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#2 Steady-State Fotokonduktif

# Elektronika Organik

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# Kerangka materi

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- **Tujuan:**

Memberikan pemahaman tentang mekanisme efek fotokonduktif dalam bahan organik.



**mekanisme pergerakan elektron bebas dan hole, bahan fotokonduktor organik untuk aplikasi optoelektronika**

## Pertanyaan Dasar

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Bagaimana cara merubah cahaya  
menjadi aplikasi elektronik?

### Keajaiban “Elektron”



# Fotokonduktif

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## Konsep Dasar Fotokonduktif:

- ❑ Fenomena optis dan elektris dalam material semikonduktor yg mempengaruhi daya hantar listrik.
- ❑ Pengaruh konduktivitas yang diakibatkan oleh **penyerapan gelombang elektromagnetik**.
- ❑ Paparan cahaya mengenai material semikonduktor sehingga menyebabkan pertukaran elektron-hole.
- ❑ Energi foton memicu pergerakan elektron bebas dalam Diagram Tingkat Energi [*valence band – conduction band*].



# Cahaya ~ sumber energi bebas tak terbatas

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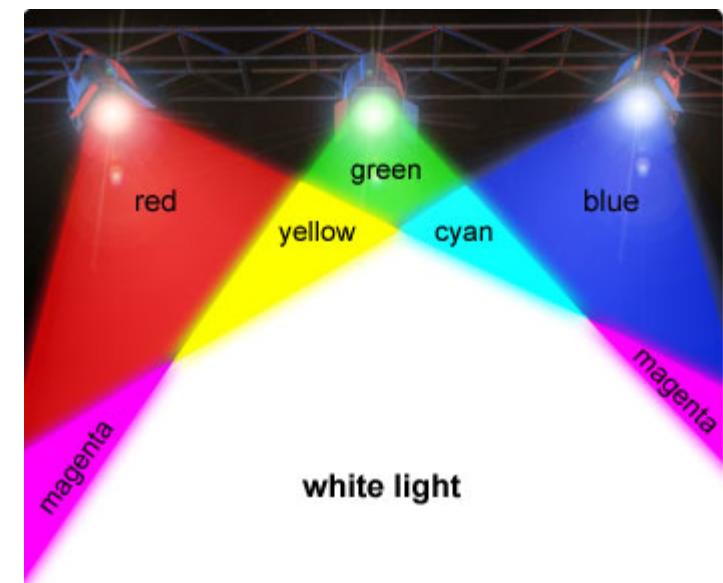
- Cahaya memiliki sifat dualisme

- Gelombang elektromagnetik (Teori Maxwell) dengan  $\lambda$  tertentu
  - Kecepatan propagasi c
  - Gelombang radio, Microwave, IR, Visible, UV, X-Ray,  $\gamma$ -Ray
- Paket energi, foton atau partikel (teori Planck & Einstein)

$$E = \frac{hc}{\lambda_o} = \frac{1240 \text{ eV} \cdot \text{nm}}{\lambda_o}$$

- Sifat-sifat cahaya

- Propagasi
- Polarisasi
- Interferensi
- Difraksi
- Radiasi



## Sifat-sifat Cahaya

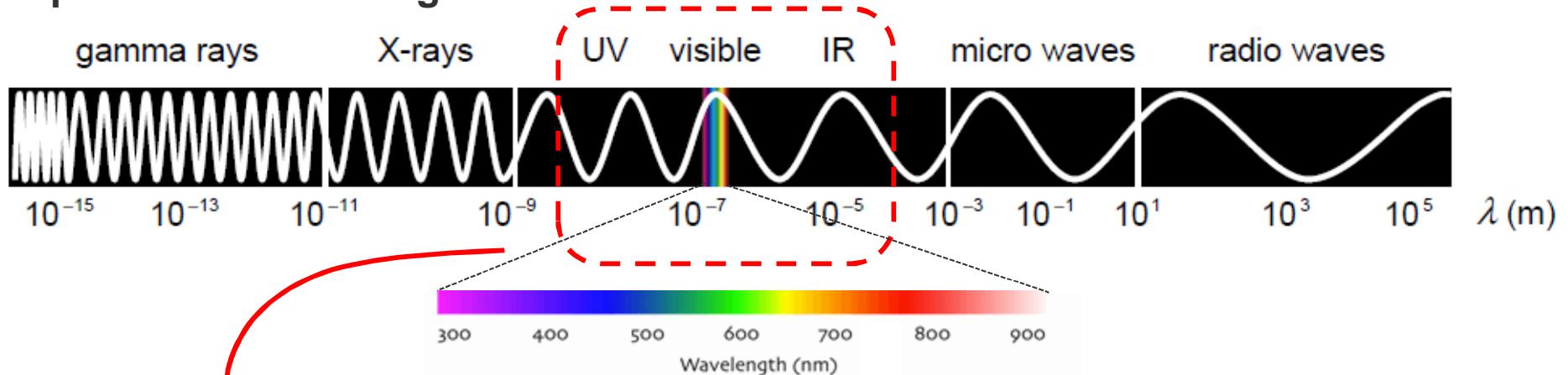
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Warna	$\lambda_o$ (nm)	f (Hz)	$E_{\text{foton}}$ (eV)
red	630-760	$\sim 4.5 \times 10^{14}$	$\sim 1.9$
orange	590-630	$\sim 4.9 \times 10^{14}$	$\sim 2.0$
yellow	560-590	$\sim 5.2 \times 10^{14}$	$\sim 2.15$
green	500-560	$\sim 5.7 \times 10^{14}$	$\sim 2.35$
blue	450-500	$\sim 6.3 \times 10^{14}$	$\sim 2.6$
violet	380-450	$\sim 7.1 \times 10^{14}$	$\sim 2.9$

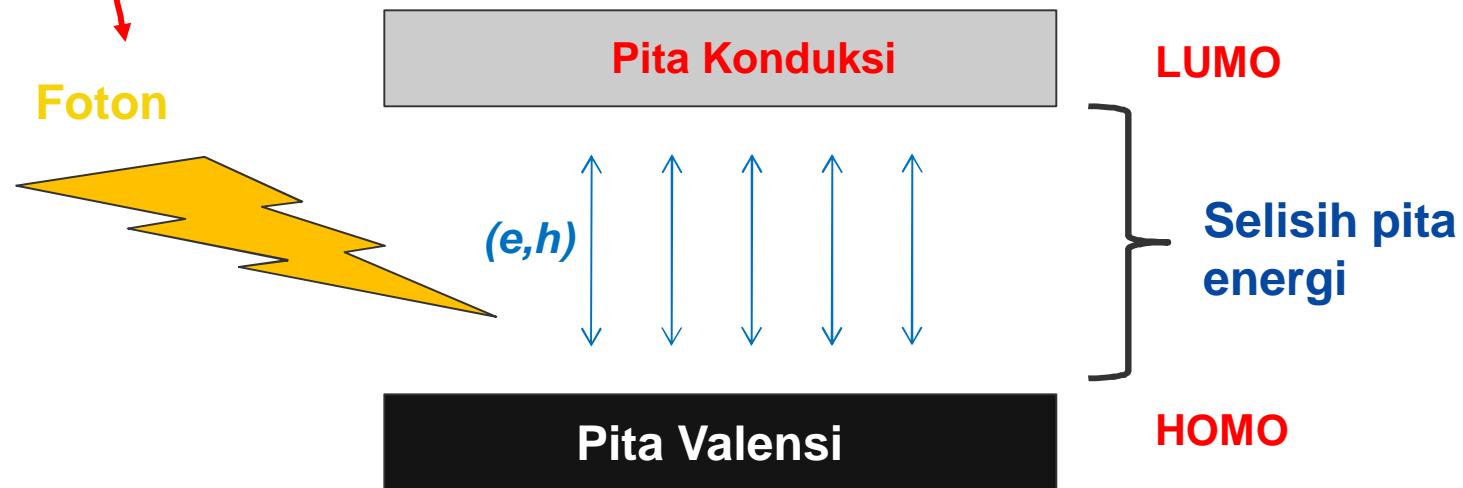
- ⊕ Cahaya dengan panjang gelombang  $\lambda_o < 400$  nm disebut **ultraviolet (UV)**.
- ⊕ Cahaya dengan panjang gelombang  $\lambda_o > 700$  nm disebut **infrared (IR)**.
- ⊕ Cahaya tersebut tidak dapat kita lihat langsung, namun bisa dirasakan dengan cara mendekati efek panasnya (IR) dan dampak yang terlihat pada penderita kebakaran kulit karena UV.

