Modeling the Transient Behavior of Semiconductor Radiation Detectors

Amaranath Premasiri
Dr.Gemunu Happawana (Advisor)

Why radiation detectors?

- Radiation is too small to be observed directly
- Originally developed for atomic, nuclear and elementary particle physics. Now radiation detectors are applied in areas of science, biomedical engineering and everyday life
- Progress in science is not only by development of theory and experiment but breakthrough in instrumentation

Types of Radiation

- Charged particle such as electrons, protons, atomic nuclei and many elementary particle
- Neutral particle such as neutrons and elementary particles
- Photons such as light, X-rays ad gamma rays

Type of Detectors

- Ionization chamber
- Proportional counter
- Geiger-Mueller counter
- Scintillation detector
- Semiconductor diode detector

Semiconductor Diode Detectors

- Good response
- High sensitivity

Disadvantage of Semiconductor Detectors

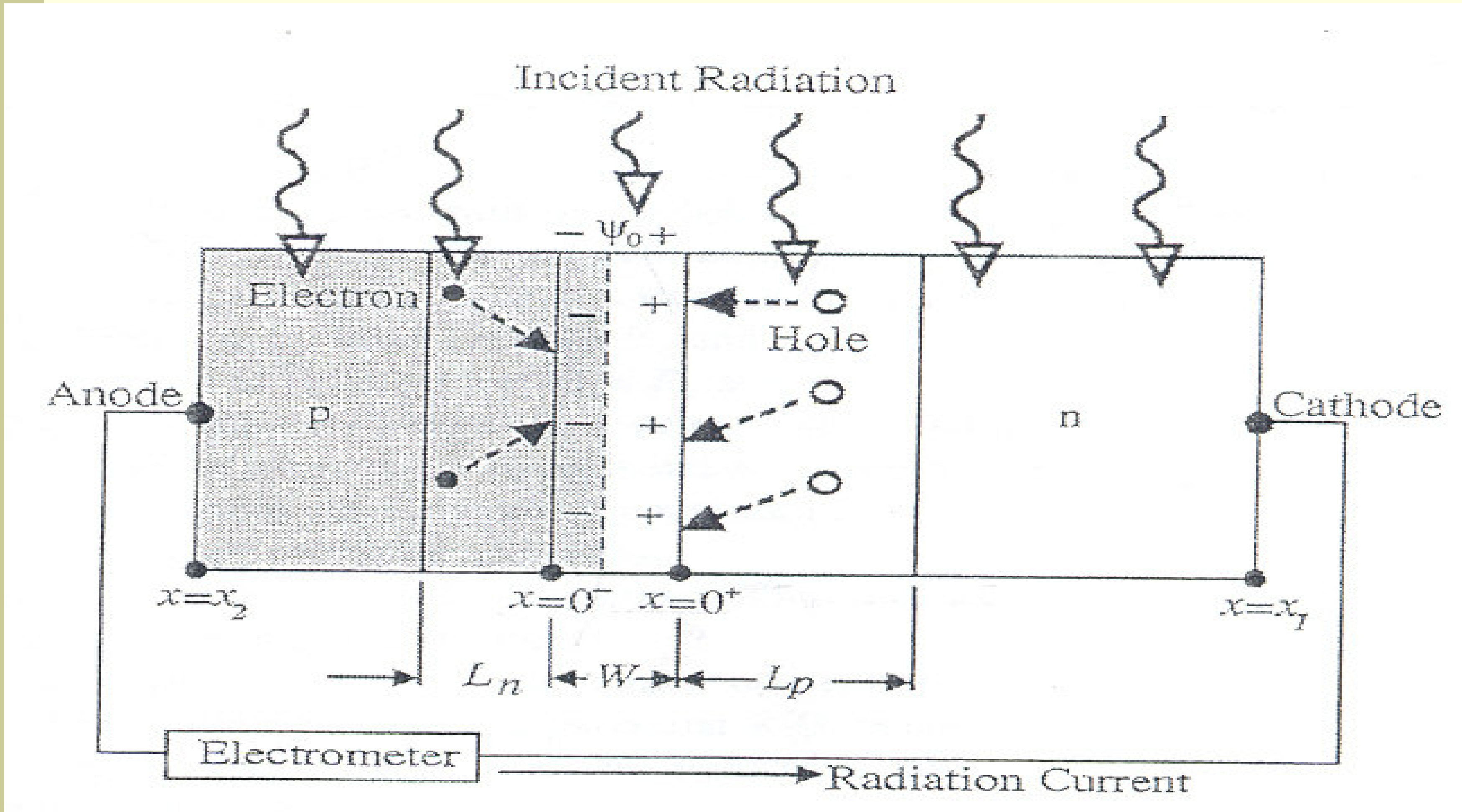
- Impurity act as a trap in addition too formation of depletion region and attract electron or hole that move in the crystalline material
- Difficult to keep the energy gap at desired level due to impurities

Advantage of Si Detectors

- Ease in use
- Real time measurement
- High reproducibility
- High sensitivity
- High spatial resolution

Limitation of *Si* Detectors

- Sensitivity degraded with the accumulated radiation dose
- Sensitivity depends on instantaneous dose rate



Schematic of a Si *pn* junction as a radiation detector

Modeling of *Si pn* junction diode

- The diode has one dimensional geometry
- The radiation intensities are not sufficient to course conductivity modulation
- The diode has negligible electric field and is uniformly doped except at the junction
- The voltage across the junction is constant

Diode current and sensitivity under radiation

- Continuity equation for carrier density

$$\frac{\partial \Delta p}{\partial t} = D_p \frac{\partial^2 \Delta p}{\partial x^2} - \frac{\Delta p}{\tau} + g_o r$$

- Current density and sensitivity for rectangular pulse beam

$$J_p = qGL_p \left\{ erf\left(\sqrt{\frac{t}{\tau}}\right) - erf\left(\sqrt{\frac{t-t_o}{\tau}}\right) - \right\}$$

$$S = Aqg_o L_p = a\sqrt{D_p \tau}$$

Limitation of the model

- The model and the expressions are for a single energy level
- Recombination life time is kept as a constant to solve the continuity equation
- Variation of carrier concentration is considered as one dimensional

Improvement to the Model

- Solving continuity equation for carrier concentration with nonlinear terms

$$\frac{\partial \Delta p}{\partial t} = D_p \frac{\partial^2 \Delta p}{\partial x^2} - \frac{\Delta p}{A + Bt} + g_0 (C + Dt)$$

Work in Progress

- Modeling the transient response for varying dose rate
- Analyze the carrier concentration for two dimensional space

Thanks