, gamma, X-rays, deep UV
- Non-ionizing
  UV-A, visible, IR, microwaves, radio waves (photons of Energy < 13 eV)
- Other
- Neutrons, cosmic rays, neutrinos, high magnetic field

- Unit: µSv (micro-sievert)
  1 sievert = quantity of radiation dose that causes biological damage on deposition of 1 joule of energy in 1 kg of material (tissues)

- SAR (Specific Absorption Rate) (W/kg)

Typical Dose Levels of Ionizing Radiation

Items	Radiation dose (μSv)
Stipulated limit per person	2/hr
Single fatal dose	10^7
Single dose causing cancer	10^6
CT scan	Max 40000 per run
Chest X-ray	70 per shot (0.1 sec)
Dental X-ray	20 per shot (0.1 sec)
Natural background radiation	0.1/hr
Chernobyl debris (today)	100
Fukushima (on the accident day)	400000
Hiroshima (back calculated)	10^8 single shot

*Over a prolonged exposure and averaged over 5 years

Radiation Hazards

- Risks from ionizing radiation (non-fatal dose level)
- Nausea, general weakness, skin diseases, cancer, gastrointestinal issues, fertility, weakening of bones and muscles

- Risks from non-ionizing radiation
- Nausea, vomiting, eye irritation, restlessness, numbness, psychosomatic diseases

