(MPM-202)
Optoelectronics and Optical Communication System

UNIT-II (Optical Sources and Detectors)

Lecture-6

by

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SYLLABUS

MPC-202 OPTOELECTRONICS AND OPTICAL COMMUNICATION SYSTEM Credits 4 (3-1-0)

UNIT I: Optical process in semiconductors

Optoelectronic properties of semiconductor: effect of temperature and pressure on bandgap, carrier scattering phenomena, conductance processes in semiconductor, bulk and surface recombination phenomena, optical properties of semiconductor, EHP formation and recombination, absorption in semiconductors, effect of electric field on absorption.

UNIT II: Optical sources and detectors

An overview of optical sources (Semiconductor Laser and LEDs), Optical Detectors: Type of photo detectors, characteristics of photo detectors, noise in photo detectors, photo transistors and photo conductors.

UNIT III: Optical fiber

Structure of optical wave guide, light propagation in optical fiber, ray and wave theory, modes of optical fiber, step and graded index fibers, transmission characteristics of optical fibers, signal degradation in optical fibers; attenuation, dispersion and pulse broadening in different types of optical fibres.

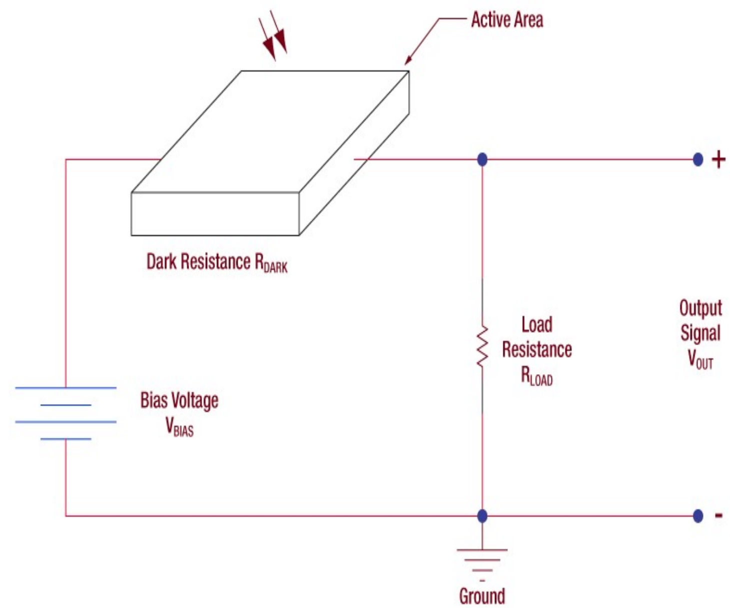
UNIT IV: Fiber components and optoelectronic modulation

Fiber components: Fibre alignments and joint loss, fiber splices, fiber connectors, optical fiber communication, components of an optical fiber communication system, modulation formats, digital and analog optical communication systems, analysis and performance of optical receivers, optoelectronic modulation.

Responsivity of Photoconductors

- If J is the current density through the photoconductor then J comprises of two components.
- One is the current density through the photoconductor when there is no photon flux i.e. J_{dark} and other is the current density when the photon flux incident i.e. J_{photo}.

$$J = J_{dark} + J_{photo} \qquad (1)$$



Responsivity of Photoconductors

$$\boldsymbol{J = \sigma\varepsilon} \qquad \text{where } \sigma \text{ is conductivity} \tag{2}$$

$$\boldsymbol{\sigma = \rho\mu} \qquad \text{where } \rho \text{ is charge density and } \mu \text{ is mobility} \tag{3}$$

$$\boldsymbol{\rho = ne} \qquad \text{where n is carrier concentration} \tag{4}$$

- If n_0 and p_0 are the dark carrier concentrations of electron and holes respectively i.e. at $\Phi = 0$ then we have

$$\boldsymbol{\sigma = (n_0\mu_e + p_0\mu_h)e} \tag{5}$$

$$\& \boldsymbol{J_{dark} = (n_0\mu_e + p_0\mu_h)e\varepsilon} \tag{6}$$

where ε *is applied electric field and e is the charge.*

Responsivity of Photoconductors

- Our interest is in to find the photo current i_p due to incident photon flux and then calculate what is responsivity.
- Simillarly if Δn and Δp is excess carrier concentration of electrons and holes respectively when photon flux Φ incident on the semiconductor and $\Delta n = \Delta p$.
- Then, the photo current density is given as (similar to dark current density)

$$\boldsymbol{J_{photo} = (\Delta n \mu_e + \Delta p \mu_h) e \varepsilon} \qquad (7)$$

