

Teori Semikonduktor

# Elektronika

## (TKE 4012)

Eka Maulana

[maulana.lecture.ub.ac.id](http://maulana.lecture.ub.ac.id)

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- Forward Bias
- Reverse Bias
- Breakdown
- Energy Level
- Barrier Potential

# #Klasifikasi Unsur

# Periodic Table of the Elements

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

# #1 Konduktor

Orbit-orbit Stabil

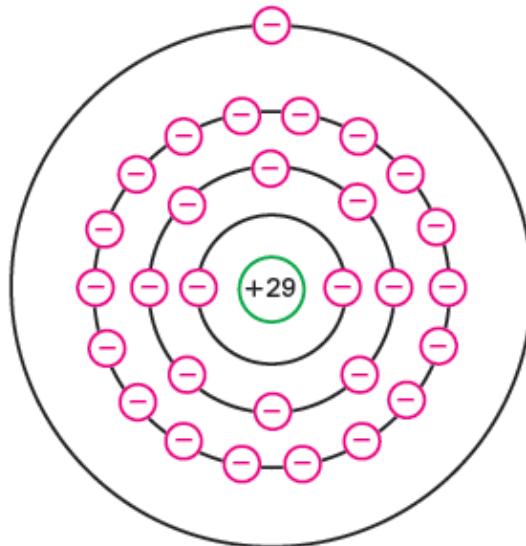
Inti Atom

Orbit valensi

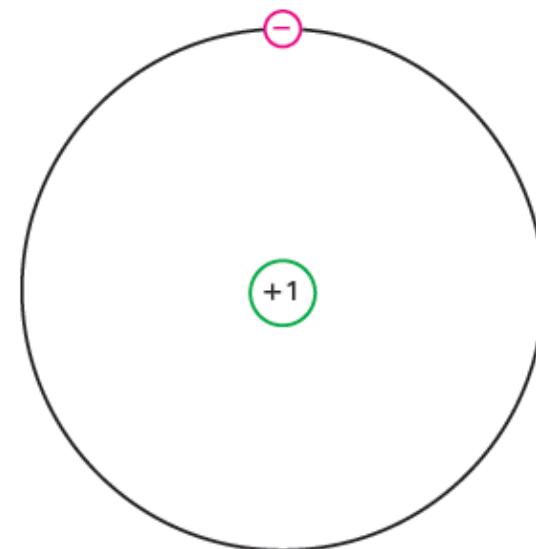
Elektron Bebas

Ex: copper, silver, gold

29	Cu
47	Ag
79	Au



Atom copper (tembaga)



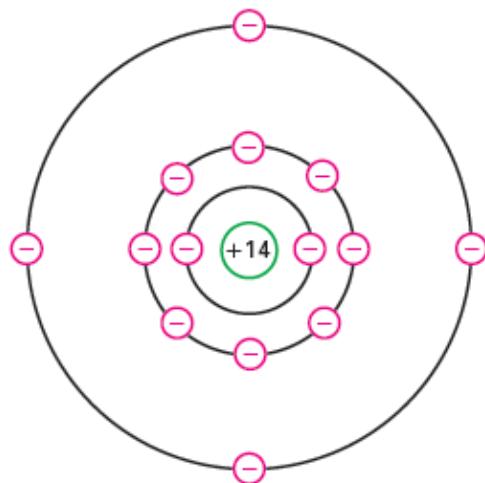
Core diagram atom copper

# #2 Semikonduktor

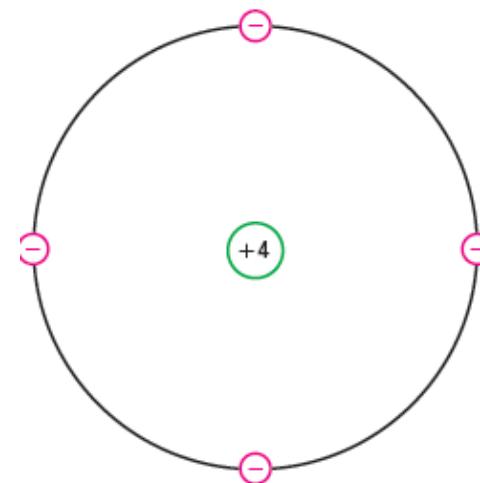
Silikon (14)

Germanium (32)

6	C
14	Si
32	Ge



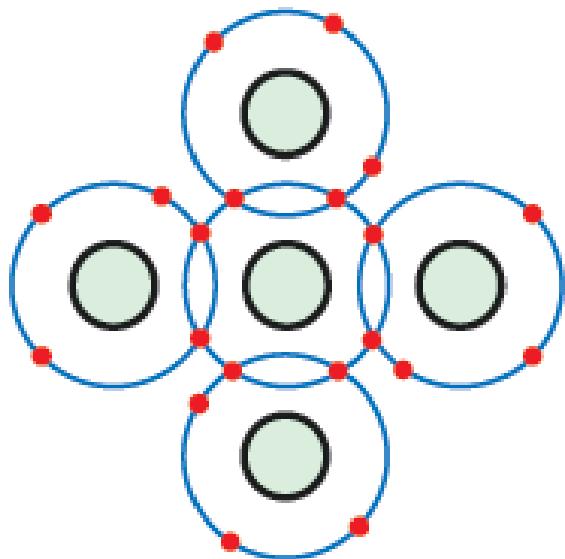
Atom Silicon



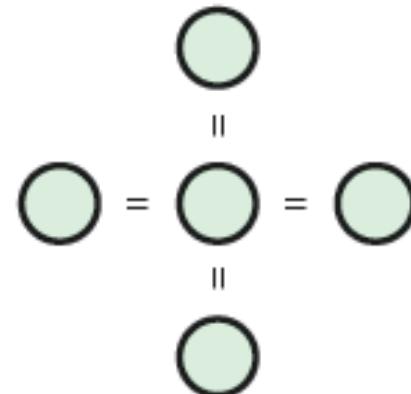
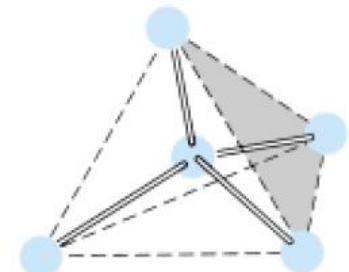
Core diagram