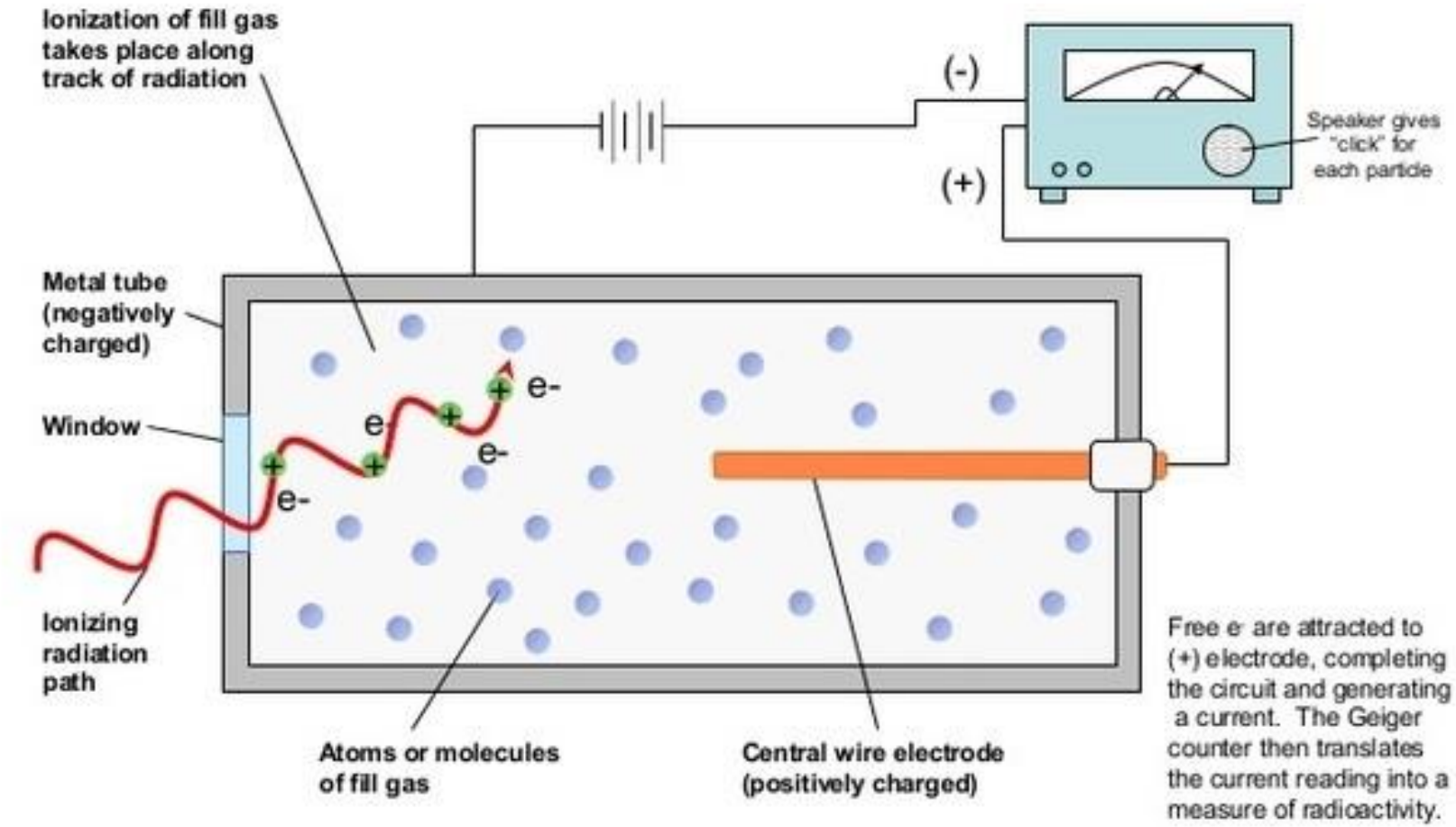
Radiation Detectors

- Gas detectors
  - Ionization chamber
  - Proportional counter
  - Geiger-Muller counter
- Scintillation detectors
  - Solid phosphors
    - Inorganic
    - Plastics/Organic
  - Liquid
  - Gases
- Solid state detectors
  - Intrinsic semiconductors
  - Photodiodes (p-i-n)
  - SDD (FET)
- CCD
  - Directly coupled
  - Indirectly coupled

Geiger-Muller Counter

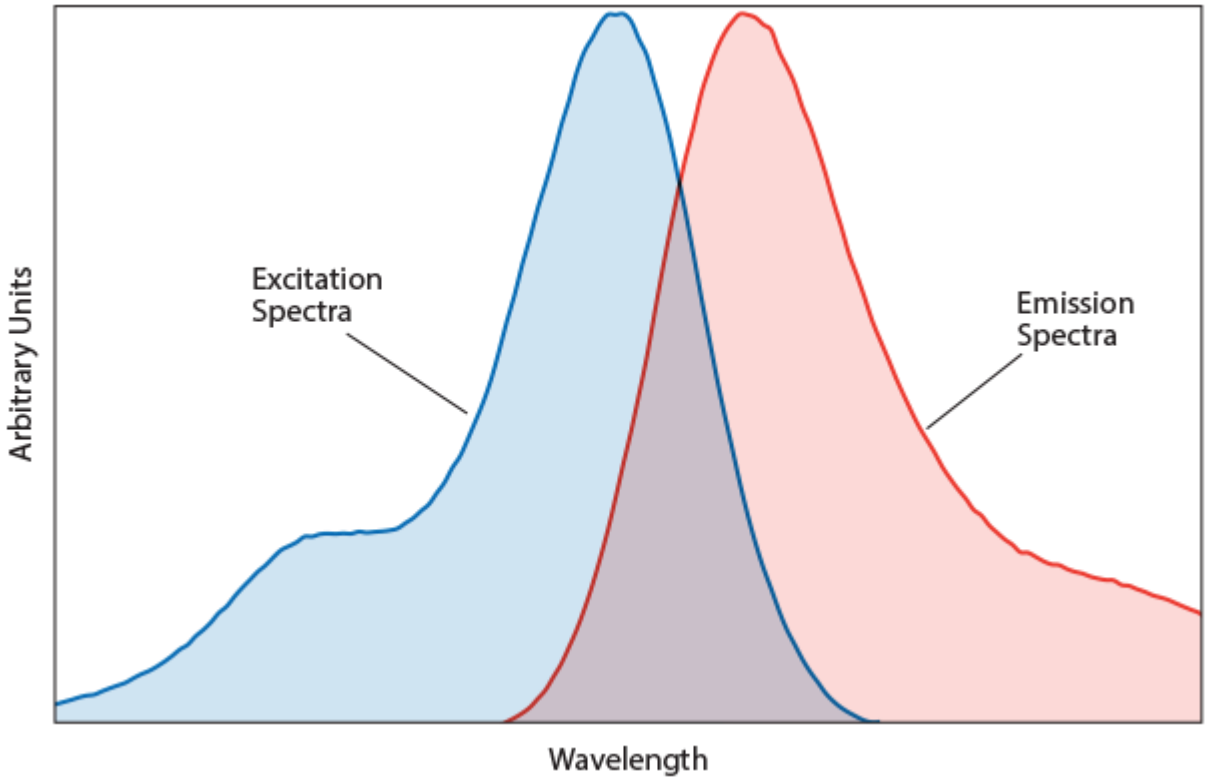
- Used for:
  - α, β and γ radiation
- Basic components:
  - quartz tube (sensor) with metallic lining inside
  - Counter (electronics)
- Working principle: electric discharge due to ionization of gas
  - Mixture of Argon and Ethyl alcohol (90:10) @ 0.01 atm pressure
  - Ethyl alcohol vapours is active component
- Main disadvantage:
  - Dead time
  - Background radiation