$$\boldsymbol{J_{photo} = \Delta n (\mu_e + \mu_h) e \varepsilon} \qquad (8)$$

Responsivity of Photoconductors

- If R is the rate of generation of excess carriers per unit volume(**wA i.e. w is width and A is area)** .Then

$$\boldsymbol{R = \frac{\eta \Phi}{wA}} \qquad \textbf{(9)}$$

- In earlier lectures on recombination we have studied rate of recombination of excess carriers is given by

$$\boldsymbol{R = \frac{\Delta n}{\tau}} \qquad \textbf{(10)}$$

where $\boldsymbol{\tau}$ is excess carrier recombination time

Responsivity of Photoconductors

- From eq. (9) and (10) we can write

$$\boldsymbol{\Delta n = \frac{\eta \Phi \tau}{wA}} \quad \textbf{(11)}$$

- Thus from equation (8) and (11), we have

$$\boldsymbol{J_{photo} = \frac{\eta \Phi \tau e}{wA}(\mu_e + \mu_h)\varepsilon} \quad \textbf{(12)}$$

- Since $i_p = J_{photo}.A$ therefore,

$$\boldsymbol{i_p = \frac{\eta \Phi \tau e}{w}(\mu_e + \mu_h)\varepsilon} \quad \textbf{(13)}$$

- Also $v_e = \mu_e \varepsilon$ and $v_h = \mu_h \varepsilon$ thus

Responsivity of Photoconductors

$$\boxed{i_p = \frac{\eta\Phi\tau e}{w}(v_e + v_h)} \qquad (14)$$

- $\frac{w}{v_e}$ is transit time of electrons and $\frac{w}{v_h}$ is transit time of holes. Thus,

$$i_p = \eta\Phi\tau e\left(\frac{1}{t_e} + \frac{1}{t_h}\right) \qquad (15)$$

- **Since $\Phi = \frac{P_{opt}}{h\nu} = \frac{P_{opt}}{hc}\lambda$**

$$i_p = \eta\tau\frac{P_{opt}}{\left(hc/_e\right)}\lambda\left(\frac{1}{t_e} + \frac{1}{t_h}\right)$$

if c and λ are in micrometer then (hc/e)=1.24

Responsivity of Photoconductors

- Then,

$$i_p = \eta\tau \frac{P_{opt}}{\left({hc}/{e}\right)} \lambda \underbrace{\left(\frac{1}{t_e} + \frac{1}{t_h}\right)}_{\left(\frac{1}{t}\right)}$$

- Thus we have expression for photocurrent ,

$$\boxed{i_p = \eta\left(\frac{\tau}{t}\right)\frac{\lambda}{1.24} P_{opt}} \qquad (16)$$

Responsivity of Photoconductors

- Thus the responsivity of a photoconductor is given by-

$$\Re = \frac{i_p}{P_{opt}}$$

$$\Rightarrow \boxed{\Re = \frac{i_p}{P_{opt}} = \eta\left(\frac{\tau}{t}\right)\frac{\lambda}{1.24}\ \text{A/watt}} \qquad \textbf{(17)}$$

This gives the responsivity of a photoconductor.

- τ may be in few picosecond $(10^{-12}s)$ to few milisecond $(10^{-3}s)$ depending on material.

Gain in Photoconductors

- In general mobility of electron is much grater than hole mobility thus the velocity of electron is larger than that of hole thus

$$\frac{1}{t} \approx \frac{1}{t_e}$$

- And $\boldsymbol{t_e} = \frac{w}{v_e} = \frac{1\,mm}{10^7\,cm/s} = 10^{-8} sec$
- If responsivity is greater than 1 than we have **gain.**
- $\textbf{Gain}\ \left(\frac{\tau}{t}\right) = \left(\frac{10^{-12}s - 10^{-3}s}{10^{-8}s}\right) = \mathbf{10^{-4} - 10^{5}}$ **(18)**

Gain in Photoconductors

- Thus in photoconductors gain is very high thus gain is large.
- If one photon incidents on the material it generates one electron-hole pair. The electron and hole either recombine or if **they have larger recombination time,** they will move towards contacts. As the electron starts moving faster than hole it is collected by the contact very soon while hole is still in the way. Then to maintain charge neutrality electron is injected by the contact up to the time when hole is also collected by the electrode.
- So for one hole many electrons are transited which causes a constant current for a longer period in the external circuit.

Application of Photodetectors

❖ Photodetectors are essential elements applied in-

- Video imaging
- Optical communications
- Biomedical imaging
- Security
- Night-vision
- Gas sensing
- Motion detection
- It possess the ability to transform light into electrical signals precisely.


THANK YOU