# #3 Kristal Silikon

- Ikatan Kovalen
- Saturasi Valensi
- Hole
- Rekombinasi dan Lifetime



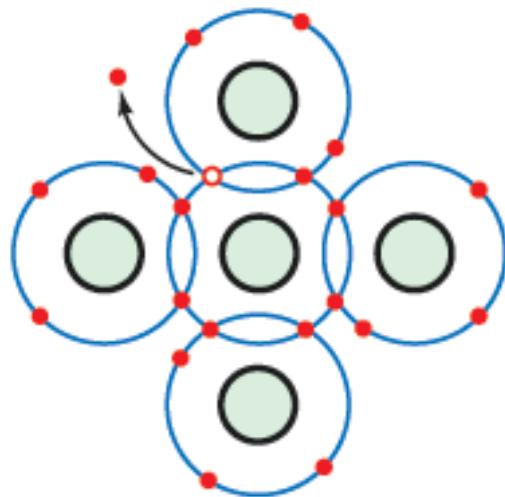
Kristal Atom



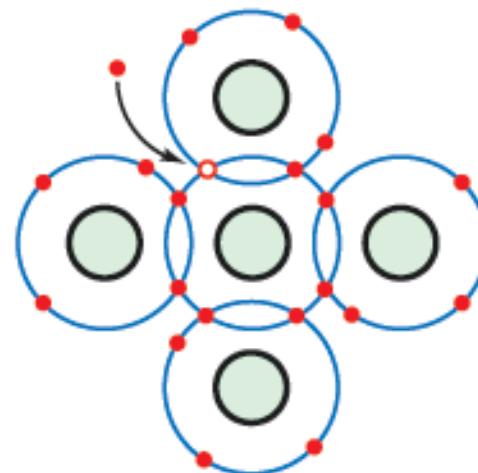
Ikatan Kovalen

# #3 Kristal Silikon

## Rekombinasi dan Lifetime

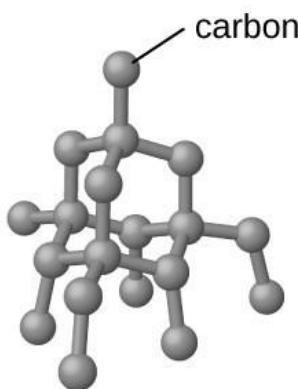
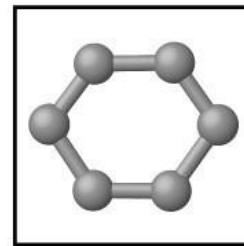
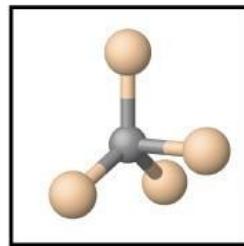
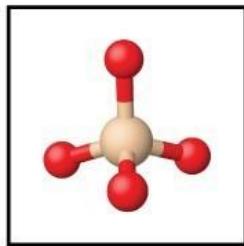
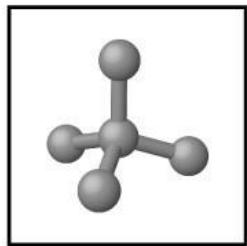