# Efek Fotokonduktif

## Spektrum Elektromagnetik

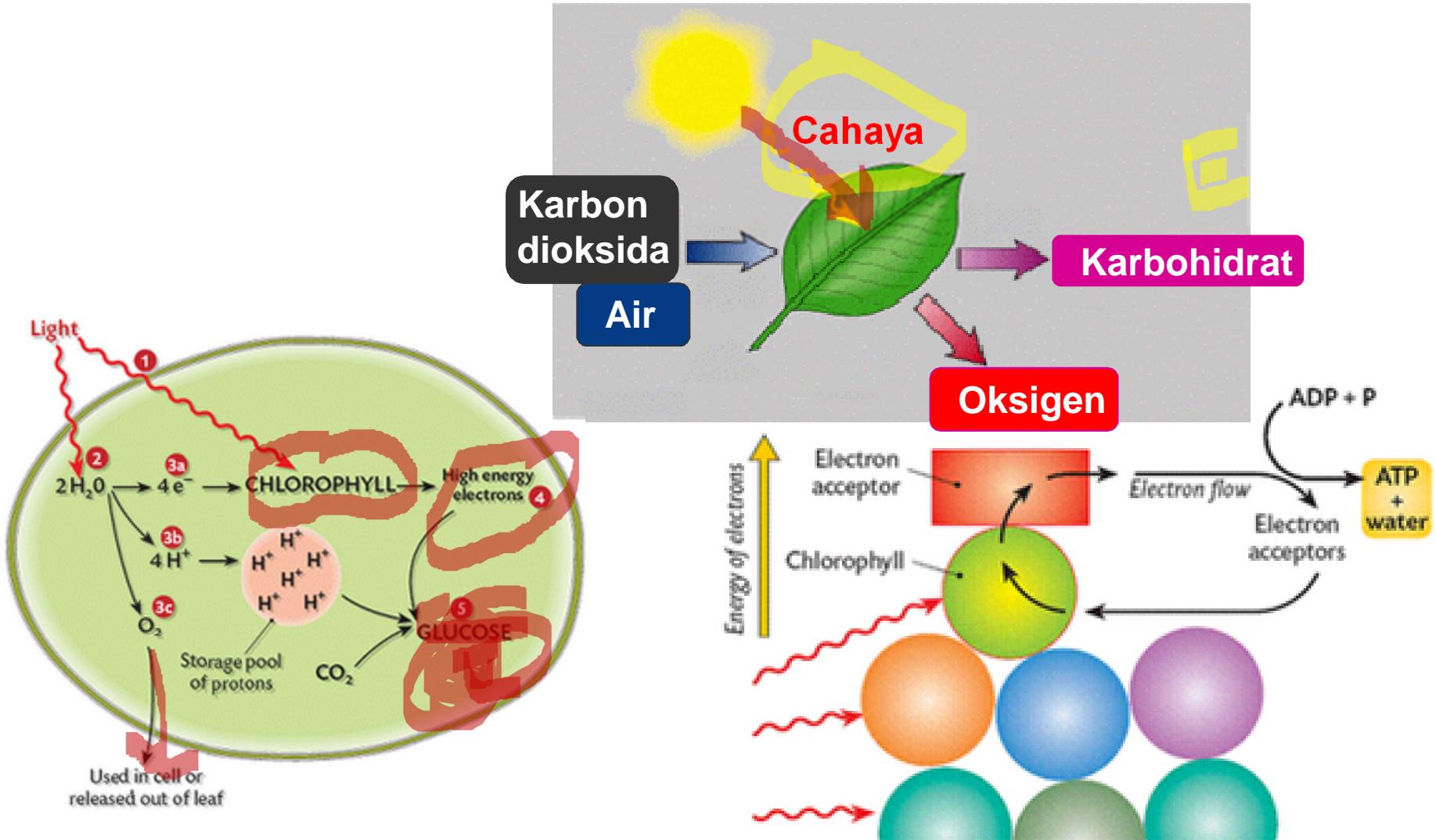


## Diagram Tingkat Energi Elektron

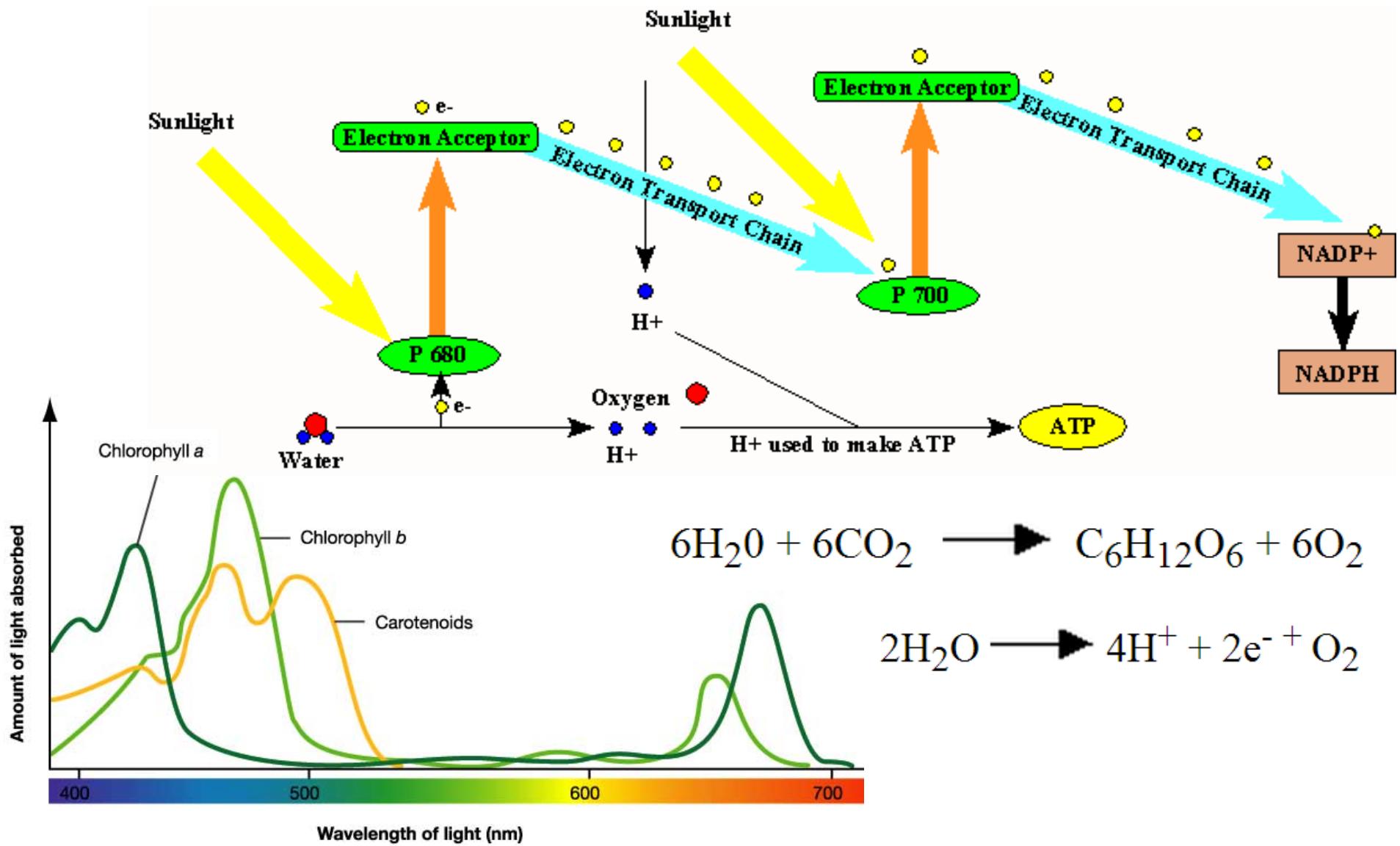


# Latarbelakang Pendekatan Konsep

## Diilhami dari mekanisme fotosintesis

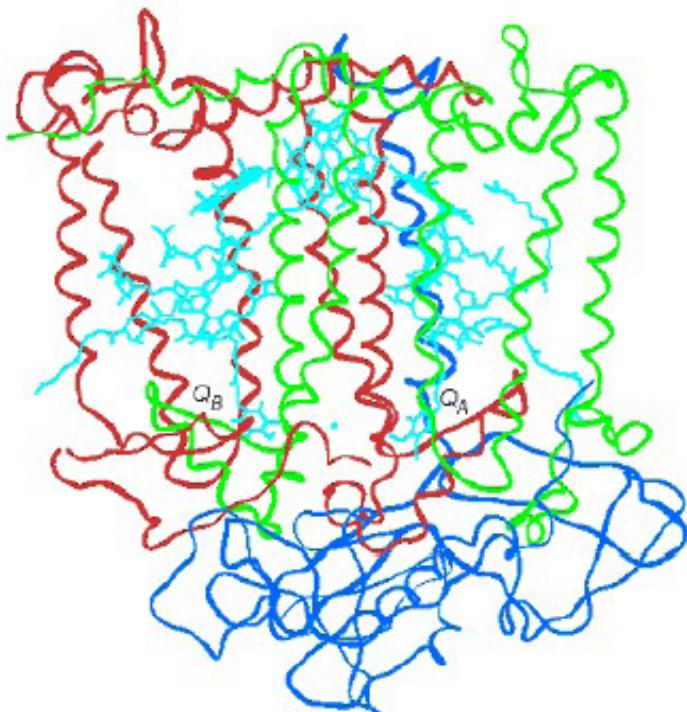


# Pengaruh Panjang Gelombang Cahaya dan Proses Pelepasan Elektron



# Mekanisme transfer energi sering terjadi dalam sistem biologi

Schematic picture of a photosynthetic reaction center from the bacterium *Rhodopseudomonas virdis*. The polypeptide chains are drawn as ribbons of different colors for the four different protein subunits.



The reaction center is composed of four protein subunits. Two of these, the L and M subunits, each form five membrane-spanning helices. The structure shows the precise arrangement in the L and M subunits of the photochemically active groups - two chlorophyll molecules forming a dimer, two monomeric chlorophylls, two pheophytin molecules (these lack the central magnesium ion of chlorophyll), one quinone molecule, called QA (a second quinone molecule, QB, is lost during the preparation of the reaction center) and one iron ion (Fe). The L and M subunits and their chromophores are related by a twofold symmetry axis that passes through the chlorophyll dimer and the iron. A third subunit, H, without active groups and located on