



Fundamental of Electronics

Lecture 2-semiconductor

Part 1

EE1224

Fundamentals of Electronic Devices

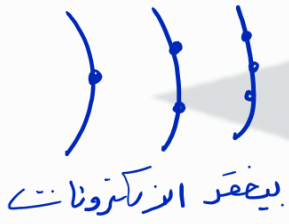


Material

Conductors

Semiconductor

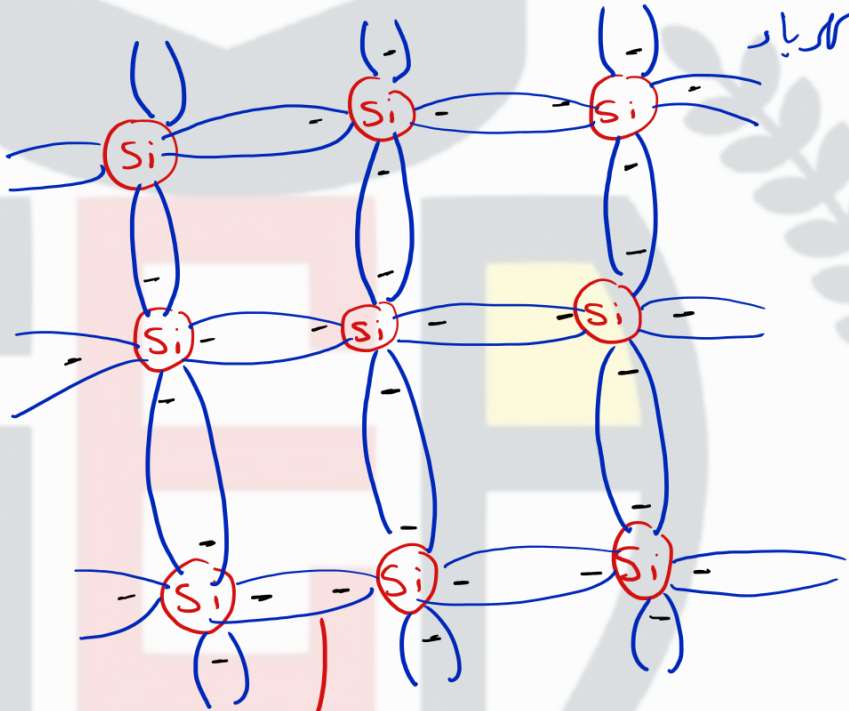
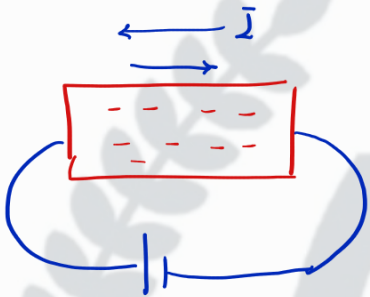
Insulators



