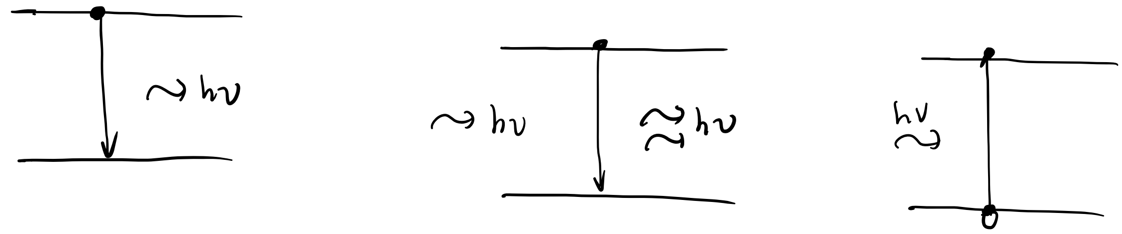
# Lecture 19. Photodetection.

Learning objectives:

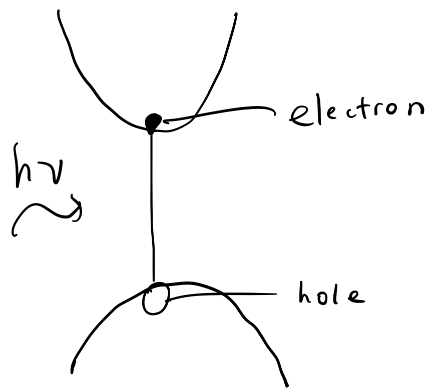
1. Review of PN junction
2. PIN photodiode

## Recap:

Spontan. emission | Stimulated emission. | Absorption



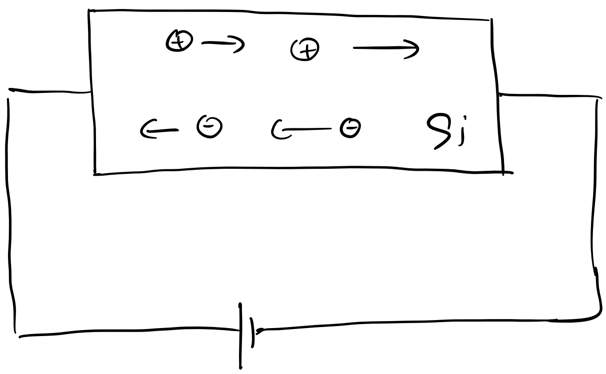

In semiconductors:

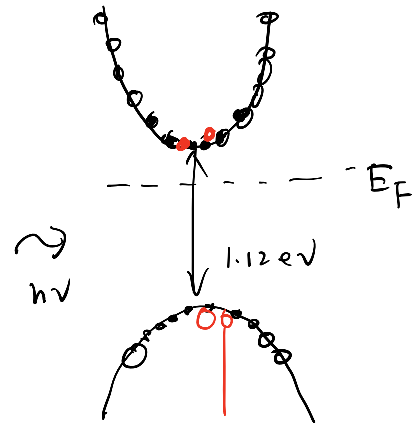



Problem to study: how to harness the generated $e^-$. $h^+$ pairs to dectect photons?

Let's assume you just have a chunck of semiconductor, i.e. Silicon

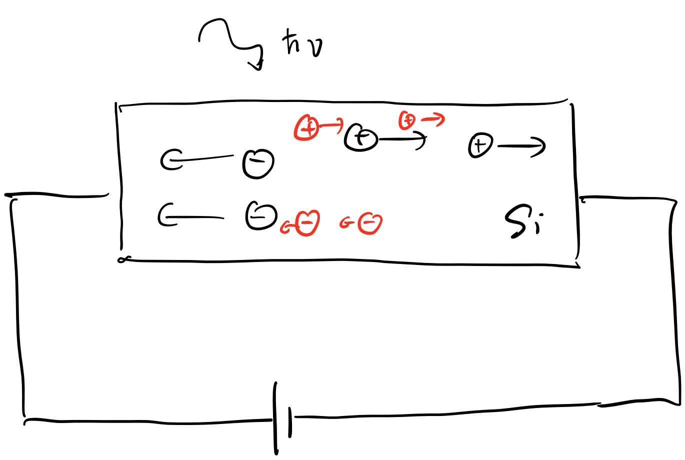
Dark.

