Silicon Photoreceptors

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Silicon Photoreceptors – Levels of Abstraction

Model Equations

\[ I_D = I_{SAT} \left( e^{\frac{qV_A}{k_B T}} - 1 \right) \]

\[ V_{oc} = N \times V_t \ln \left( \frac{I_{photo}}{I_{dark}} + 1 \right) \]

MATHEMATICAL

PHYSICAL

Current – Voltage Characteristics

SEM picture

Layout
How do we see?
Silicon material: a solid-state physics primer

$\text{Bandgap}$

$$P(E) \propto e^{\frac{E_c - E_v}{kT}}$$

Energy: $h\nu = \frac{hc}{\lambda} = 1.24 / \lambda(\text{m}) \text{ in eV}$

$hv = E_g = 1.1\text{eV for Si}$
From photons to electrons: the physics of phototransduction

Green: 550 nm ~ 2.5 eV
Red: 700-800 nm ~ 1.7 eV
GaAs LEDs: 860nm ~ 1.3eV
PN junction under Illumination

Carriers “Go home”

Junction is forward biased by the light
Photodiode Models
PN Junction in CMOS: your ideas?
PN junctions in CMOS (I)

n-well / p-sub diode

n-well / p-diff diode

n-diff / p-sub diode
PN junctions in CMOS (II)

p-diff / n-well / p-sub bipolar

photogate
Photons, current, shot-noise ..
How about optics? Ommatidia in compound eyes

Optics structures on Silicon

- Microlens layer
- Color filter layer
- Metal opaque layer
- Photodiode
- Silicon substrate

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