لا يفقد الإلكترونات
لا يوجد الإلكترونات
لا يوصل الكهرباء

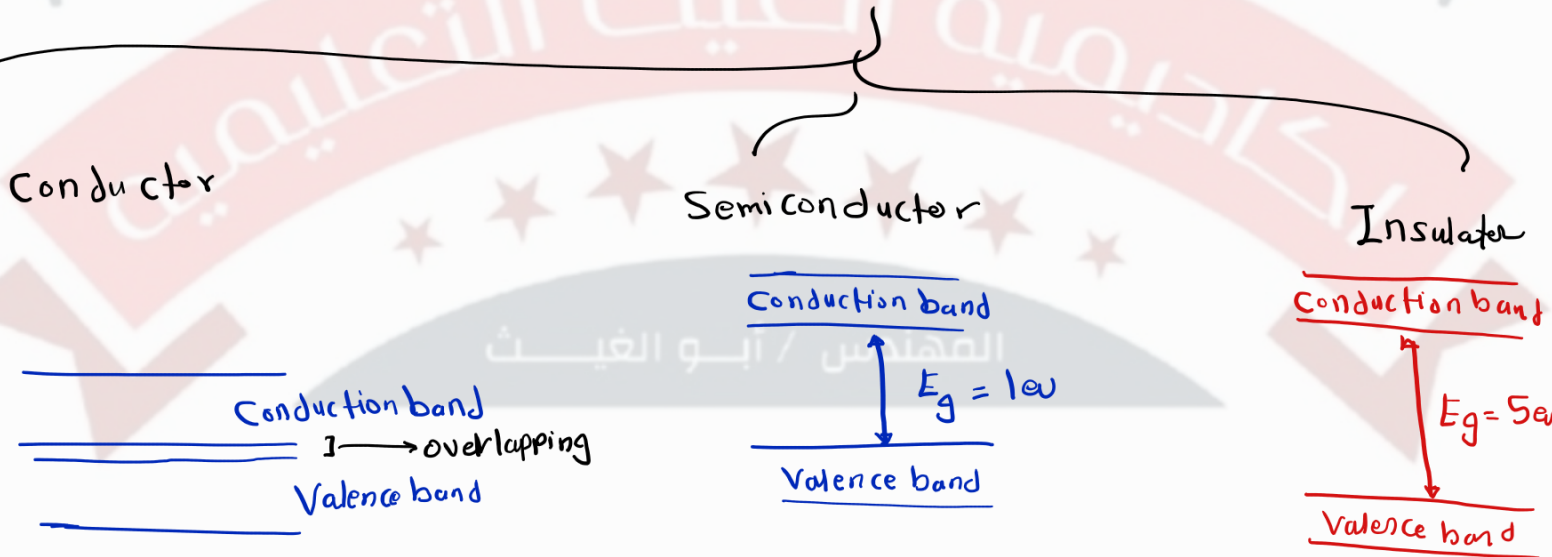