the membrane inner surface, is anchored to the membrane by a protein helix. The remaining subunit, a cytochrome with four heme groups (related to the blood pigment hemoglobin), binds at the outer surface of the membrane.

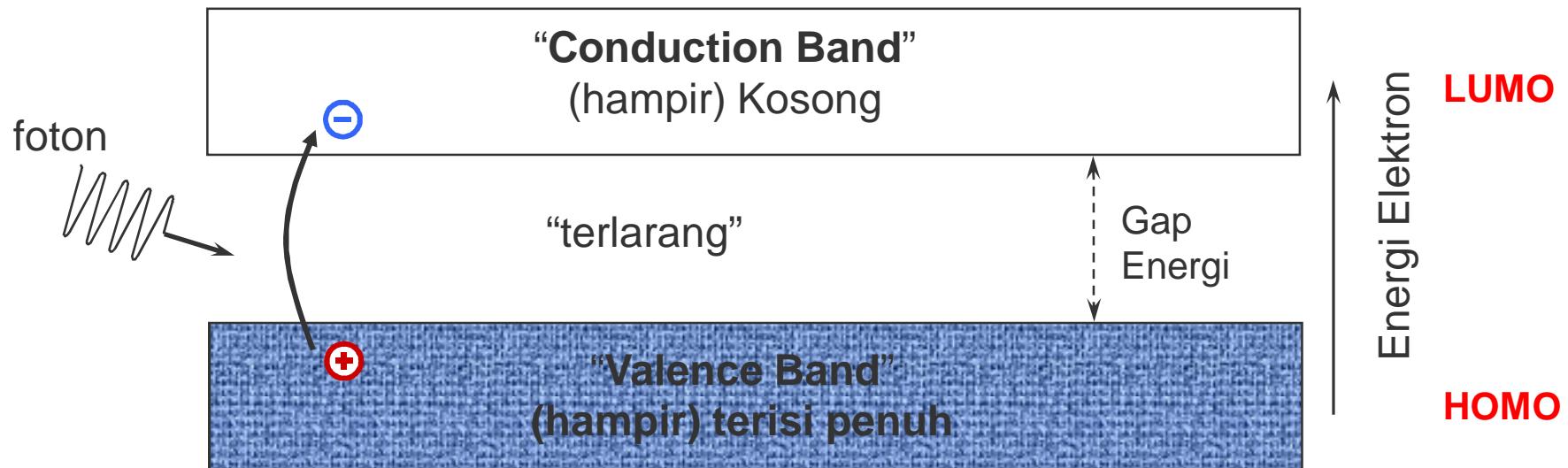
Photosynthesis and respiration are based on the transfer of electrons between donor and acceptor molecules bound to biological membranes - sheet-like structures composed of lipids and proteins which surround the cells and their inner compartments. The photosynthetic reactions in plants take place in the inner membranes of the chloroplasts, the organelles which contain the chlorophyll. Some bacteria have a simpler form of photosynthesis, to some extent similar to that in plants but without the ability to form oxygen.

In all types of photosynthesis, the light energy absorbed by chlorophyll is transferred to membrane-bound protein-pigment complexes, known as reaction centers. In these complexes the light energy initiates electron-transfer reactions which are coupled to the translocation of hydrogen ions across the membrane. The resulting pH gradient is utilized by another membrane-bound protein, ATPase, to synthesize ATP, a compound used as a fuel in energy-demanding biological processes. In cell respiration, too, electron transport is coupled to proton translocation and ATP synthesis.