**Thermal Energy** menghasilkan  
hole dan free elektron

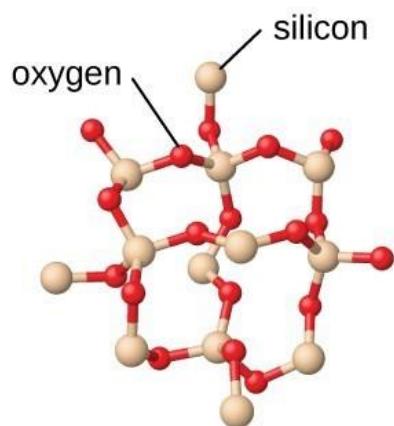


**Rekombinasi**  
elektron bebas dengan hole

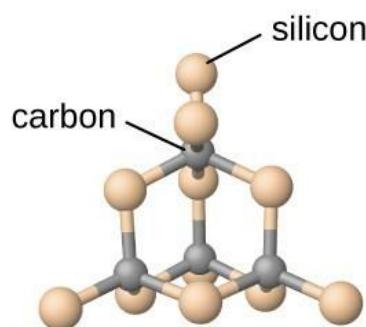
# Bentuk-bentuk kristal



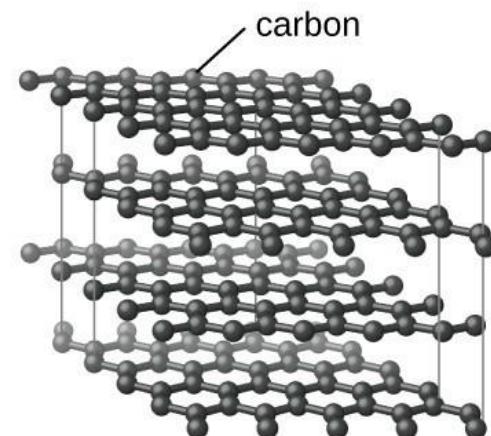
diamond



silicon dioxide

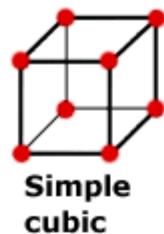


silicon carbide



graphite

# *Bravais lattice* kristal tiga dimensi



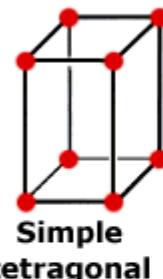
Simple  
cubic



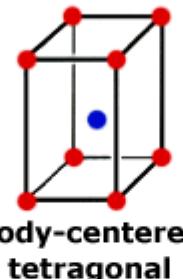
Face-centered  
cubic



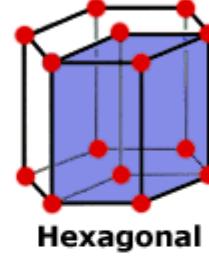
Body-centered  
cubic



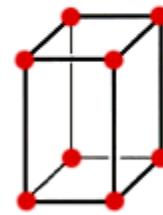
Simple  
tetragonal



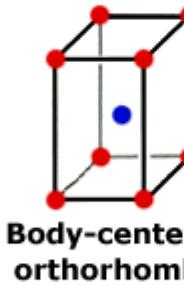
Body-centered  
tetragonal



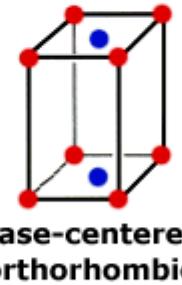
Hexagonal



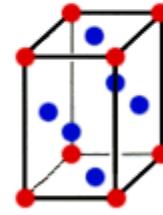
Simple  
orthorhombic



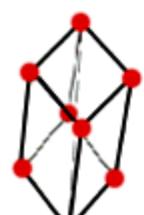
Body-centered  
orthorhombic



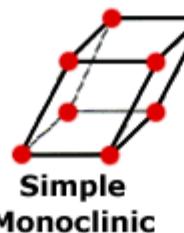
Base-centered  
orthorhombic



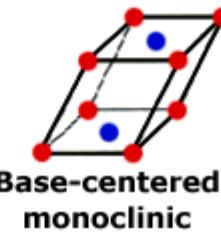
Face-centered  
orthorhombic



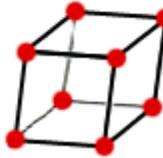
Rhombohedral



Simple  
Monoclinic



Base-centered  
monoclinic

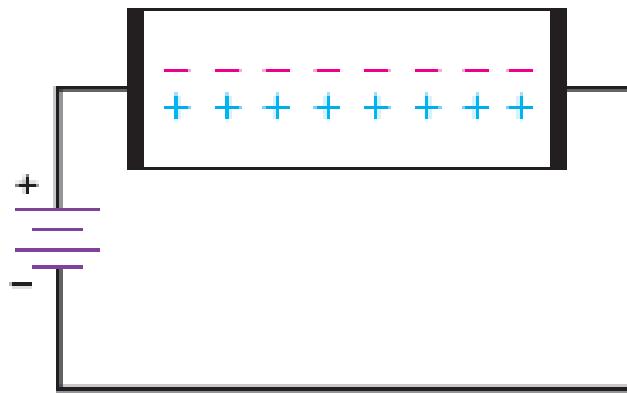


Triclinic

# #4 Semikonduktor Intrinsik

Semikonduktor intrinsik → semikonduktor murni

Pada suhu ruang kristal silikon perperilaku sebagai insulator karena hanya memiliki jumlah elektron bebas dan hole sedikit yang dihasilkan oleh *thermal energy*



Semikonduktor intrinsik memiliki  
Jumlah elektron dan hole yg sama

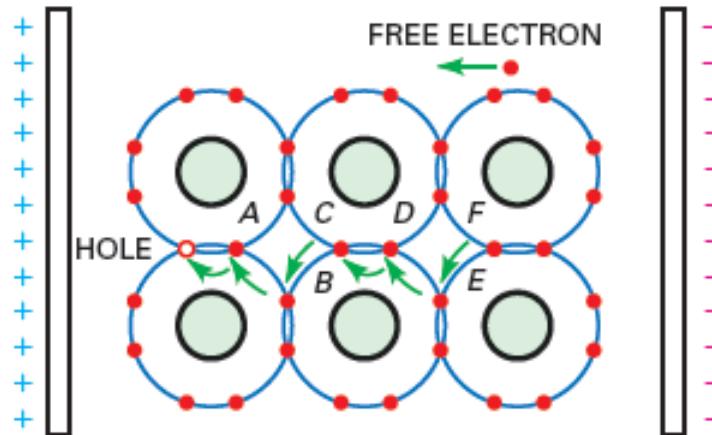
# #5 Dua Jenis Aliran

- Aliran Elektron bebas
- Aliran Hole

Asumsikan energi termal menghasilkan elektron bebas dan hole.

Elektron bebas mengalir dari sisi plat negatif ke plat positif

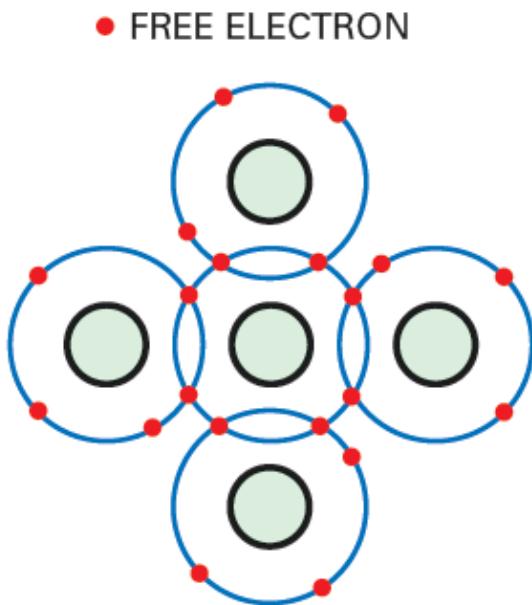
Ketika elektron pada posisi A berpindah ke kiri, maka hole berpindah ke A