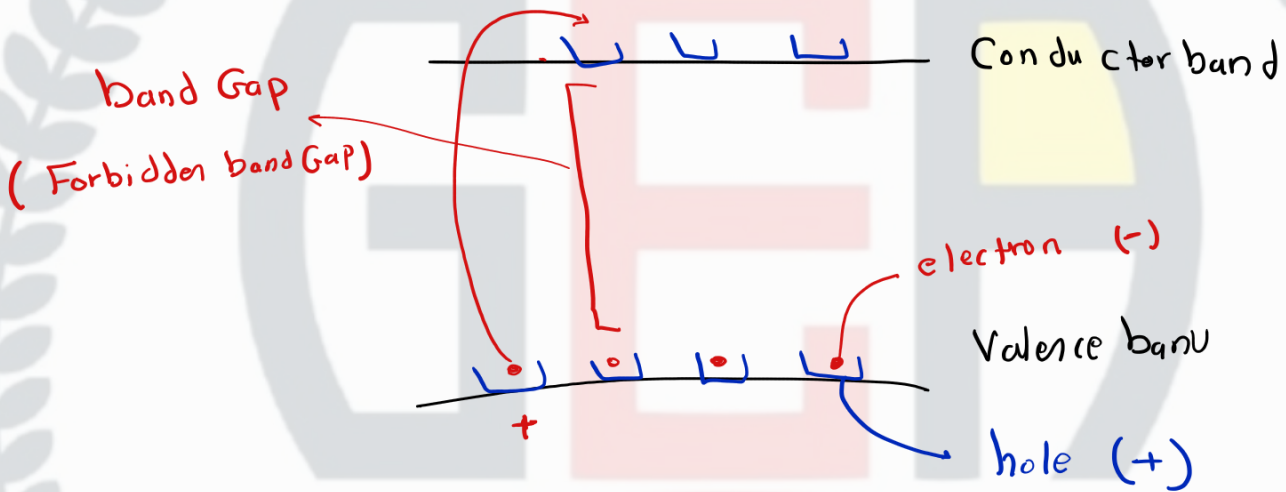
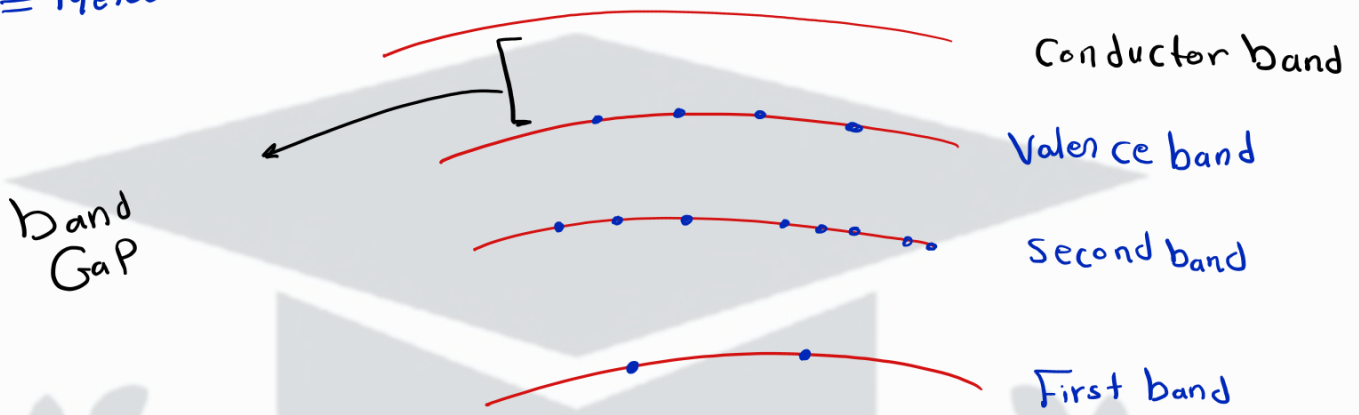
Si $\Rightarrow$ 14 electron

