LECTURE 9

- Diode summary
- photovoltaic effect
- the Sun as a resource
- absorption of photons
- generation of electron-hole pairs
Practical np-junction diodes and our model

Discrete diode: 200V, 70A

IC diode: 1V, 1mA

np diode with ohmic contact to p-region

Our 1-D model
Sec. 6.6

**Bipolar conduction**

What is going on here?
Diode calculations

Sec. 6.6

Pick a region, e.g., p-QNR for n and $J_e$

General solution:

$$n(x) - n_{0p} = A e^{x/L_e} + B e^{-x/L_e}$$

Boundary conditions:

$$n(x_p) \equiv n(\infty) = n_{0p} \quad \text{if contact is?}$$

$$n(x_{dp}) = n_{0p} e^{-V_a/V_{th}}$$
We need to consider:

1. Energy source
2. Absorption
3. Transport
4. Collection
PV: large and small

12 MW Arnstein, Germany
90 MW Sarnia, Ontario
5kW Boston, Massachusetts
http://256.com/solar/
Sec. 7.1

The sun as a resource

- Value for $H_{\text{sun}}$?
- How is the energy generated?
- Value for $H_0$?
- How much is lost in the atmosphere?
- What is Air Mass?
Sec. 7.1

Irradiance standards

ASTM G173-03 Reference Spectra

What are the scatterers and absorbers?

Ref. 7.1
Absorption

Sec. 7.2

TEM plane wave

\[ \mathcal{E}_y(x) = \mathcal{E}_0 e^{ikx} \]

Refractive index

\[ k = \frac{\omega}{c/n^*} = \frac{T(n_r + ik_r)}{c} \equiv \frac{2\pi(n_r + ik_r)}{\lambda} \]

\[ \mathcal{E}_y(x) = \mathcal{E}_0 e^{i2\pi n_r x/\lambda} e^{-2\pi k_r x/\lambda} \]

What's this?

\[ \vec{S} = \vec{E} \times \vec{H} \]

What characterizes the attenuation?

\[ S_x = \mathcal{E}_y H_z = \sqrt{\frac{\varepsilon}{\mu}} |\mathcal{E}_y|^2 = \sqrt{\frac{\varepsilon}{\mu}} \mathcal{E}_y(x) \mathcal{E}_y^*(x) = \sqrt{\frac{\varepsilon}{\mu}} \mathcal{E}_0^2 e^{-\alpha x} \]

What's this?

\[ \alpha = \]
Consider materials with indirect and direct bandgaps.

Which material is likely to have the higher absorption coefficient?
What is the cut-off energy?

Which of these materials has a direct bandgap?
Derivation of Generation rate

Let $p$ be photon density $P$ photons/m$^3$s
Let $J_h$ be photon flux $F$ photons/m$^2$s
Let $U$ be generation of EHPs $G_{op}$ EHPs/m$^3$s

Write down the photon balance equation

\[ \frac{\partial P(\lambda)}{\partial t} + \nabla \cdot J = 0 \]

Express $F$ in terms of $S$

Define $\Phi_0 = \ldots$

Solve for $G_{op}$

$G_{op}(\lambda) = \ldots$
Sec. 7.2

The generation rate

\[ G_{op}(\lambda) = \alpha(\lambda) \Phi_0(\lambda) e^{-\alpha x} \]

How does this curve help in the design of the solar cell?
Basic design issues resulting from $G_{op}(x)$

- How deep should the junction be?
- Should the emitter be lightly or heavily doped?
- Should the emitter be $n$- or $p$-type?
- Should the base be thick or thin?
- Should the base be $n$- or $p$-type?