Geiger-Muller Counter



Scintillation Counter

- Used for:
  - α, β, γ radiation and X-rays
- Basic components:
  - Phosphor (Scintillator)
    - solid, liquid or gaseous state
  - Photomultiplier tube
  - Counter (electronics)
- Working principles:
  - Luminescence
  - Photoelectric effect
  - Photon multiplication

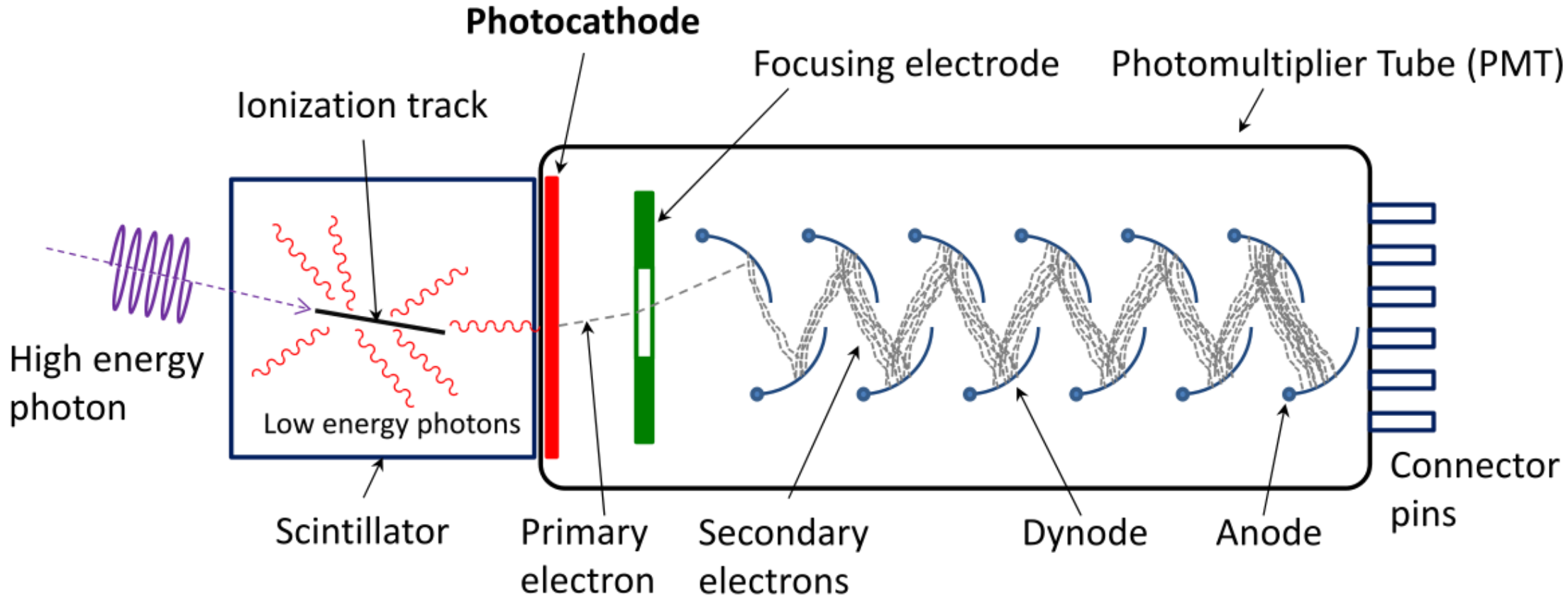


Common Scintillators Used

State	Examples	Application
Solid	ZnS	α particles
	Anthracene ($C_{14}H_{10}$), Stilbene ($C_{14}H_{12}$)	β particles
	NaI, CsI	γ radiation, X-rays
Liquid	Butyl PBD*, Naphthalene, p-Terphenyl (solvent: toluene)	β particles
Gas	Xenon	γ radiation