توصيل كهربائي



Covalent bond
الروابط التساهمية

Si = 14 electrons



Semi Conductors

Intrinsic

اشباه الموصلة نصفية مثل Si و Ge .
ذرات رباعية التكافؤ وبالتالي كل electron مرتبط بـ electron مجاور له.

• No free electron

$n = p = n_i$
تذكر electron
تذكر hole
intrinsic concentration
التركيز الداخلي

Extrinsic

نقوم بإضافة ذرات وهي عبارة
عن ذرات خماسية التكافؤ
أو ثلاثية التكافؤ ولذلك يوجد

Free electron
أو
Free hole

N-Type

P-Type

Doping
التطعيم

عن طريق

أكاديمية الغيث التعليمية

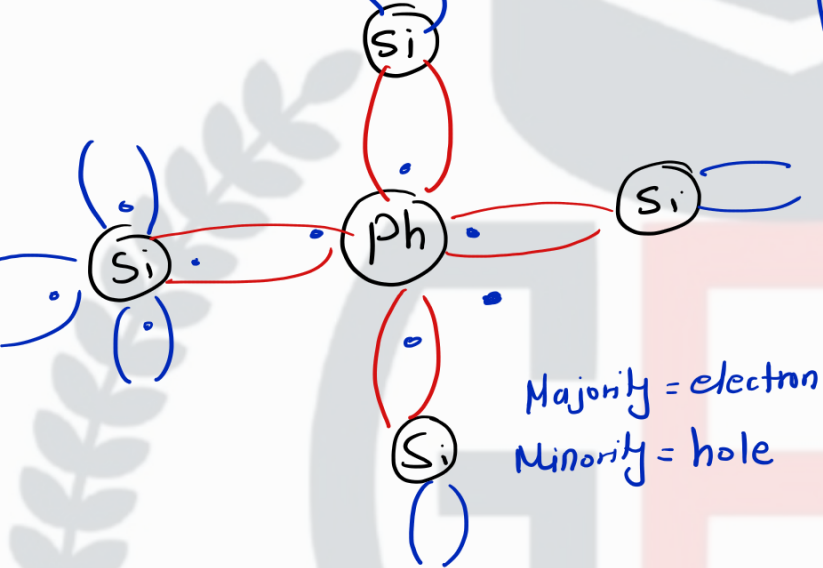
المهندس / أبو الغيث

Extrinsic Semiconductor

N-Type

is Doped with 5th

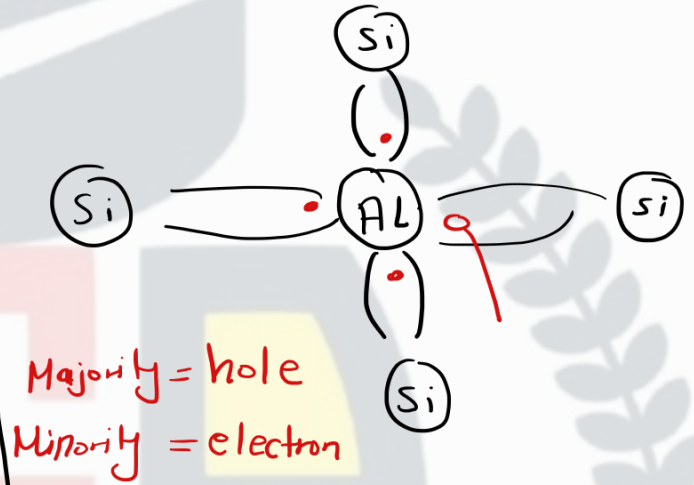
group electron



ph $\Rightarrow$ Donor

P-Type

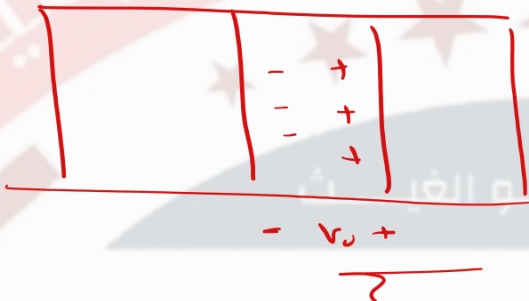
is Doped with 3th



AL $\Rightarrow$ Acceptor

current in semi conductor

Drift Current



Diffusion Current

"Concentration" نتيجة اختلاف
"Diffusion" يحدث انتشار



Semiconductor Materials and Properties

Conductors
Copper, Gold, and Silver

Semiconductors

Insulators
Glass, Plastics, and Paper

المادة موجودة في الطبيعة وفي الجدول الدوري

Two kinds of semiconductors:

① single-element semiconductors, such as germanium and silicon, group IV in the periodic table.

② compound semiconductors, such as gallium-arsenide, which are formed by combining elements from groups III and V or groups II and VI.