From

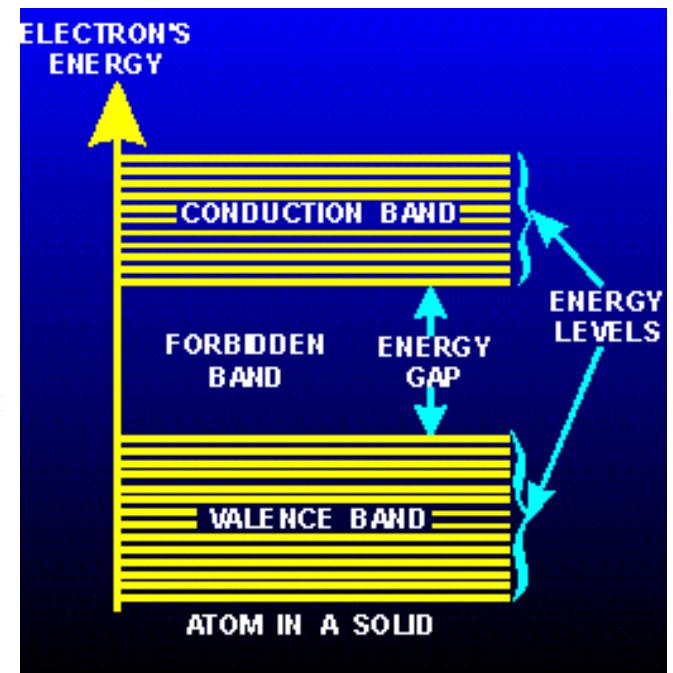
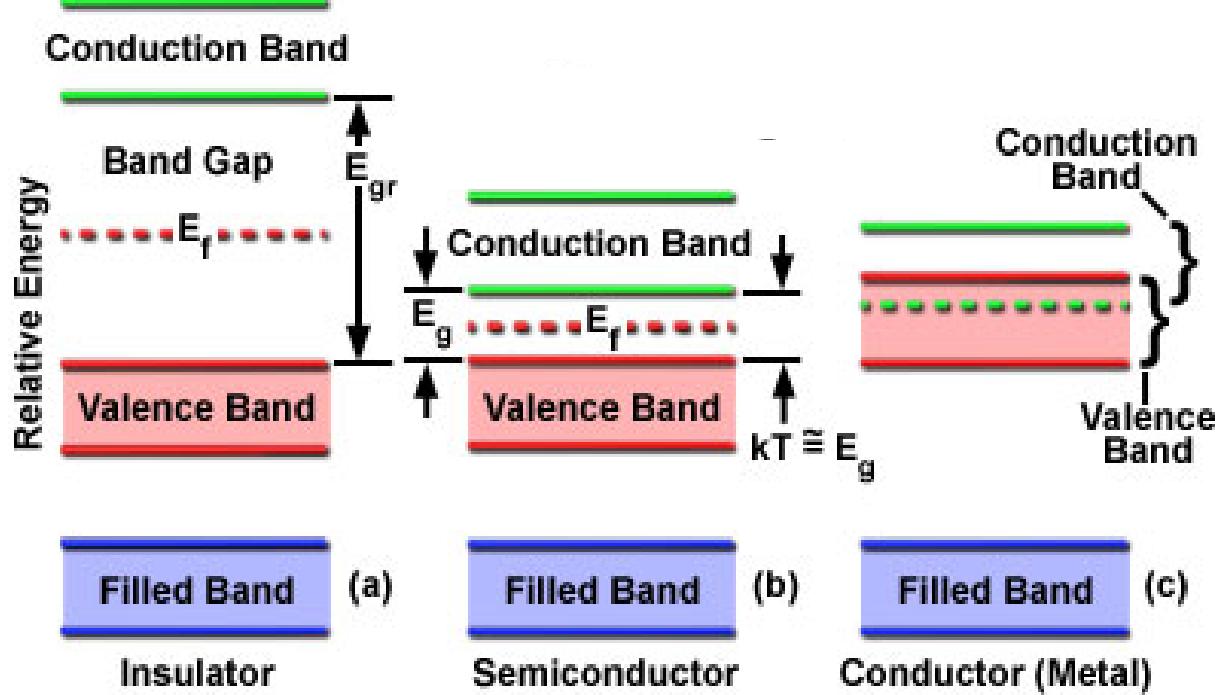
<http://www.nobel.se/chemistry/educational/poster/1988/>

## Optical Generation dari Model elektron bebas dan hole



- ⊕ Jika foton memiliki energi yang lebih besar daripada **Gap Energi**, foton akan diserap oleh semikonduktor, mengeluarkan elektron dari pita valensi ke pita konduksi, ***dimana elektron bebas untuk bergerak.***
- ⊕ **Hole bebas berada disebelah kiri pada pita valensi.**
- ⊕ Proses penyerapan (absorbsi) ini mendasari operasi detektor cahaya fotokonduktif, fotodioda, fotovoltaik (solar) cell, dan kamera solid-state.

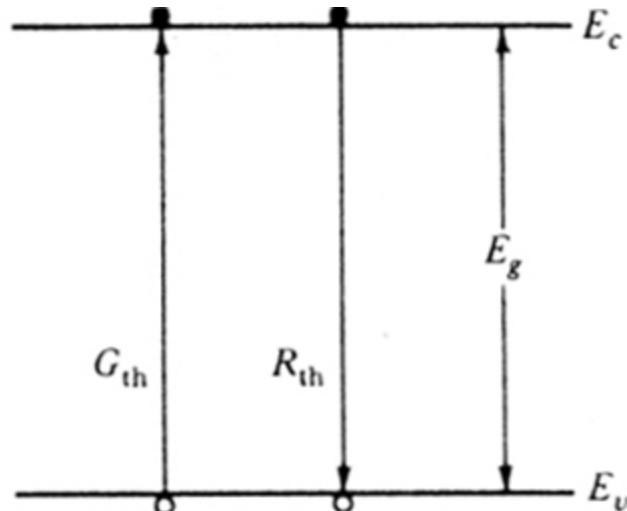
# Pita Energi dalam Material



# Carrier Generation and Recombinations

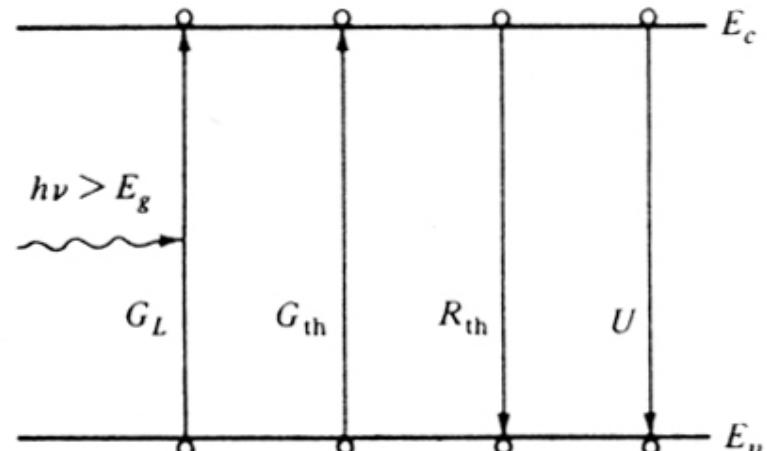
- Melalui mekanisme pasangan elektron & hole.
- Hamburan transport bisa terjadi karena variasi ketidak-sempurnaan kristal.