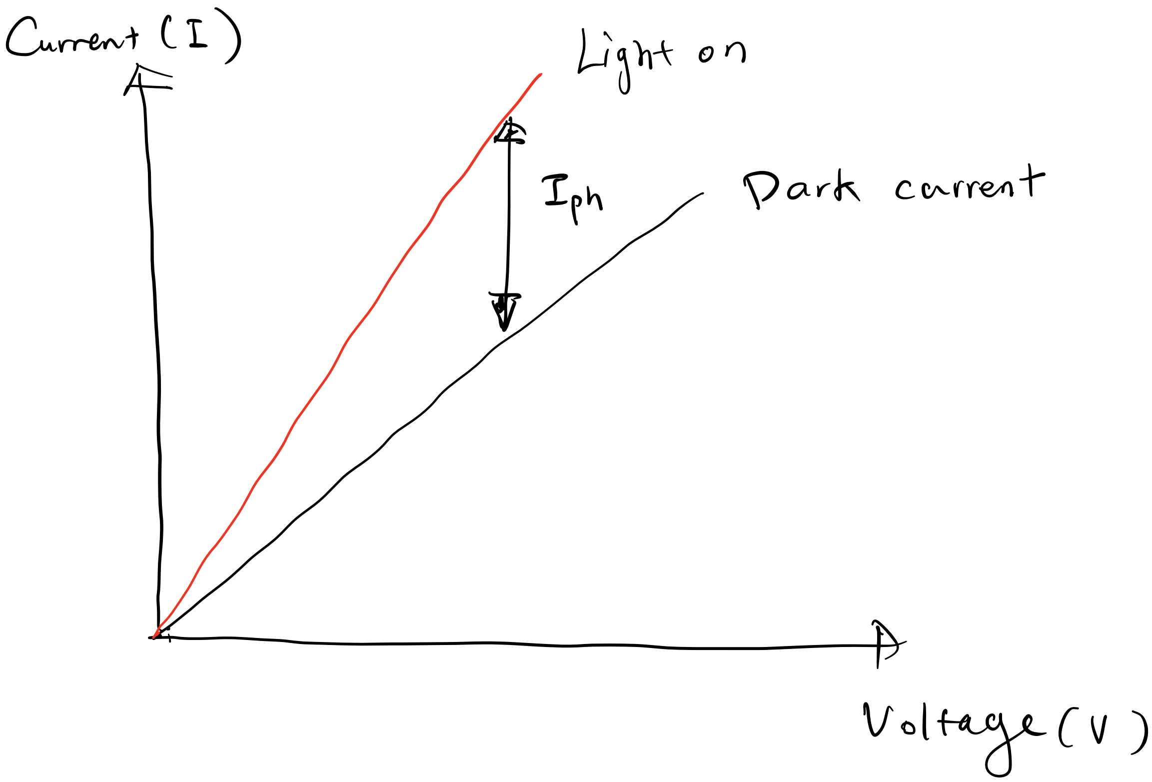



(n-type)

Light on






Photocurrent:

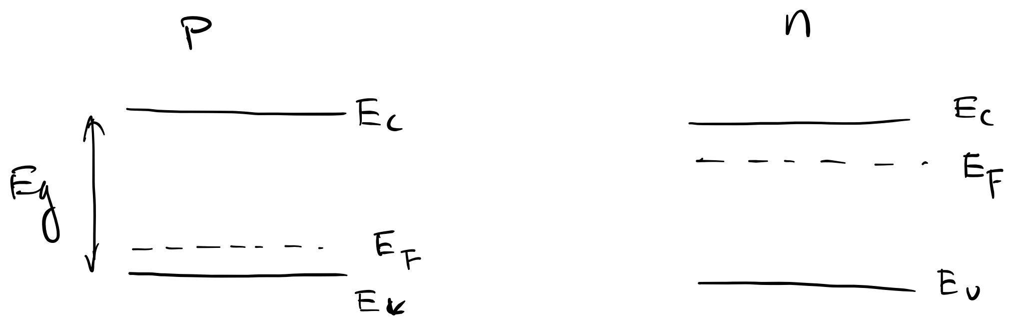
$$I_{ph} = I_{light\text{-}on} - I_{dark}$$

Q: Why don't we use this configuration for photodetection?