أكثر من مادة من بعض

1																	18																																																																											
1 H Hydrogen Nonmetal	2 He Helium Noble Gas																																																																																											
3 Li Lithium Alkali Metal	4 Be Beryllium Alkaline Earth Me.	Atomic Number										17 Cl Chlorine Halogen	Atomic Mass, u					35.45																																																																										
		Name										Symbol																																																																																
												Chemical Group Block																																																																																
11 Na Sodium Alkali Metal	12 Mg Magnesium Alkaline Earth Metal	13 Al Aluminum Post Transition Me.	14 Si Silicon Metalloid	15 P Phosphorus Nonmetal	16 S Sulfur Nonmetal	17 Cl Chlorine Halogen	18 Ar Argon Noble Gas	19 K Potassium Alkali Metal	20 Ca Calcium Alkaline Earth Me.	21 Sc Scandium Transition Metal	22 Ti Titanium Transition Metal	23 V Vanadium Transition Metal	24 Cr Chromium Transition Metal	25 Mn Manganese Transition Metal	26 Fe Iron Transition Metal	27 Co Cobalt Transition Metal	28 Ni Nickel Transition Metal	29 Cu Copper Transition Metal	30 Zn Zinc Transition Metal	31 Ga Gallium Metal	32 Ge Germanium Metalloid	33 As Arsenic Metalloid	34 Se Selenium Nonmetal	35 Br Bromine Halogen	36 Kr Krypton Noble Gas	37 Rb Rubidium Alkali Metal	38 Sr Strontium Alkaline Earth Me.	39 Y Yttrium Transition Metal	40 Zr Zirconium Transition Metal	41 Nb Niobium Transition Metal	42 Mo Molybdenum Transition Metal	43 Tc Technetium Transition Metal	44 Ru Ruthenium Transition Metal	45 Rh Rhodium Transition Metal	46 Pd Palladium Transition Metal	47 Ag Silver Transition Metal	48 Cd Cadmium Transition Metal	49 In Indium Metal	50 Sn Tin Post-Transition M.	51 Sb Antimony Metalloid	52 Te Tellurium Metalloid	53 I Iodine Halogen	54 Xe Xenon Noble Gas	55 Cs Cesium Alkali Metal	56 Ba Barium Alkaline Earth Me.	57 La Lanthanum Lanthanide	58 Ce Cerium Lanthanide	59 Pr Praseodymium Lanthanide	60 Nd Neodymium Lanthanide	61 Pm Promethium Lanthanide	62 Sm Samarium Lanthanide	63 Eu Europium Lanthanide	64 Gd Gadolinium Lanthanide	65 Tb Terbium Lanthanide	66 Dy Dysprosium Lanthanide	67 Ho Holmium Lanthanide	68 Er Erbium Lanthanide	69 Tm Thulium Lanthanide	70 Yb Ytterbium Lanthanide	71 Lu Lutetium Lanthanide	72 Hf Hafnium Transition Metal	73 Ta Tantalum Transition Metal	74 W Tungsten Transition Metal	75 Re Rhenium Transition Metal	76 Os Osmium Transition Metal	77 Ir Iridium Transition Metal	78 Pt Platinum Transition Metal	79 Au Gold Transition Metal	80 Hg Mercury Transition Metal	81 Tl Thallium Post-Transition M.	82 Pb Lead Post-Transition M.	83 Bi Bismuth Post-Transition M.	84 Po Polonium Metal	85 At Astatine Metal	86 Rn Radon Noble Gas	87 Fr Francium Alkali Metal	88 Ra Radium Alkaline Earth Me.	89 Ac Actinium Actinide	90 Th Thorium Actinide	91 Pa Protactinium Actinide	92 U Uranium Actinide	93 Np Neptunium Actinide	94 Pu Plutonium Actinide	95 Am Americium Actinide	96 Cm Curium Actinide	97 Bk Berkelium Actinide	98 Cf Californium Actinide	99 Es Einsteinium Actinide	100 Fm Fermium Actinide	101 Md Mendelevium Actinide	102 No Nobelium Actinide	103 Lr Lawrencium Actinide

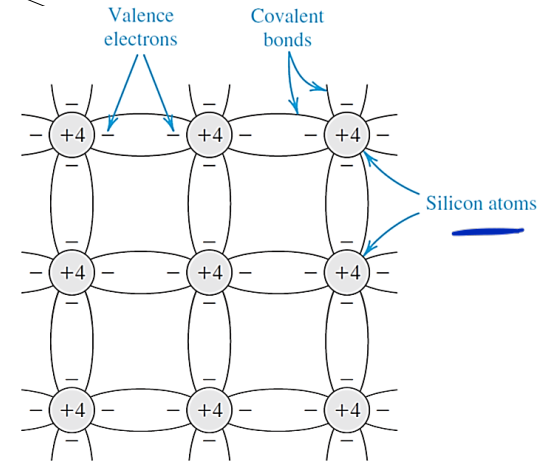
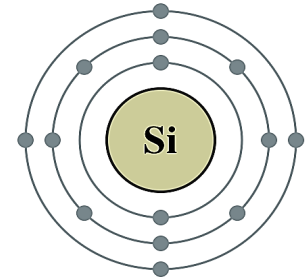
A. S. Sedra and K. C. Smi, *Microelectronic Circuit*, 7th ed. 2016, pp. 44.