Aliran hole pada semikonduktor intrinsik

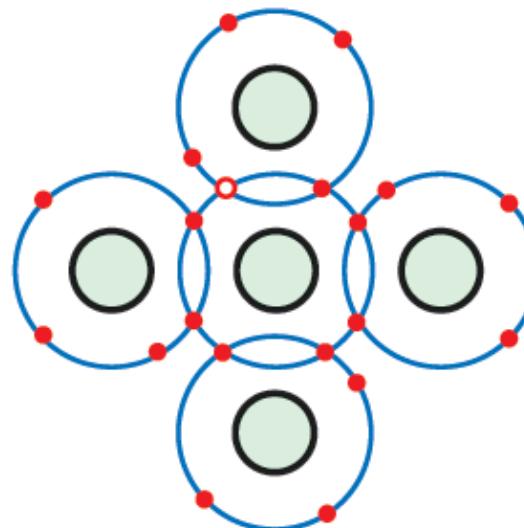
# #6 Doping Semikonduktor

Meningkatkan Elektron Bebas



Doping untuk dapat elektron bebas

Meningkatkan jumlah *Hole*



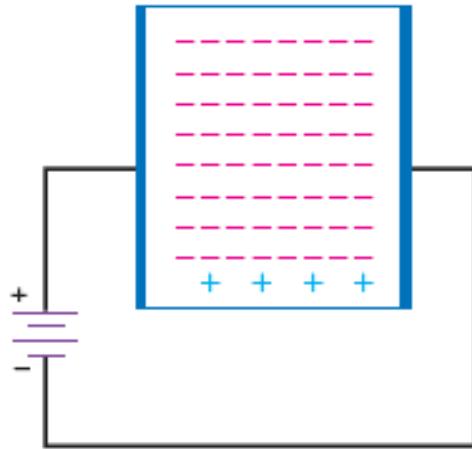
Doping untuk mendapatkan hole

- Peningkatan jumlah **elektron bebas** dapat dilakukan dengan penambahan atom donor (impuriti) atom **pentavalent** (arsenic, antimon, phosfor)
- Peningkatan jumlah **hole** dapat dilakukan dengan penambahan atom donor (impuriti) atom **trivalent** (Al, Boron, gallium)

# #7 Doping Semikonduktor Ekstrinsik

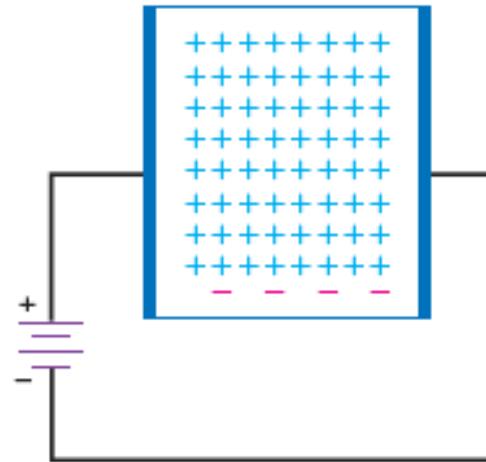
Doping pentavalent impuriti → Type-N

Doping trivalent impuriti → Type-P



Semikonduktor type-N

Elektron bebas → majority carriers  
Hole → minority carrier

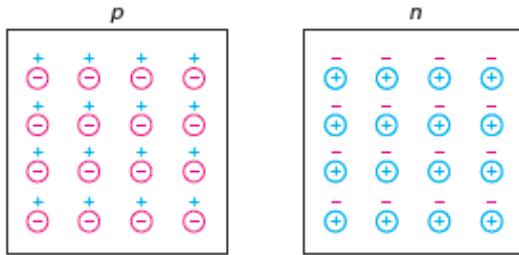


Semikonduktor type-P

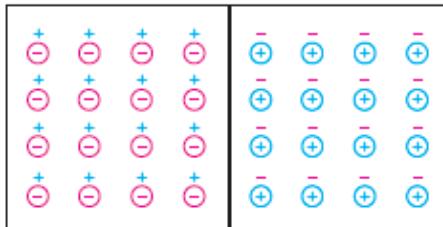
Hole → majority carriers  
Elektron bebas → minority carrier

# #8 Unbiased Diode

Jenis semikonduktor



P-N Junction



Potensial Barrier:

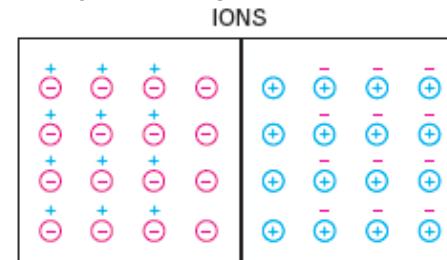
medan listrik diantara ion2 yang sebanding dengan perbedaan tegangan

$V_B$  Silicon : 0,7 volt

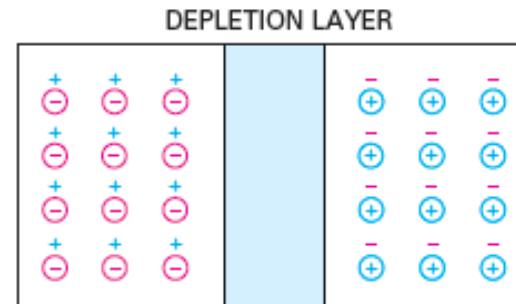
$V_B$  Germanium : 0,3 volt

T pada dioda : 25°C

Terciptanya ion-ion pada junction



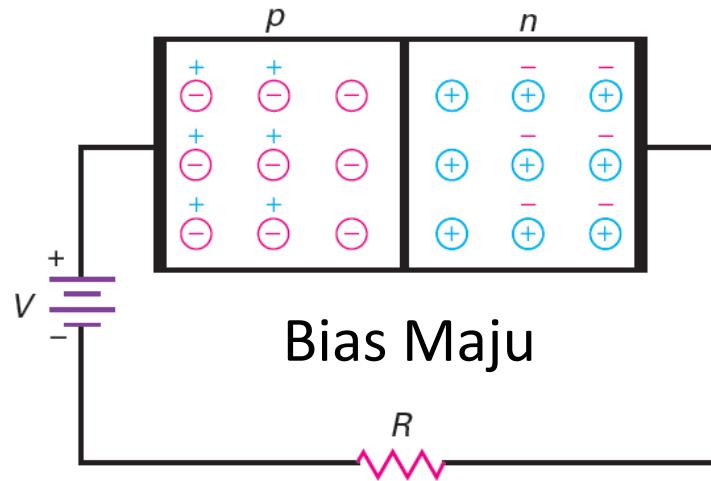
Depletion Layer



# #9 Forward Bias

Aliran Elektron Bebas  $\rightarrow$  terjadi jika  $V_{battery} > V_{barrier}$

Aliran hole ke kanan dan elektron ke kiri (jika energinya cukup)



## Aliran Satu Elektron

Jika  $V_{bat} > 0,7$  volt elektron bebas miliki energi untuk melewati layer deplesi.