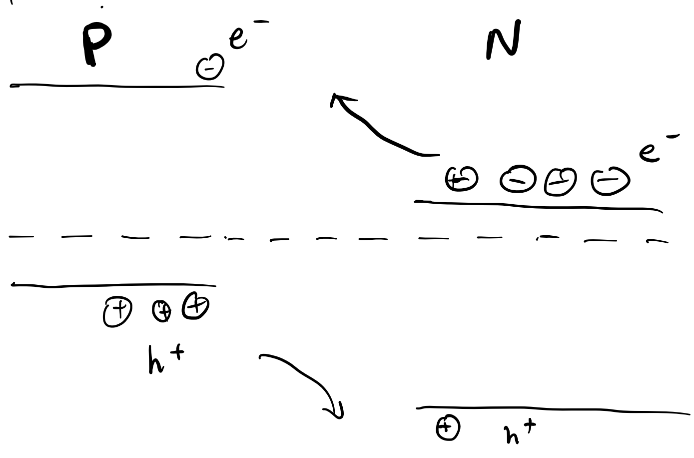
A: Too much background (dark current)

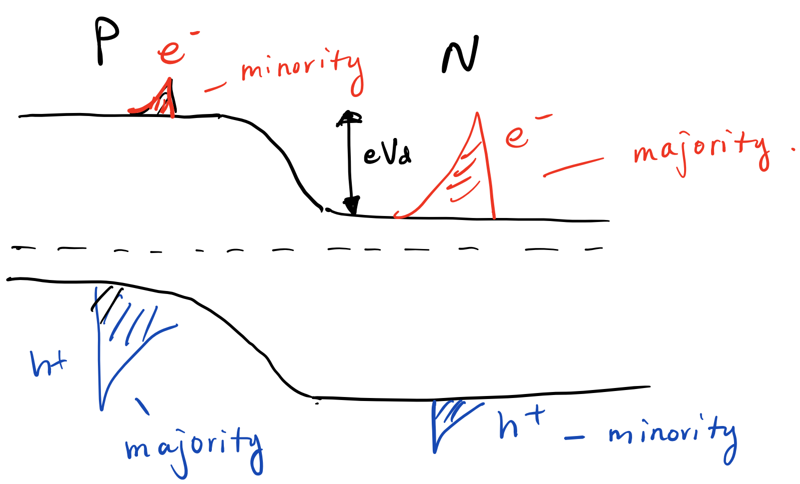
1. P·N Junction

① Before material contact:

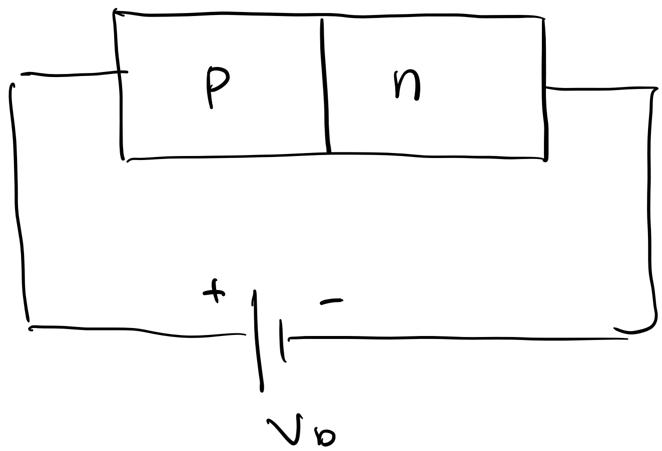


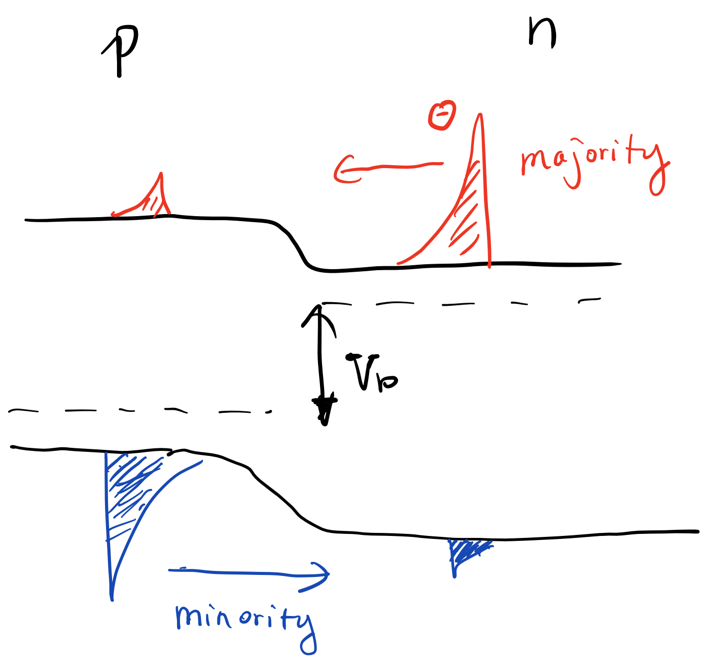

② After contact:



## ③ Forward Bias

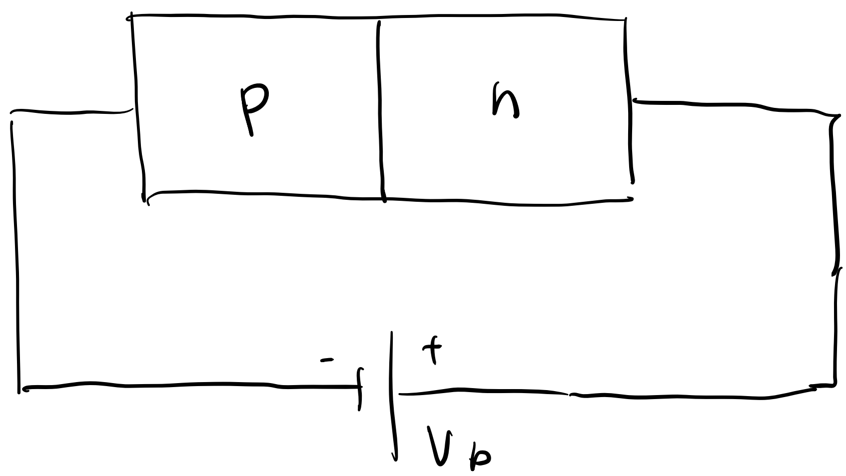


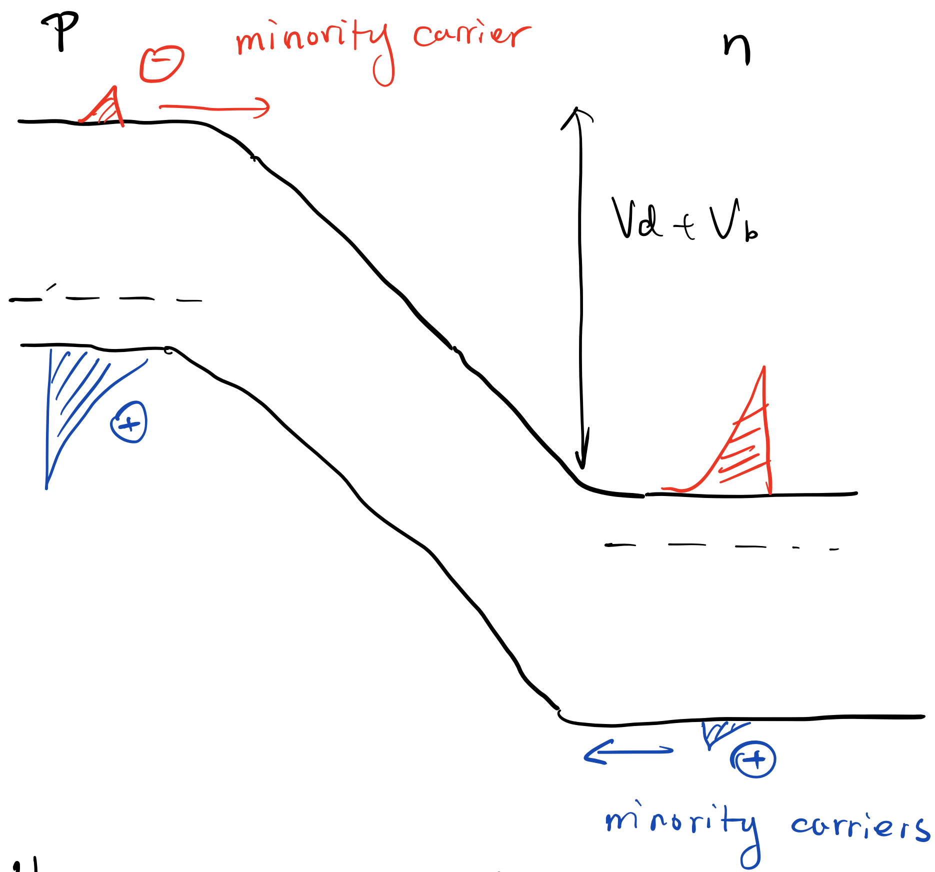




When forward biased, there's large current flow.

due to the drift of "majority carriers"