"Periodic Table," Lam Research. [Online]. Available: <https://blog.lamresearch.com>

Semiconductor Materials and Properties

A. S. Sedra and K. C. Smi, *Microelectronic Circuit*, 7th ed. 2016, pp. 44.

Semiconductor Materials and Properties



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D. Neamen, *Microelectronics Circuit Analysis and Design*, 4th ed. 2010.

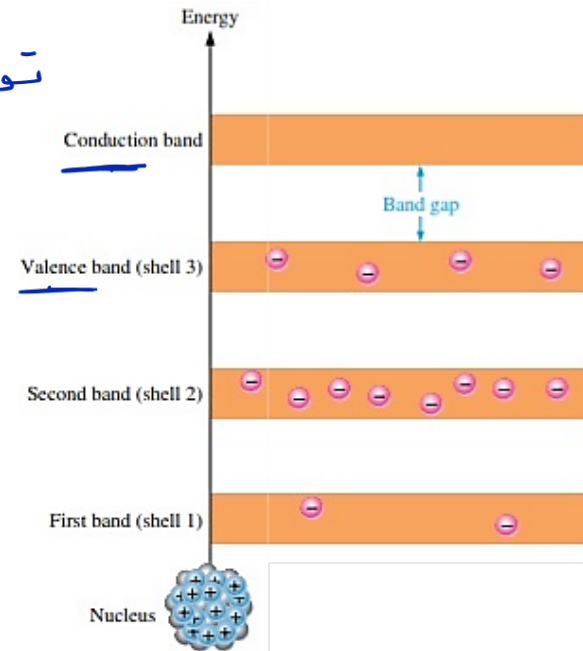
"Popular science homepage," *Popular Science*, 06-Jul-2021. [Online]. Available: <http://www.popsci.com/>.

Semiconductor Materials and Properties

توزيع الإلكترونات للمادة في الحالة الطبيعية (دورة إثارة)

- Energy band diagram for unexcited atom in a pure intrinsic silicon crystal.
- At sufficiently low temperatures, approaching absolute zero (0 K), all the covalent bonds are intact, and no electrons are available to conduct electric current.
- Thus, at such low temperatures, the intrinsic silicon crystal behaves as an insulator.

في درجات الحرارة المنخفضة المادة شبه الموصل تتصرف
كأنها مادة عازلة أي لا توصل الكهرباء



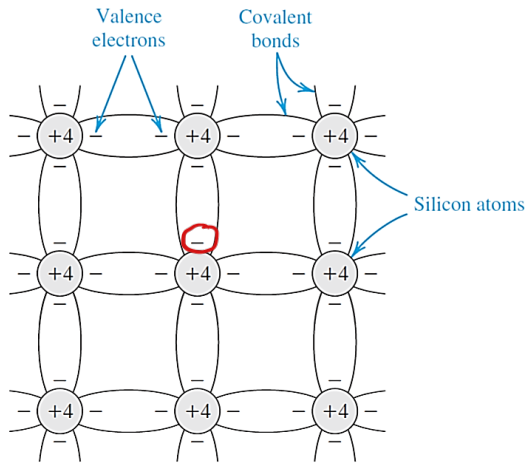
A. S. Sedra and K. C. Smi, *Microelectronic Circuit*, 7th ed. 2016.

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Henry, "Knowledge for all engineers," The Engineering Knowledge. [Online]. Available: <http://www.theengineeringknowledge.com/>.

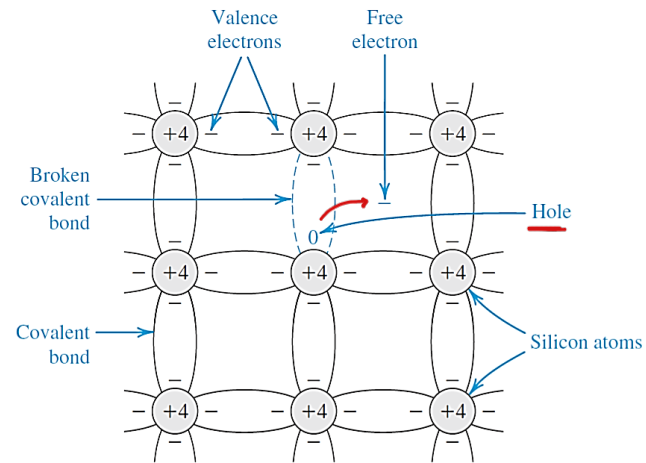
Semiconductor Materials and Properties

- Room Temperature effect:



At $T = 0 \text{ K}$

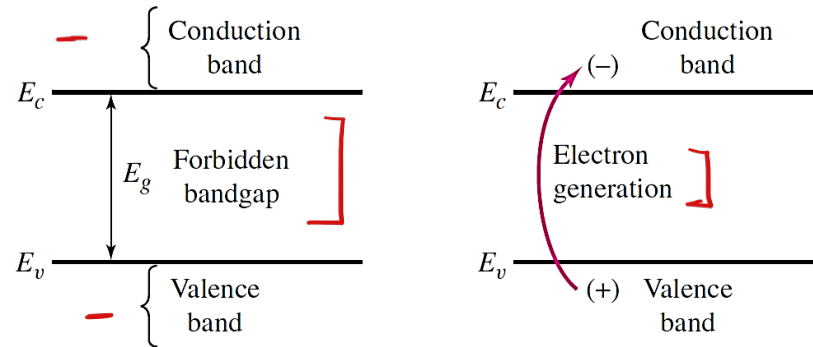
Increasing
Temperature



At $T > 0 \text{ K}$

when a covalent bond is broken, an electron is freed,
and hole is created (current can flow)

Semiconductor Materials and Properties

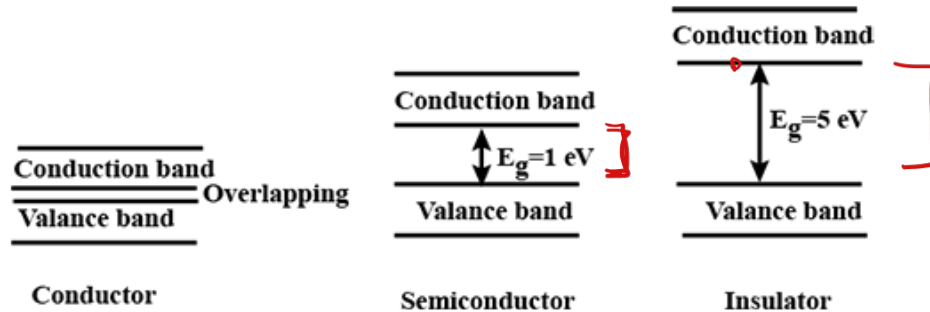


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Semiconductor Materials and Properties

- Insulator: large bandgap energies, in the range of 3 to 6 electron-volts (eV).
- Conductors: contain very large numbers of free electrons at room temperature.
- Semiconductor: the bandgap energy is on the order of 1 eV