Conduction Band



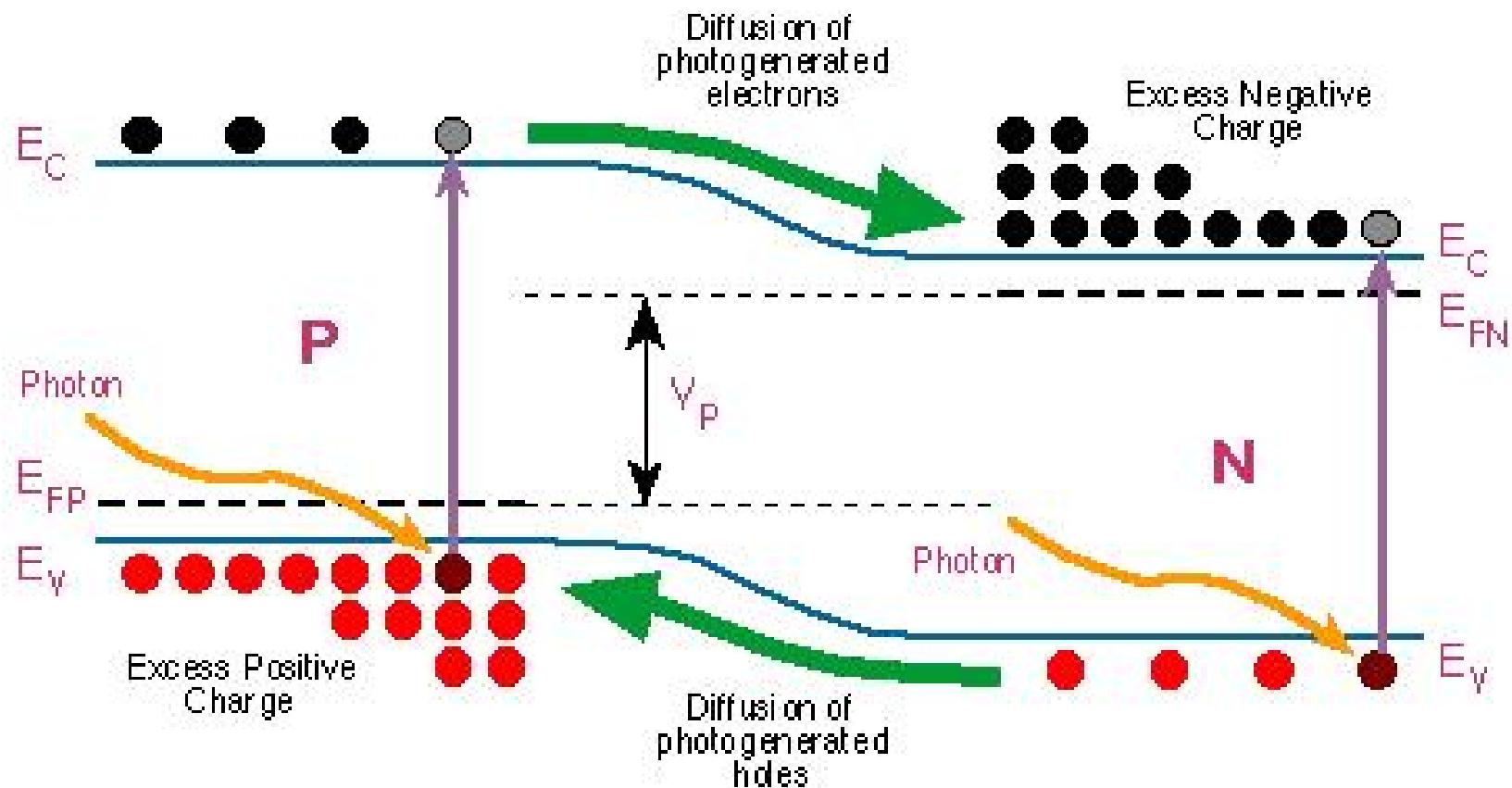
Valence Band

Pada equilibrium termal

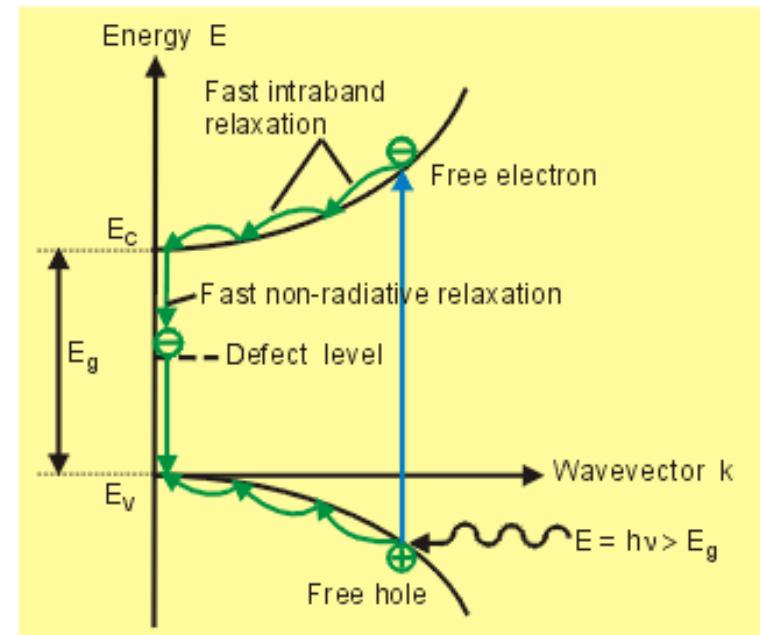
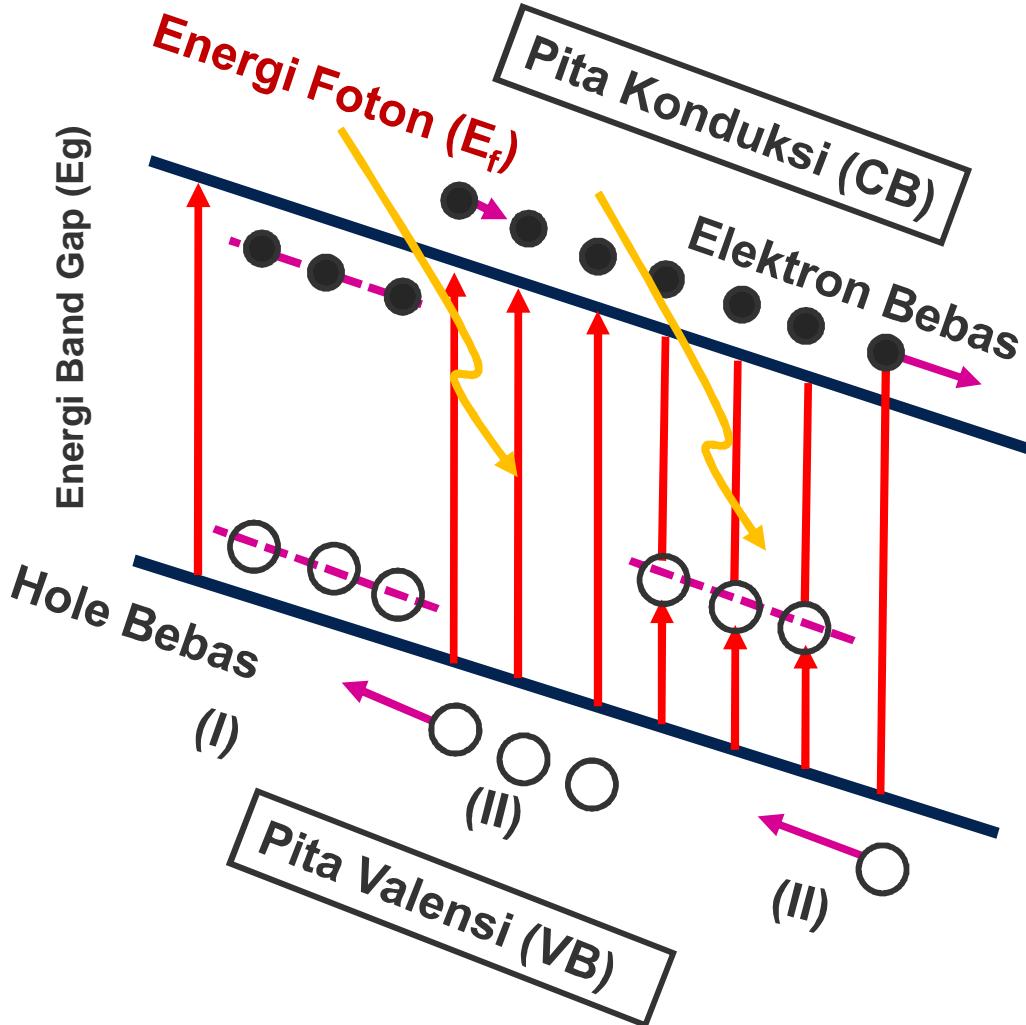