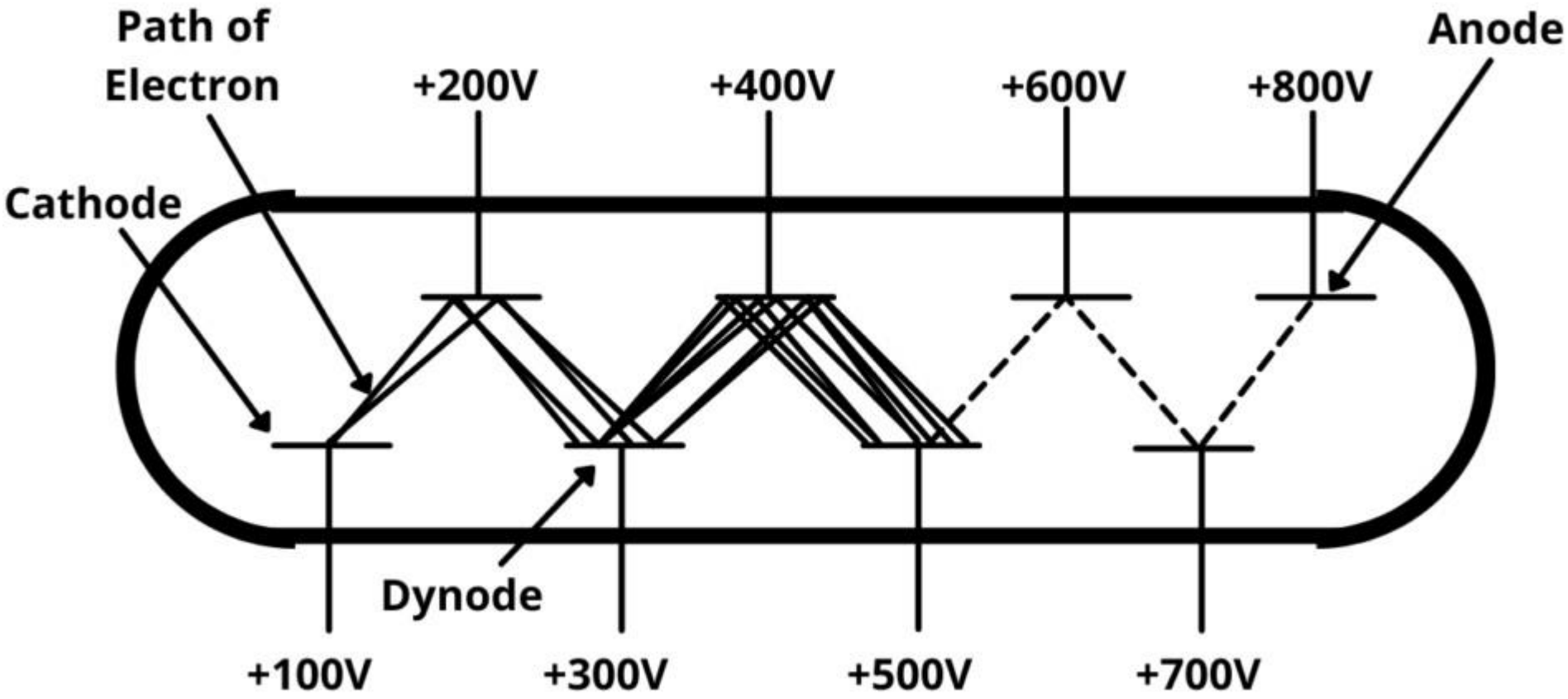
*2-[4-biphenylyl]-5-[4-tert-butylphenyl]-1,3,4-oxadiazole