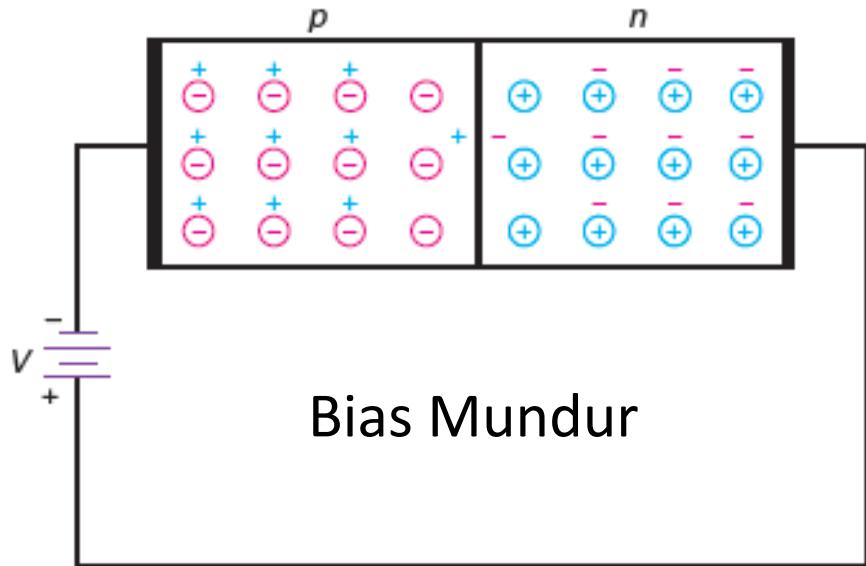
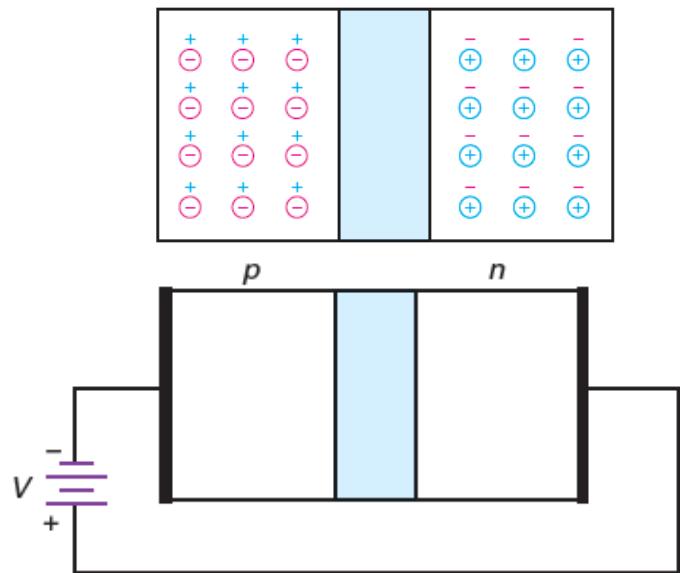
Setelah elektron melewati daerah **p**, maka terjadi rekombinasi dengan hole

:: Elektron bebas akan menjadi Elektron Valensi.

:: Terjadi arus listrik kontinyu pada dioda jika milyaran elektron berperilaku serupa

:: Resistor seri digunakan untuk?

# #10 Reverse Bias



## Pelebaran Layer Deplesi

Jika tegangan reverse meningkat → maka layer deplesi semakin melebar

## Minority-Carrier Current

Reverse current disebabkan oleh thermal yang produksi oleh carrier minority yang disebut **Saturation Current ( $I_s$ )**.

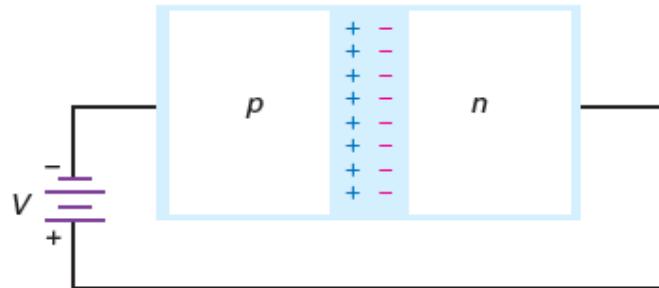
Peningkatan tegangan reverse, tidak meningkatkan jumlah thermal MC.

## Surface-Leakage Current

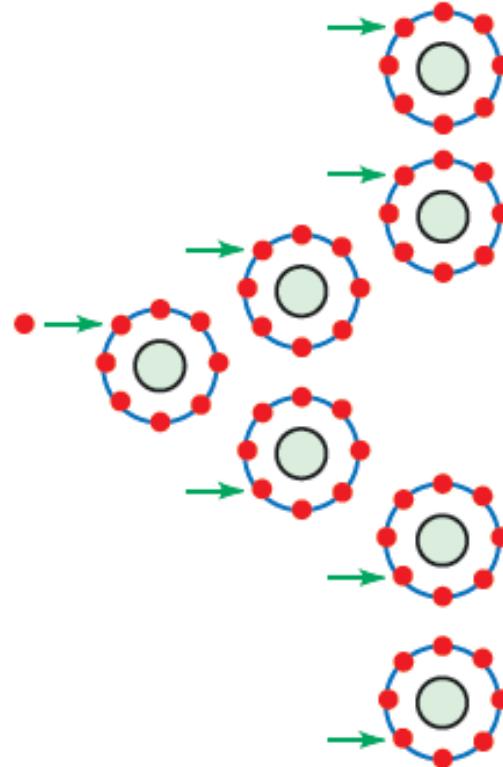
Aliran arus kecil pada permukaan kristal yang disebabkan oleh impuriti dan ketidak sempurnaan kristal.

Produksi thermal elektron bebas dan hole pada layer deplesi menghasilkan **reverse minority saturation current**

# #10 Breakdown



Avalanche menghasilkan banyak elektron bebas dan hole pada daerah deplesi



## Avalanche Effect

Sejumlah minority carrier yang muncul pada layer deplesi sehingga dioda dapat menghantar secara kuat (jebol/ dadal) ketika tegangan breakdown terpenuhi

## Minority-Carrier Current

Reverse current disebabkan oleh thermal yang produksi oleh carrier minority yang disebut **Saturation Current ( $I_s$ )**.