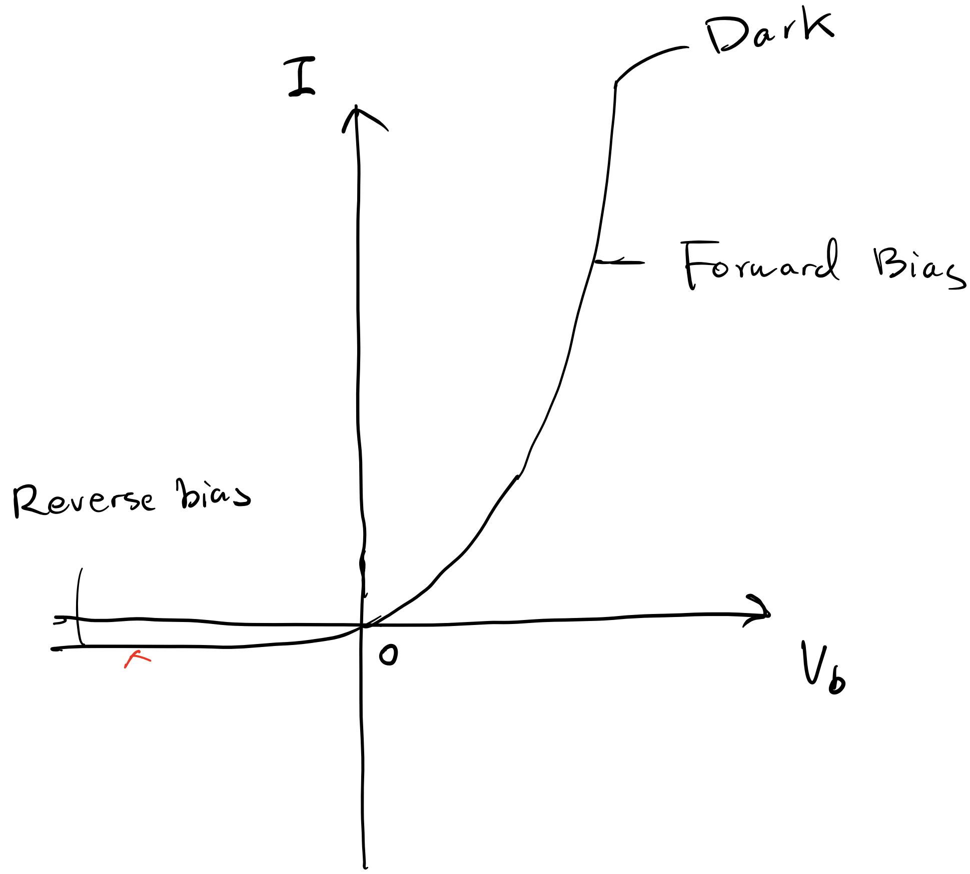
## ④ Reverse bias





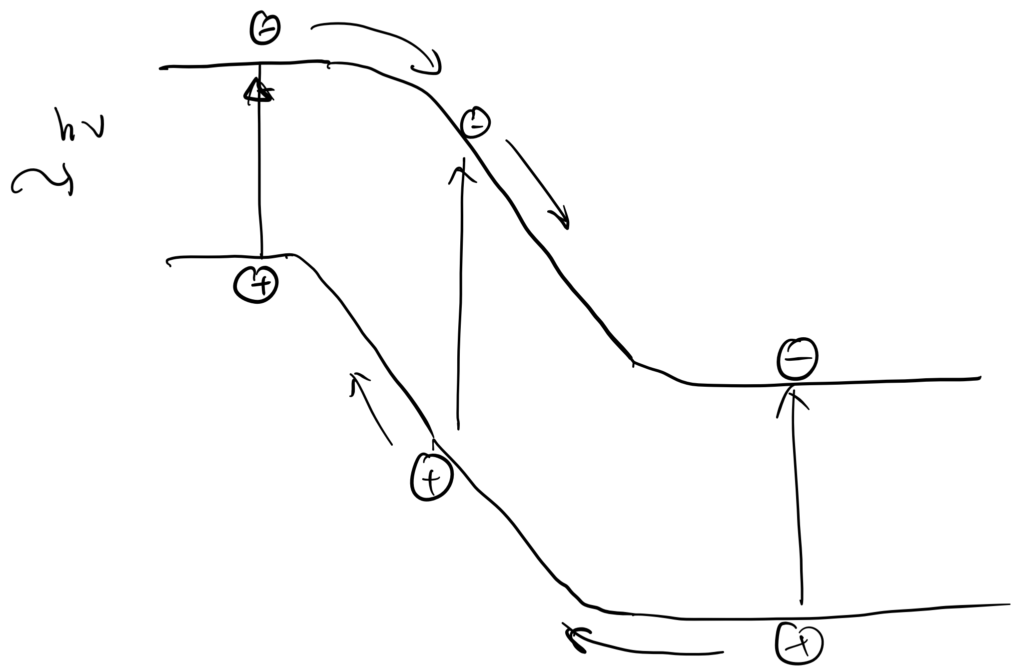

When reverse biased, there's small current flow due to the drift of minority carriers.

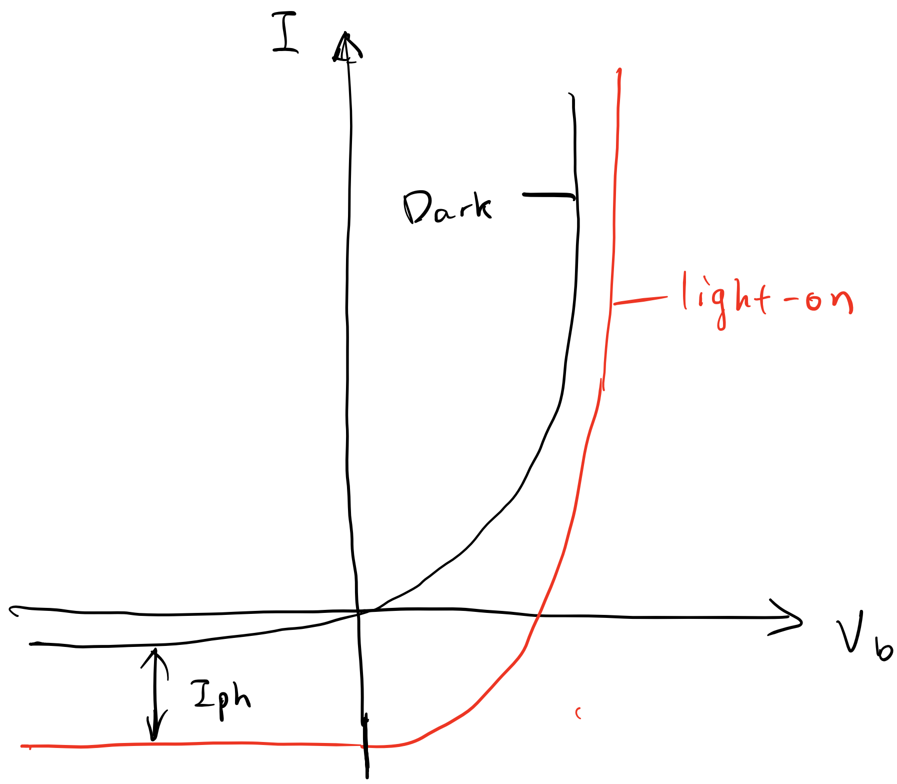
# Current-voltage (I-V characteristic)