Dibawah illuminasi optis

## Transisi Pita ke pita adalah interaksi optoelektronik dalam semikonduktor



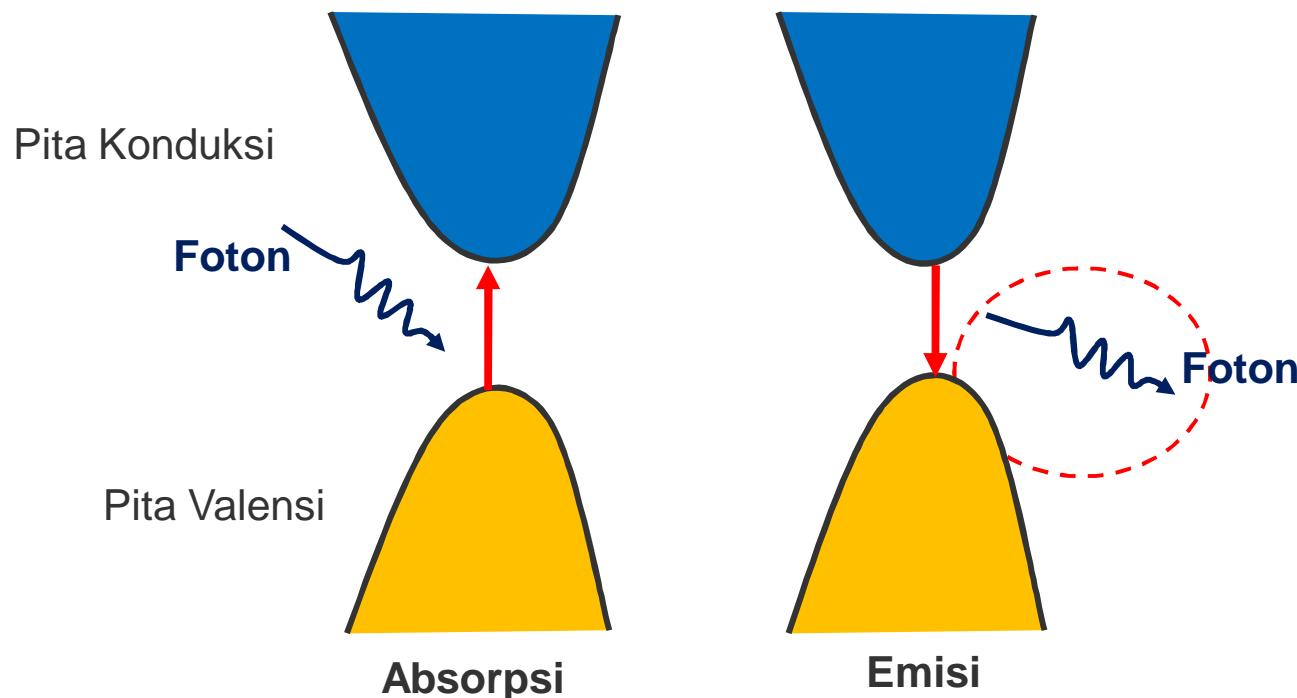
# Prinsip Kerja Efek Fotokonduktif



Kondisi (I): tidak ada foton; (II):  $E_f > E_g$ ; (III): terdapat acceptor

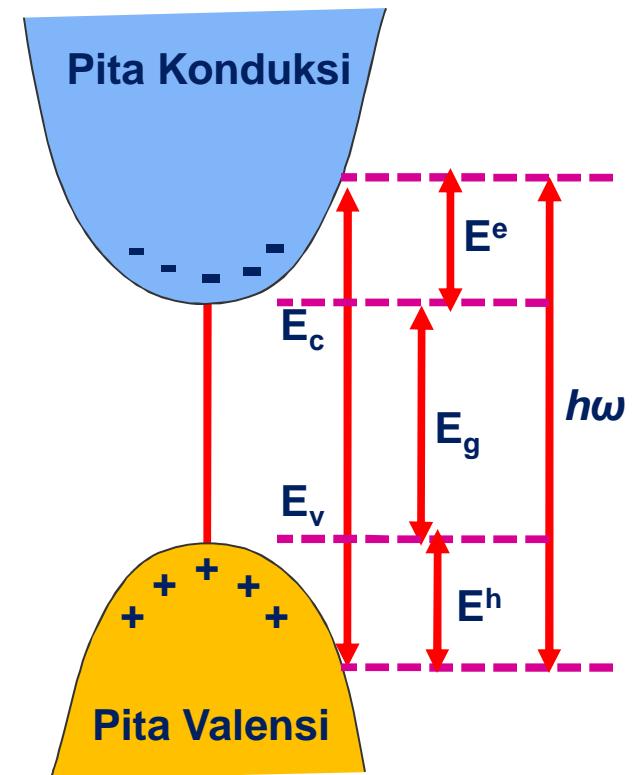
# Sifat-Sifat Optis

- Energi foton ( $hf$ ) harus lebih besar atau melebihi gap energi semikonduktor ( $E_g$ ) .
- Hamburan mempengaruhi transport elektron and hole
- Dua jenis hamburan:
  - Absorpsi foton
  - Emisi foton(dari rekombinasi e&h)



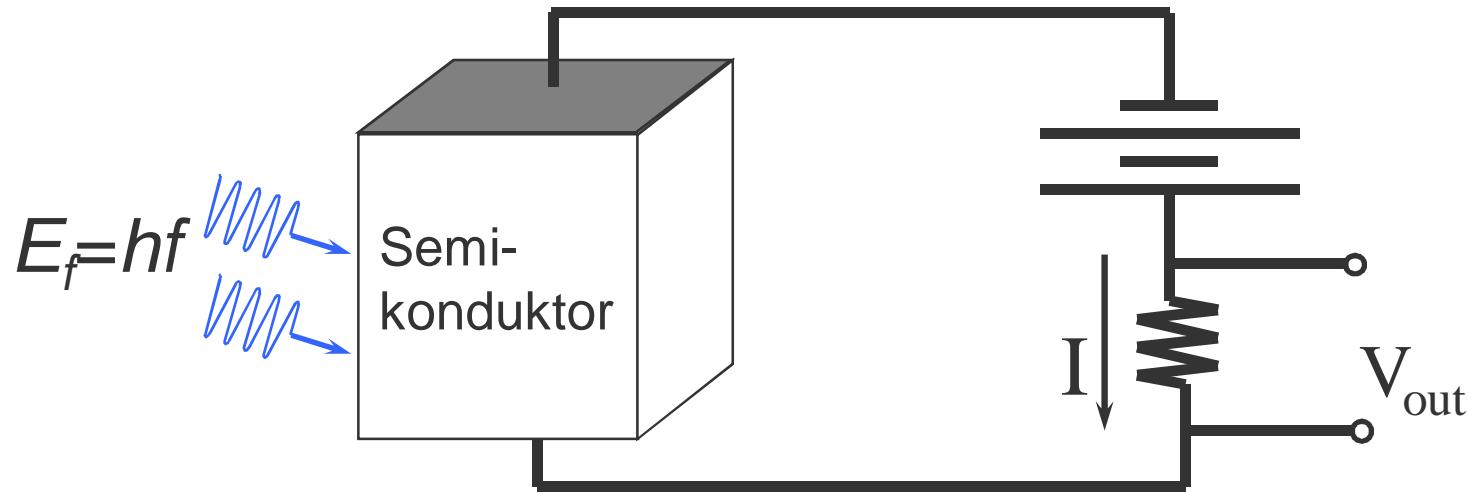
# Emisi-emisi Foton (*Radiative Recombination*)

- Emisi spontan
  - Tidak membutuhkan foton pemicu
  - Emisi tak-koheren
  - contoh: LED
- Emisi terstimulasi
  - Mensyaratkan sejumlah foton
  - Emisi Koheren
  - contoh: Laser dioda
- Rekombinasi Radiatif
  - Pasangan elektron-hole dari injeksi muatan (dari cahaya atau baterai external)
  - Gain: (Emisi - Absorpsi)
  - Sinar optik akan tumbuh sebagai hasil Gain positif
- Rekombinasi Non-radiatif
  - Ketika rekombinasi menghasilkan panas atau “phonon”



# Photoconductive Light Detectors

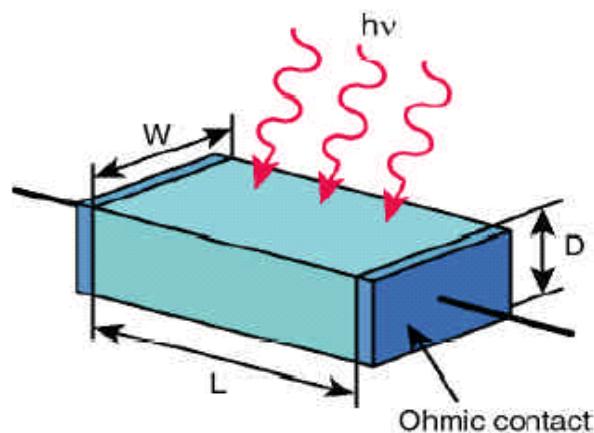
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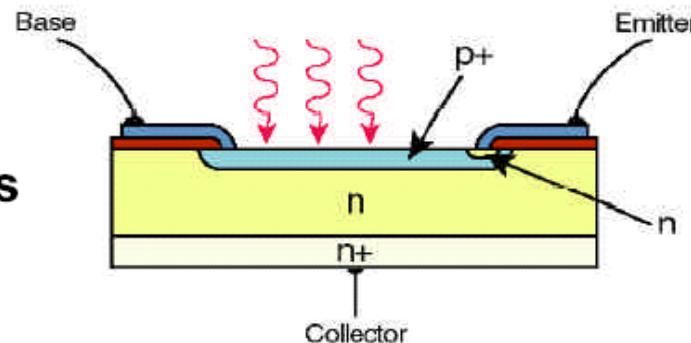
- Foton memiliki energi yang lebih besar daripada gap energi semikonduktor, terjadi penyerapan  $E_f$
- Sehingga menciptakan elektron\*\* bebas dan hole bebas,
- mengakibatkan resistivitas  $\rho$  semikonduktor menurun (konduktivitas meningkat).