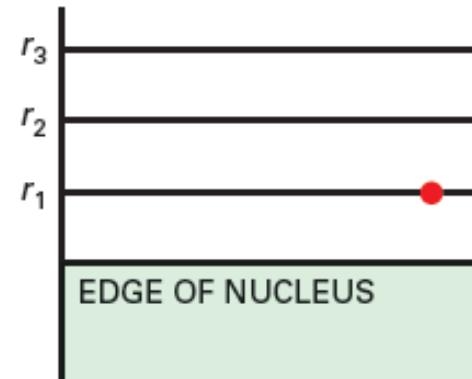
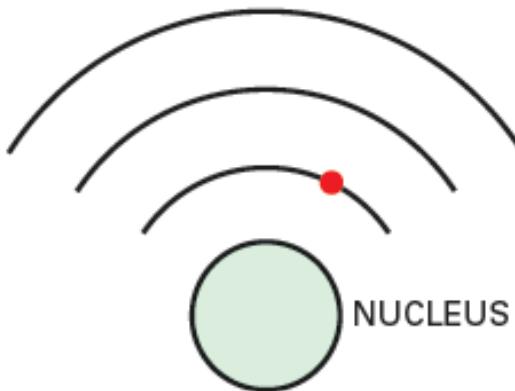
Peningkatan tegangan reverse, tidak meningkatkan jumlah thermal MC.

# Rangkuman: Bias Dioda

Forward bias		Reverse bias
$V_s$ polarity	(+) to $P$ material (-) to $N$ material	(-) to $P$ materials (+) to $N$ material
Current flow	Large forward current if $V_s > 0.7$ V	Small reverse current (saturation current and surface leakage current) if $V_s <$ breakdown voltage
Depletion layer	Narrow	Wide

# #11 Level Energi

- Energi tertinggi pada orbit terbesar
- Elektron yang jatuh Menghasilkan Cahaya
- Pita Energi (Energy Band)
- Level Energi Tipe-n dan Tipe-p

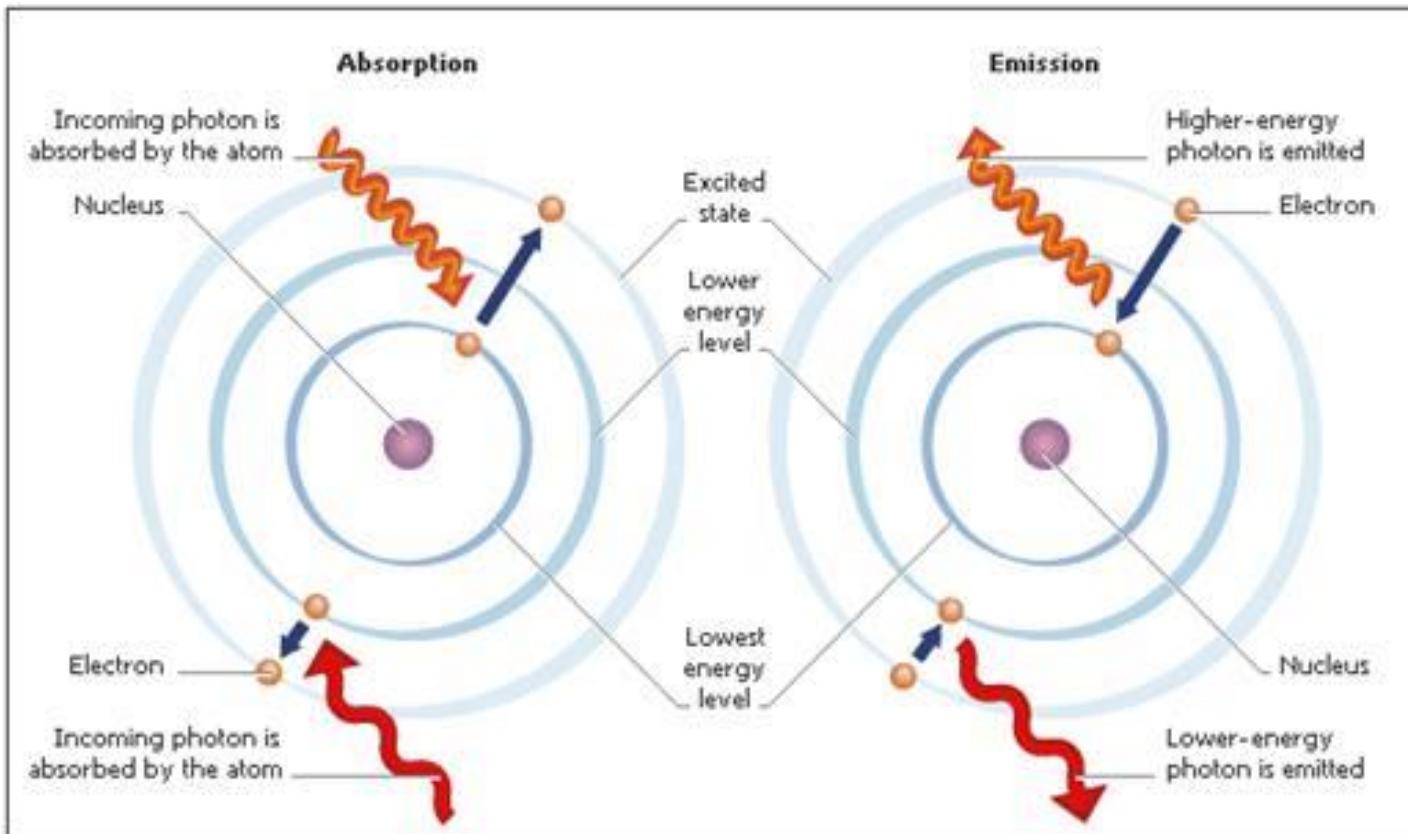


Masing-masing radius equivalent terhadap level energi

*Electrons in the smallest orbit are on the first energy level;  
electrons in the second orbit are on the second energy level.*