Scintillators Tube



Photocathode: bialikali e.g. CsKSb

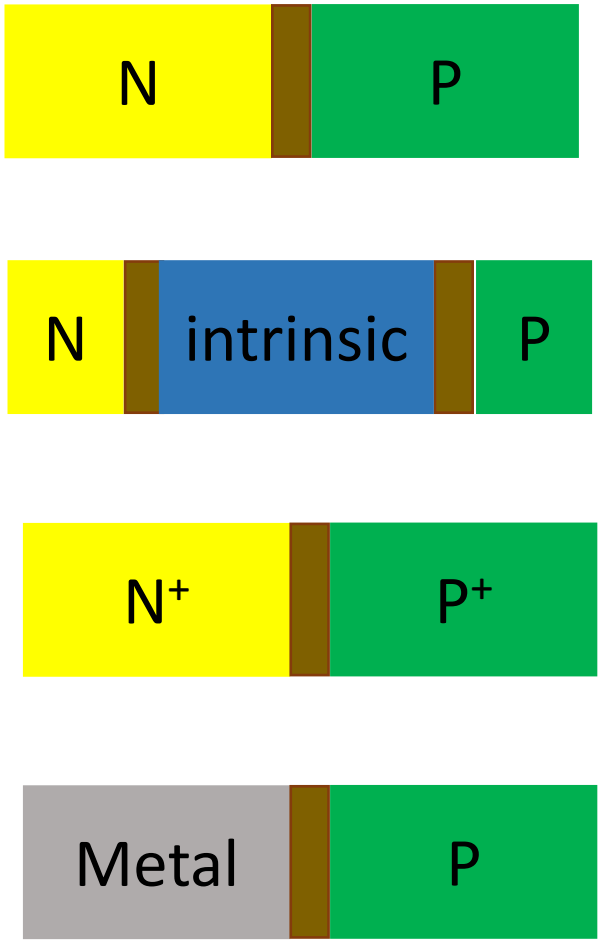
Photomultiplier Tube - Electrodes



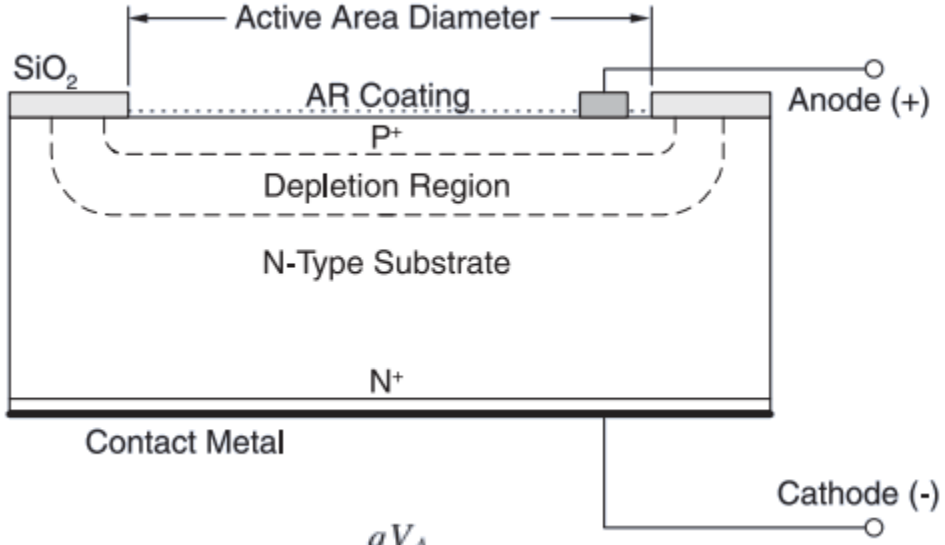
Dynode: Beryllium copper oxide

Photodiodes

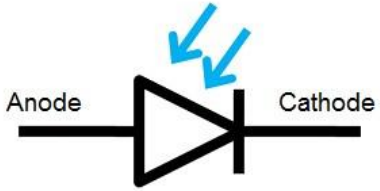
- Used for:
  - UV, visible and IR radiation
- Basic components:
  - P-N junction diode
  - Biasing and amplifier circuits
- Working principles:
  - Zero bias (photovoltaic mode)
    - Solar cell
  - Reverse bias (photoconductive mode)
    - PN Photodiode
    - PIN Photodiode
    - Avalanche Photodiode
    - Schottky Photodiode