Dark current: $I = I_0\left(e^{\frac{qV_b}{k_B T}} - 1\right)$

Turn on the light.



Total current:

$$I = I_0\left(e^{\frac{qV}{K_BT}} - 1\right) + I_{ph}$$

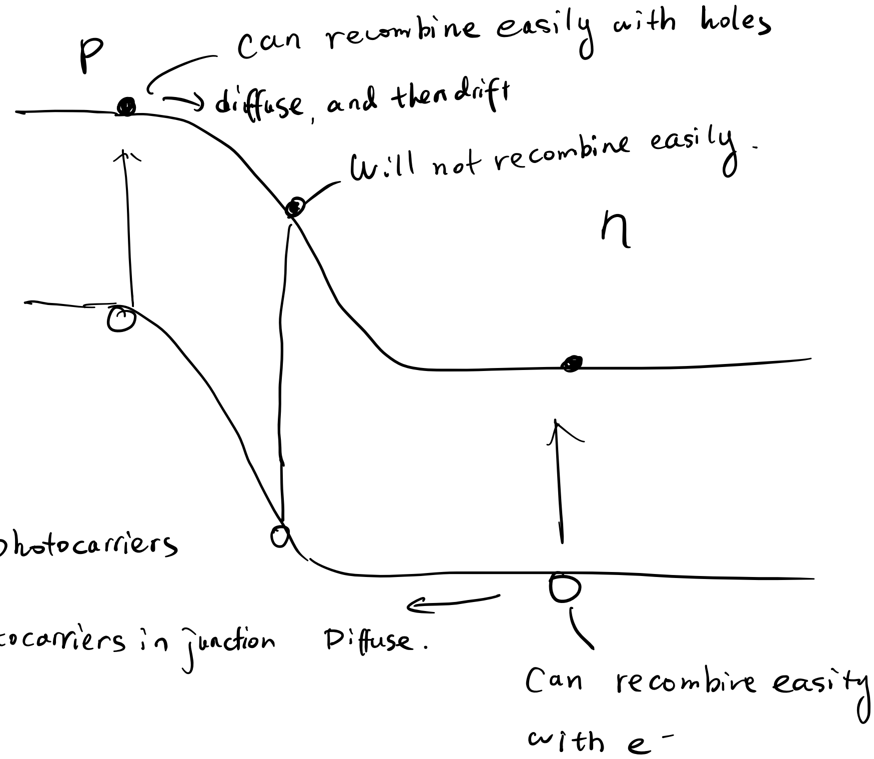
quantum efficiency ($\eta$).

$$I_{ph} = \frac{\eta q}{\omega} P_{opt}.$$

$\omega$: freq. of light

$P_{opt}$: incident optical power

# 2. PIN Junction diode




Photocurrent:

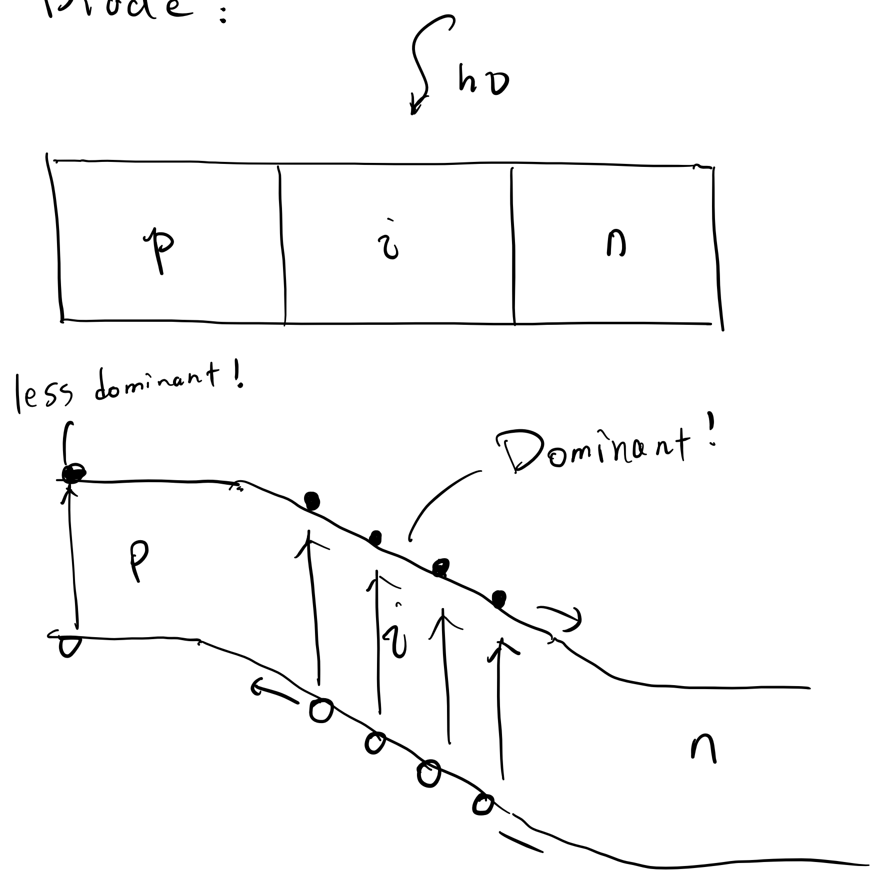
- Diffuse of photocarriers
- Drift of photocarriers in junction

## Problem of P-N Junction for photodetection:

① Generated e-h pairs in p and n regions (minority photocarriers) can easily recombine with majority carriers in these regions.

② Finite diffusing time of generated photocarriers in p and n regions will delay the current response.

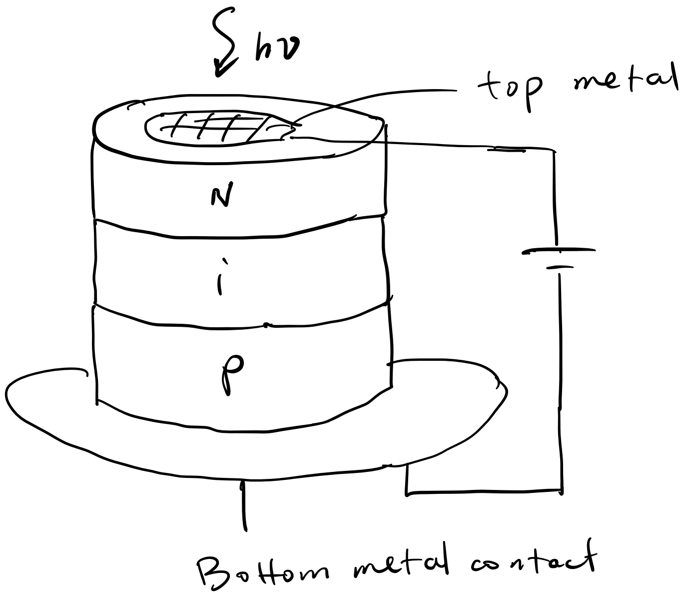
PIN Diode :




Key idea : make the drift of photocarriers dominant !

Advantages : ① higher responsivity (A/W)

② higher response speed .



hν
top metal
N
i
P
Bottom metal contact