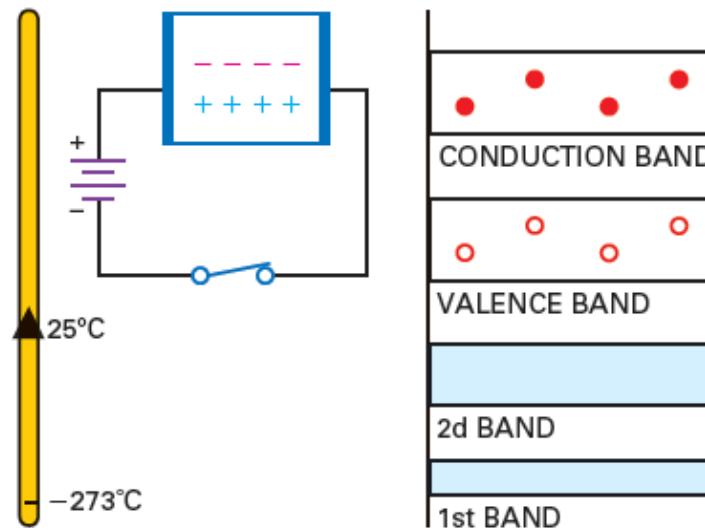
# #11 Level Energi

- Energi tertinggi pada orbit terbesar
- Elektron yang jatuh Menghasilkan Cahaya
- Pita Energi (Energy Band)
- Level Energi Tipe-n dan Tipe-p



# #11 Level Energi

- Energi tertinggi pada orbit terbesar
- Pita Energi (Energy Band)

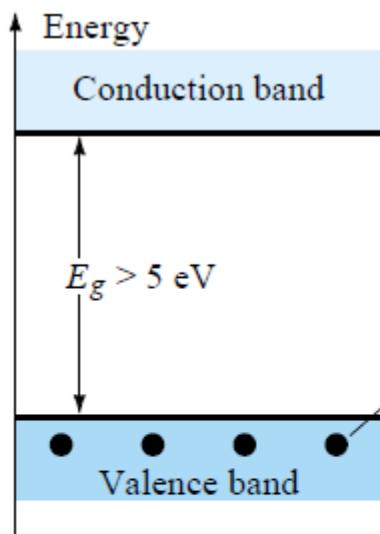
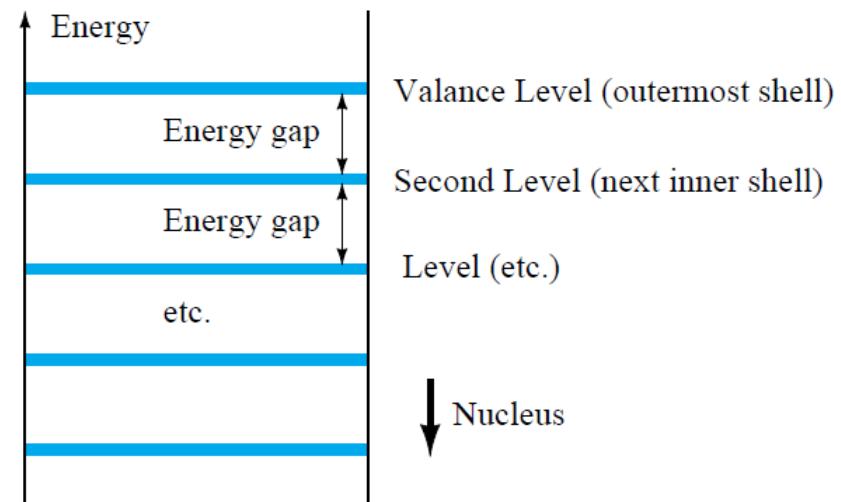


Thermal energy produces a few free electrons and holes. The holes remain in the valence band, but the free electrons go to the next-higher energy band, which is called the **conduction band**.

When the switch is closed, a small current exists in the pure semiconductor. The free electrons move through the conduction band, and holes move through the valence band.

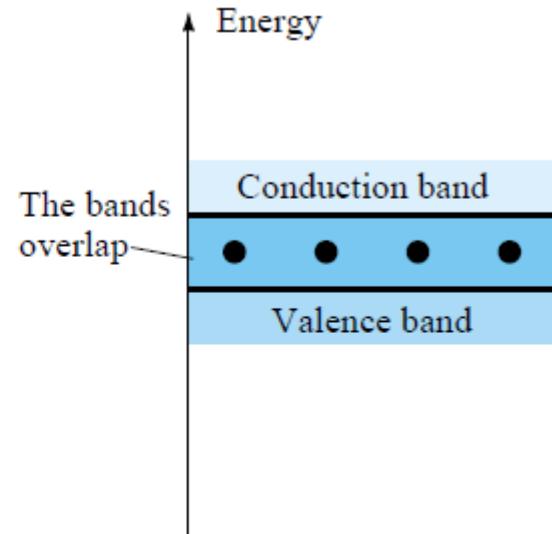
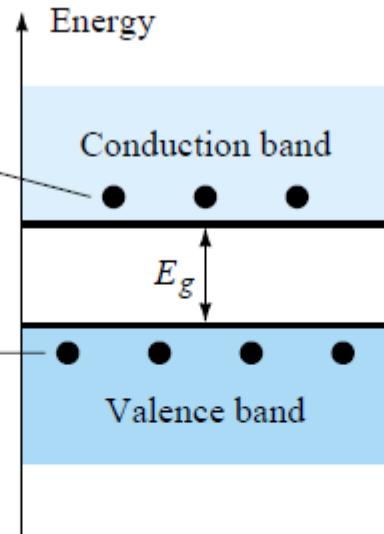
# #11 Level Energies