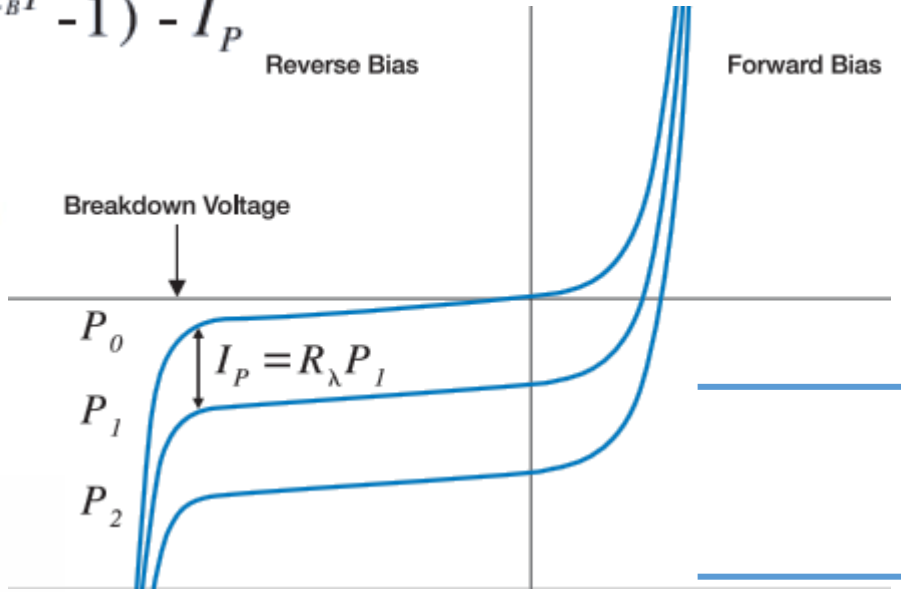
P-I-N Photodiodes

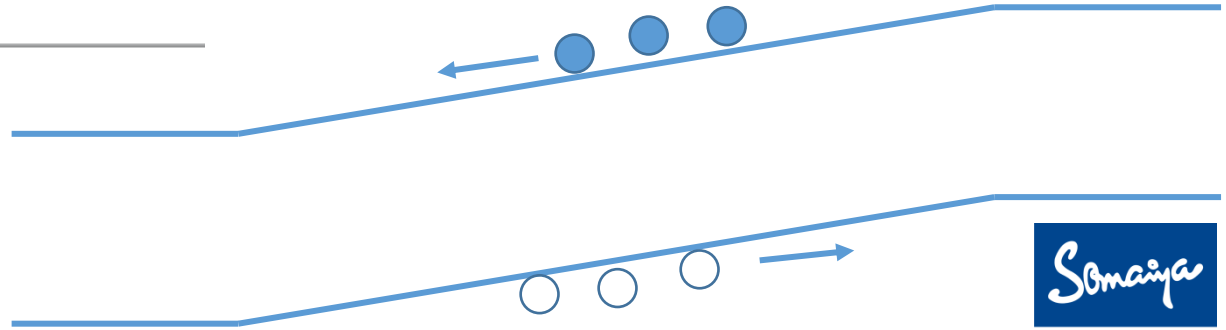


$$I_{TOTAL} = I_{SAT}\left(e^{\frac{qV_A}{k_BT}} - 1\right) - I_P$$



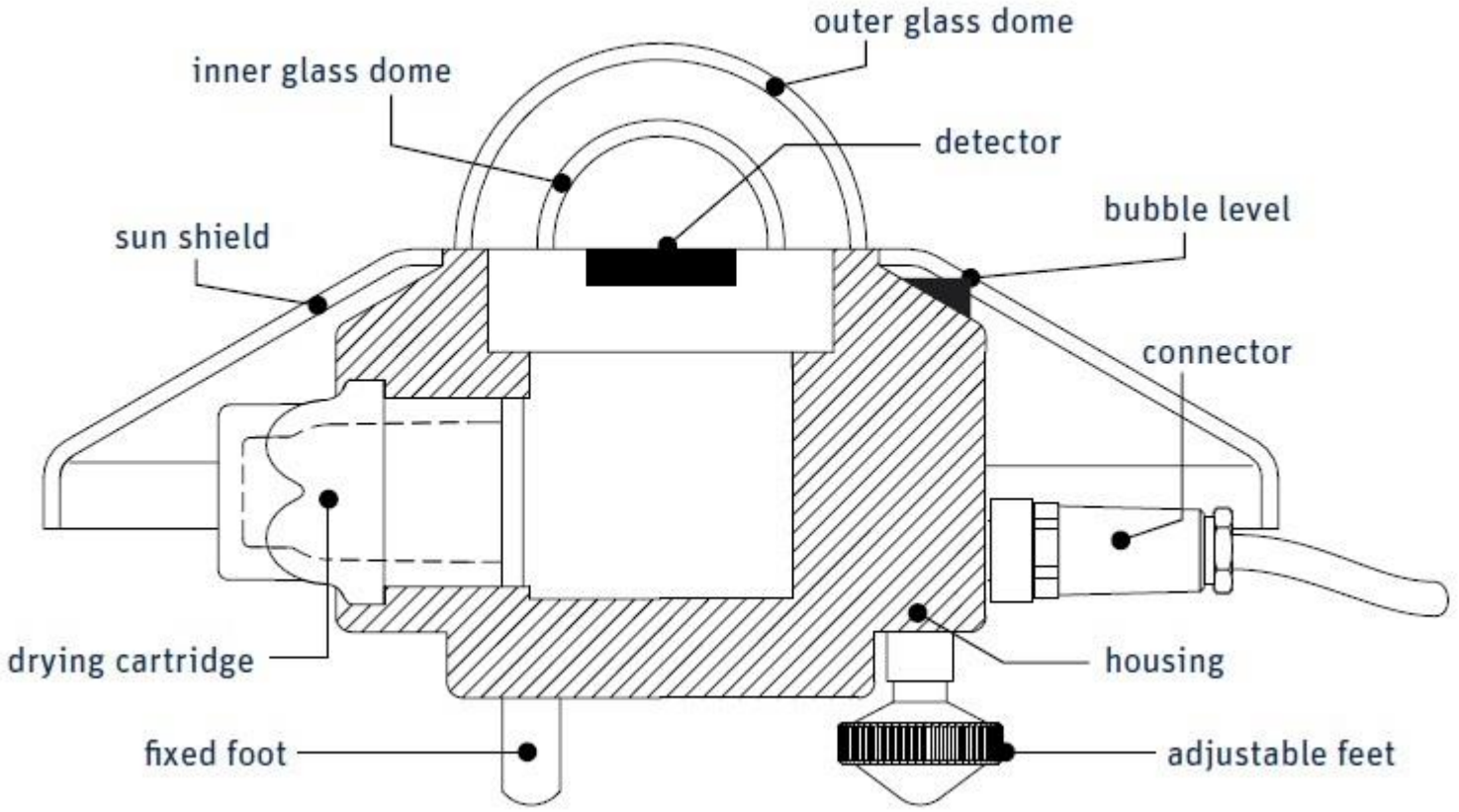