# Jenis-jenis Detektor Foton (anorganik)

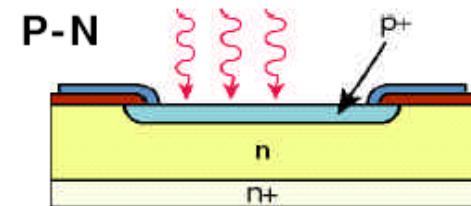
**Photoresistor**



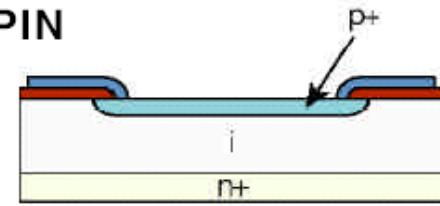
**Phototransistors**



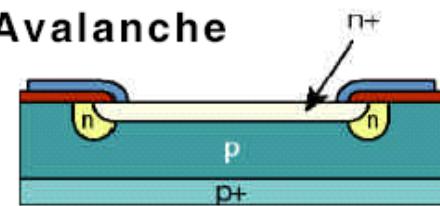
**Photodiode**



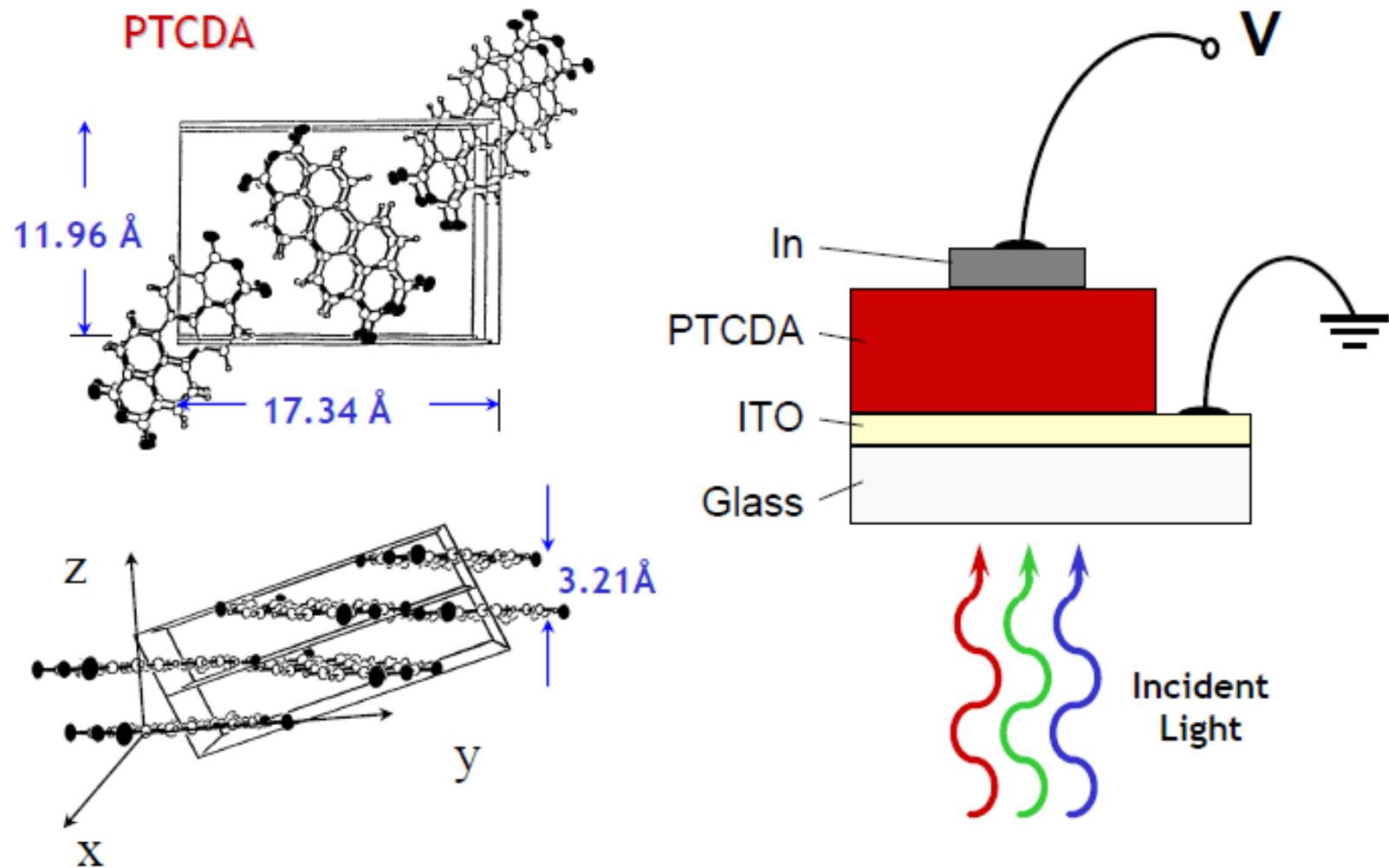
**PIN**



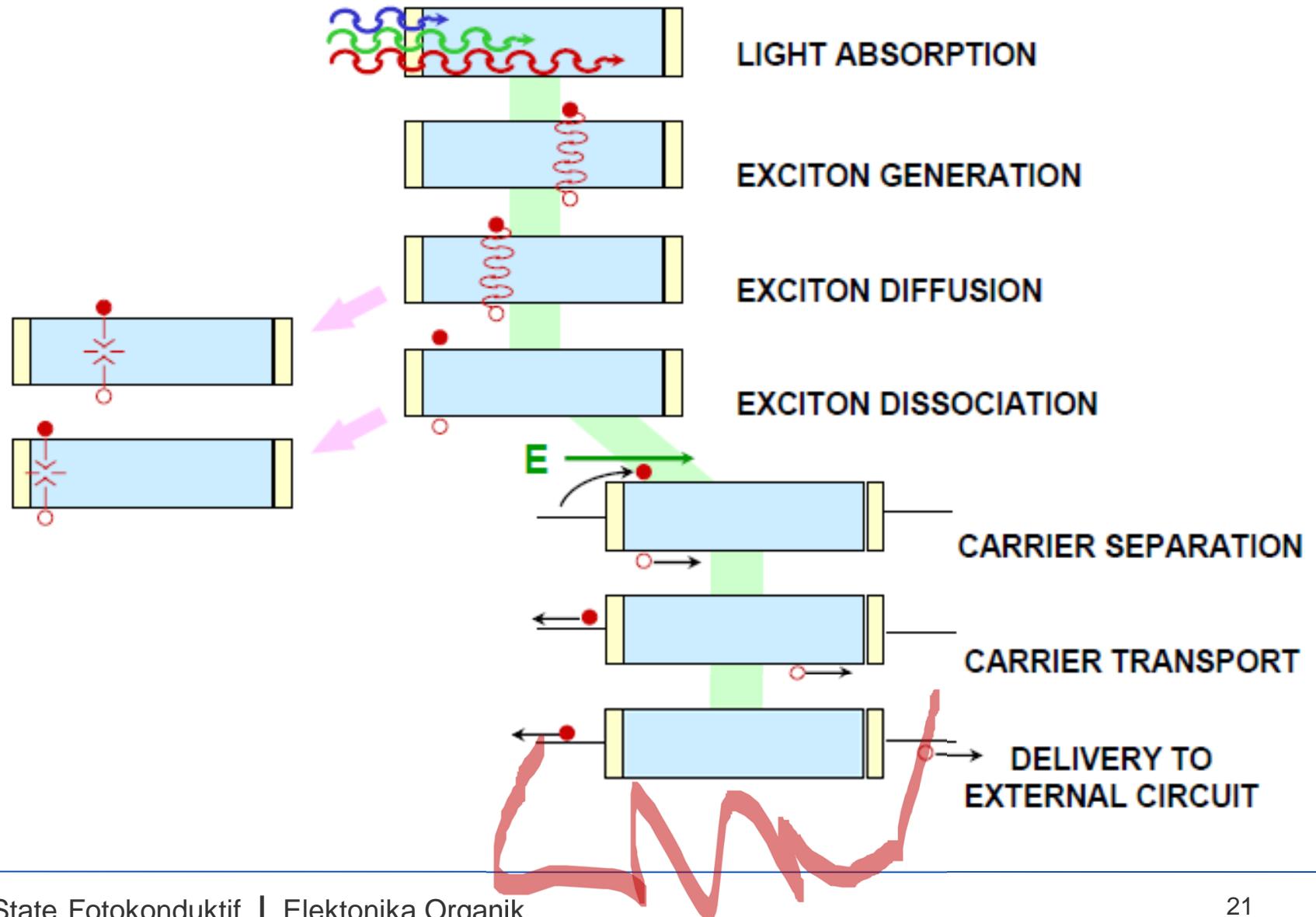
**Avalanche**



## PV cell Organik Single layer

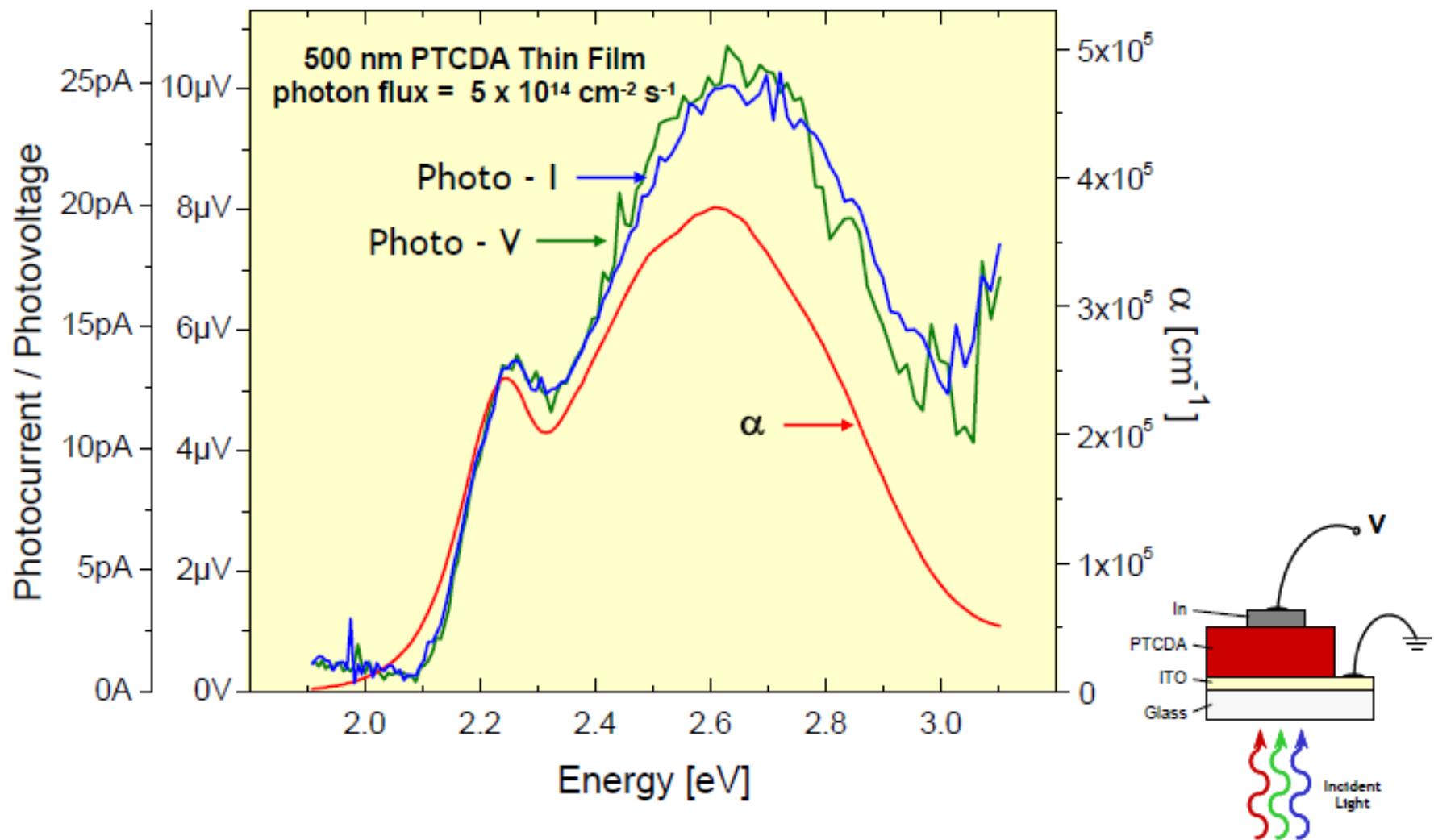


# Proses Pembangkitan Photocurrent



# Photocurrent, Photovoltage, Absorpsi

Photocurrent measured at 0V external bias



# Material Fotokonduktor Organik

Product Name	4,4'-Di-phenyl-tetrathiafulvalene
CAS Number	5152-94-3
Molecular Formula	C <sub>18</sub> H <sub>12</sub> S <sub>4</sub>
Molecular Weight (g/mol)	356.53
Melting Point °C	204 (DSC)
Appearance	Orange Crystals or Powder
Application	Organic Electronic Conductor
Absorption Maximum (nm)	261
Comments	Charge transport material

## Organik PhotoConductor

Product Name	p-Diethylaminobenzaldehyde-N,N-diphenyl-hydrazone
CAS Number	68189-23-1
Abbreviation	DEH
Molecular Formula	C <sub>23</sub> H <sub>25</sub> N <sub>3</sub>
Molecular Weight (g/mol)	343.47
Melting Point °C	93-94
Assay (%)	99
Appearance	Light Yellow Powder
Application	OPC
Absorption Maximum (nm)	366
TSCA	Yes
EINECS	269-181-3
Comments	Volatiles: 0.30%, Toluene free-recrystallized from Ethanol

# Material Fotokonduktor Organik

<b>Product Name</b>	N-Ethyl-carbazole-3-aldehyde-N,N-diphenyl-hydrazone