- Pita Energi



Electrons "free" to establish conduction

Valence electrons bound to the atomic structure



$$E_g = 1.1 \text{ eV (Si)}$$

$$E_g = 0.67 \text{ eV (Ge)}$$

$$E_g = 1.41 \text{ eV (GaAs)}$$

Insulator

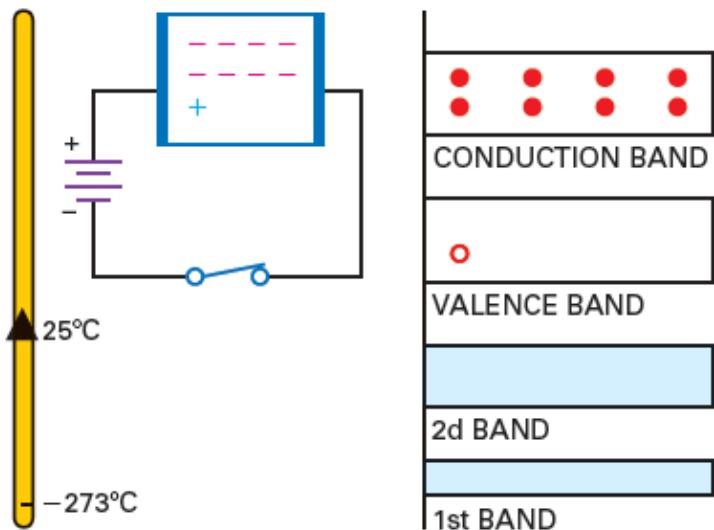
Semiconductor

Conductor

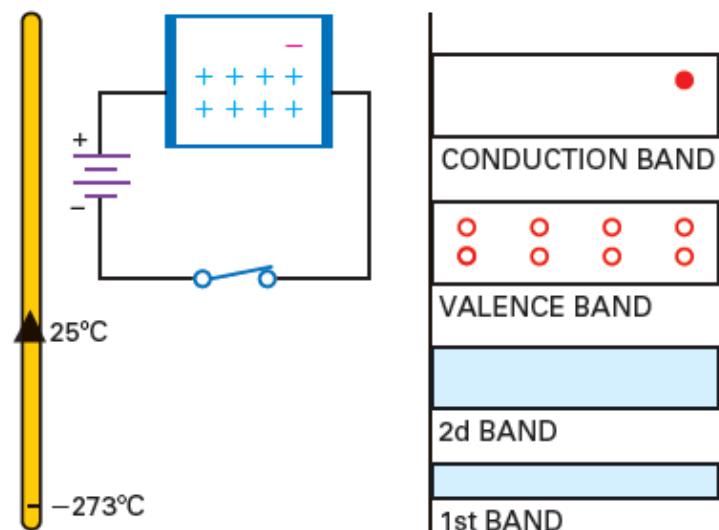
# #11 Level Energi

- Pita Energi
- Level Energi Tipe-n dan Tipe-p

**Level Energi Semikonduktor tipe-n**



**Level Energi Semikonduktor tipe-p**



## N-Type

The majority carriers are the free electrons in the conduction band, and the minority carriers are the holes in the valence band.

Since the switch is closed, the majority carriers flow to the left, and the minority carriers flow to the right.

# #12 Petensial Barrier dan Temperatur

## Junction Temperature

adalah temperatur didalam dioda, tepat pada persambungan p-n.

## Ambien Temperature

adalah temperatur temperatur udara diluar komponen.

## Potensial Barrier

Tegangan yang tergantung pada temperatur junction.

Meningkatnya temperatur junction, menyebabkan lebih banyak elektron bebas dan hole dalam daerah doping.

Terdapat difusi muatan pada layer deplesi sehingga LD semakin menyempit.

*“less barrier potential at higher junction temperatures.”*

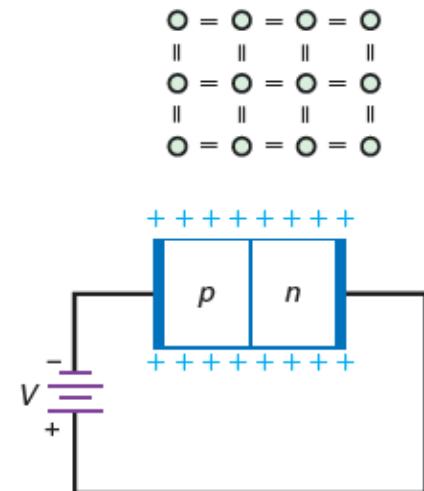
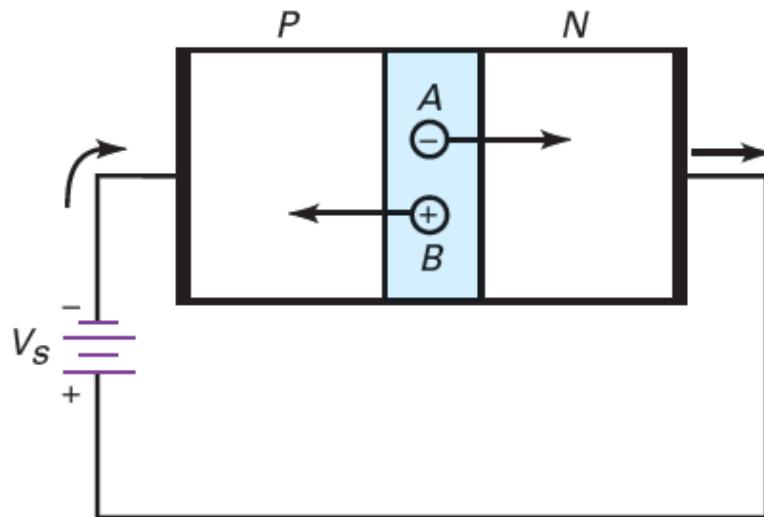
$\Delta$  = the change in

$$\frac{\Delta V}{\Delta T} = -2 \text{ mV/}^{\circ}\text{C}$$

$$\Delta V = (-2 \text{ mV/}^{\circ}\text{C}) \Delta T$$

# #13 Reverse-Biased Diode

- Transient Current
- *Reverse Saturation Current*
- *Survafe Leakage Current*



Permukaan kristal dengan hole

$$R_{SL} = \frac{V_R}{I_{SL}}$$

Perubahan arus saturasi 100% tiap peningkatan 10 C

Percent  $\Delta I_S = 100\%$  for a  $10^\circ\text{C}$  increase

Jika perubahan temperature < 10C

Percent  $\Delta I_S = 7\%$  per  $^\circ\text{C}$