Photodiode symbol



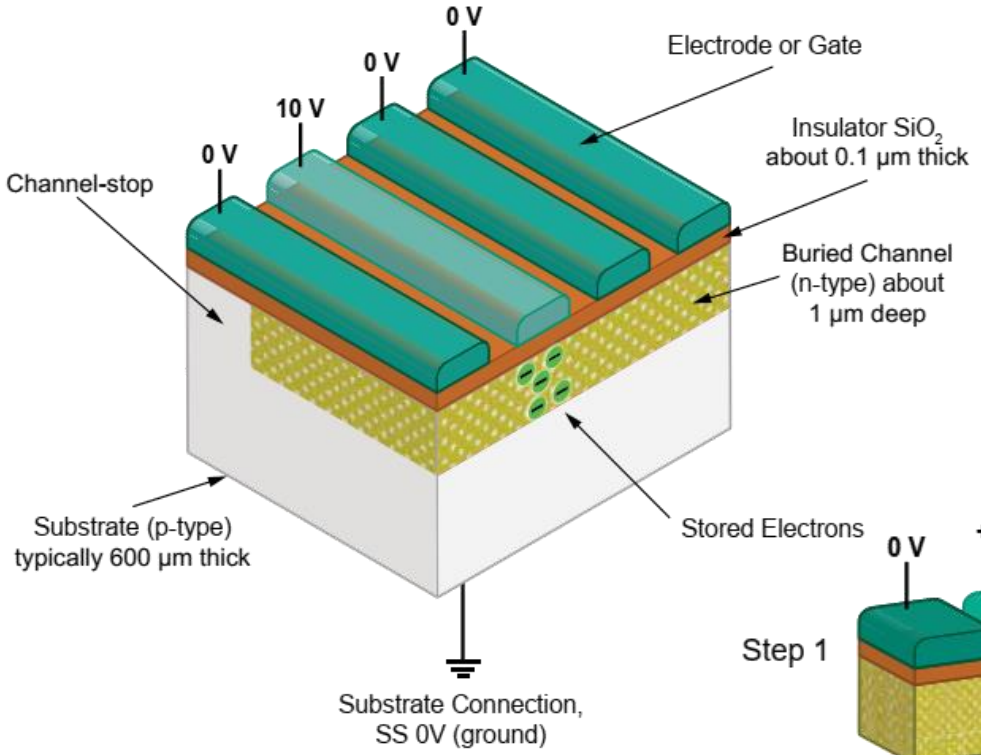


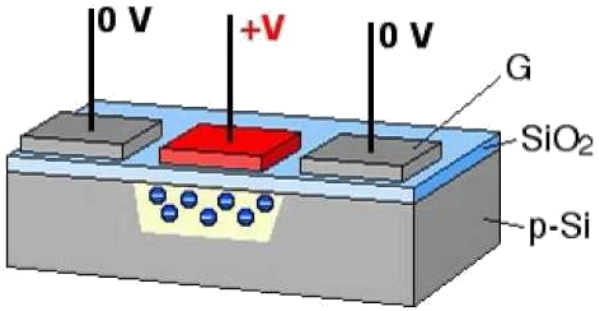
Pyranometer

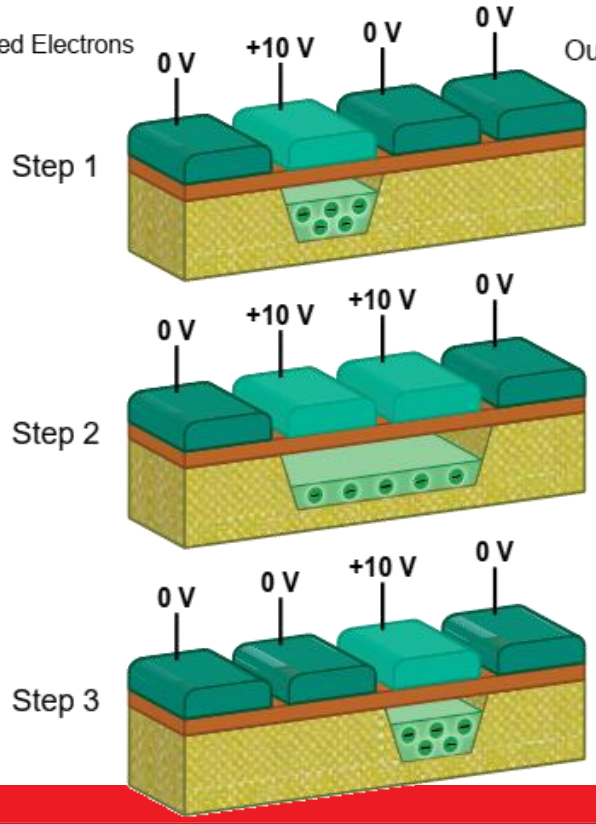
- Used for:
  - Solar radiation
- Basic components:
  - Thermopile
  - Environmental shield
  - electronics
- Working principles:
  - Thermo-emf
    - Cr-Al

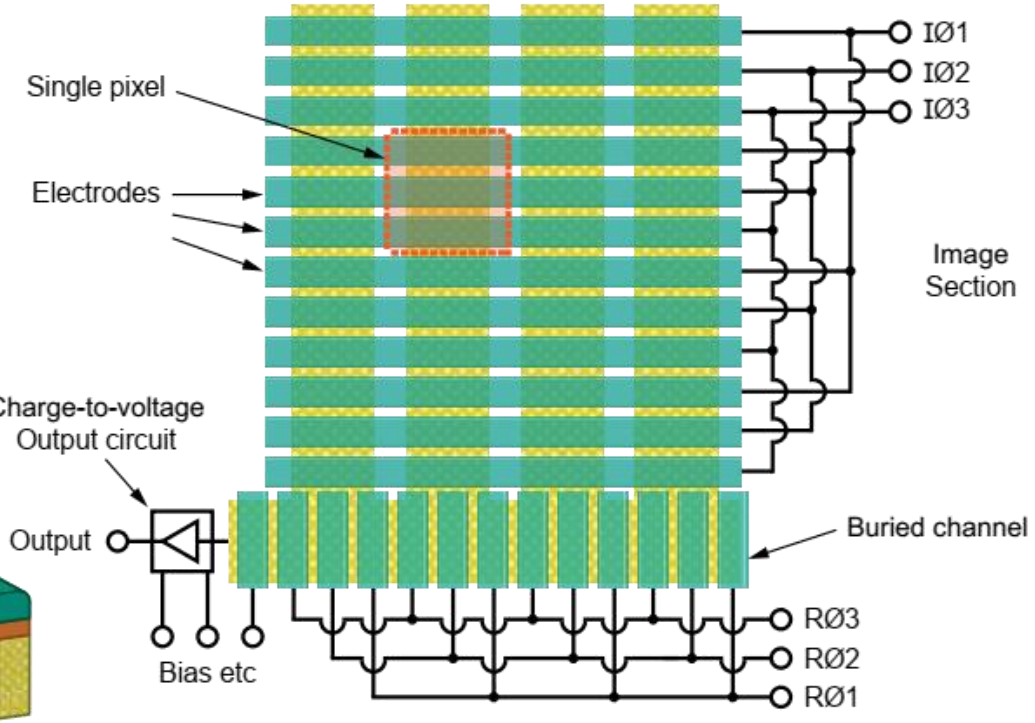


CCD









Reference: Teledyne Imaging

CCD Readout Sequence