<b>CAS Number</b>	73276-70-7
<b>Molecular Formula</b>	C <sub>27</sub> H <sub>23</sub> N <sub>3</sub>
<b>Molecular Weight (g/mol)</b>	389.50
<b>Melting Point °C</b>	158-160
<b>Solubility</b>	Soluble in Toluene (111 g/L), CHCl <sub>3</sub> (385 g/L) and Methanol (3.0 g/L)
<b>Assay (%)</b>	95
<b>Appearance</b>	Colorless to Pale Yellow
<b>Application</b>	OPC/CTM
<b>Absorption Maximum (nm)</b>	345
<b>Comments</b>	T <sub>g</sub> = 58.5 C
<b>Product Name</b>	9-Ethyl-carbazole-3-aldehyde-N-methyl-N-phenyl-hydrazone
<b>CAS Number</b>	75232-44-9
<b>Molecular Formula</b>	C <sub>22</sub> H <sub>21</sub> N <sub>3</sub>
<b>Molecular Weight (g/mol)</b>	327.43
<b>Solubility</b>	Soluble in Toluene (170g/L), CHCl <sub>3</sub> (630 g/L), Methanol (3.0 g/L), Benzene and Acetone
<b>Assay (%)</b>	98
<b>Appearance</b>	Pale Yellow Compound
<b>Application</b>	OPC/CTM
<b>Absorption Maximum (nm)</b>	342
<b>Comments</b>	T <sub>g</sub> = 37.3 C

# Tugas Individu

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- 1. Jelaskan tentang definisi, mekanisme, dan contoh**  
*meliputi:* photo-conductive, photo-current, photo-voltage, photo-voltaic, dan photo-electric effect.
- 2. Faktor-faktor apa saja yang harus dipenuhi untuk mekanisme tersebut diatas dalam bahan organik!**
- 3. Jelaskan perkembangan devais photovoltaic organic!**

Tugas softcopy

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