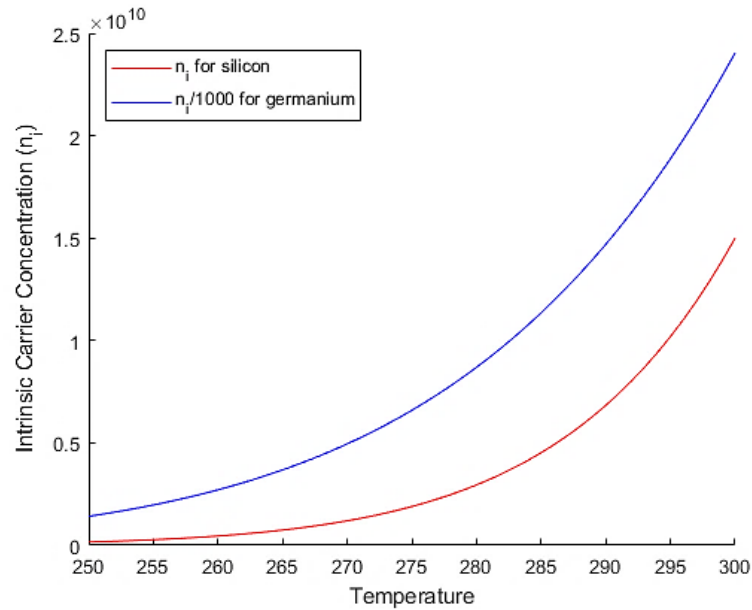
Semiconductor Materials and Properties

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Table 1.3 Semiconductor constants		
Material	E_g (eV)	B ($\text{cm}^{-3} \text{K}^{-3/2}$)
Silicon (Si)	1.1	5.23×10^{15}
Gallium arsenide (GaAs)	1.4	2.10×10^{14}
Germanium (Ge)	0.66	1.66×10^{15}

Semiconductor Materials and Properties



A. S. Sedra and K. C. Smi, *Microelectronic Circuit*, 7th ed. 2016.

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Semiconductor Materials and Properties

Extrinsic Semiconductor

- **Intrinsic semiconductor**: has equal concentrations of free electrons and holes, generated by thermal generation.
- These concentrations are far too small for silicon to conduct appreciable current at room temperature.
- To solve the issue: a method was developed to change the carrier concentration in a semiconductor crystal.
- This process is known as **doping**, and the resulting silicon is referred to as doped silicon.
- **Doping**: introducing impurity atoms into the silicon crystal to increase the concentration of either free electrons or holes.

توزيع الشحنات
اصنيق ذرات

Semiconductor Materials and Properties

Conductors
Copper, Gold, and Silver

Semiconductors

Insulators
Glass, Plastics, and Paper

- Two kinds of semiconductors:
 - single-element semiconductors, such as germanium and silicon, group IV in the periodic table.
 - compound semiconductors, such as gallium-arsenide, which are formed by combining elements from groups III and V or groups II and VI.

group	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

lanthanoid series	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

actinoid series	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

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Semiconductor Materials and Properties

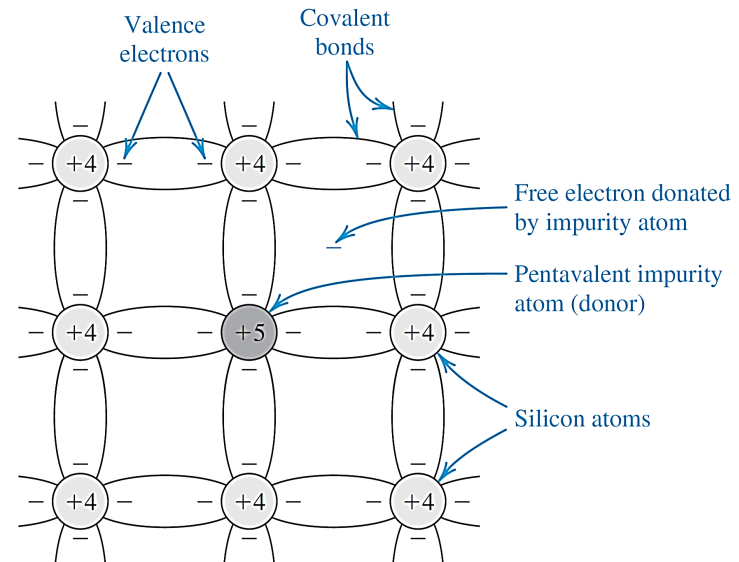
Extrinsic Semiconductor

- Increasing the concentration of free electrons (n) such as phosphorus

silicon is n-type

- Four of phosphorus's electrons form covalent bonds.
- The fifth electron becomes a free electron.
- Each phosphorus atom donates a free electron
- Phosphorus impurity is called a **donor**.
- No holes are generated by this process.**
- Electrons: majority carrier while holes: minority carrier

~~Doping~~ with an element with a valence of 5



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Semiconductor Materials and Properties

Extrinsic Semiconductor

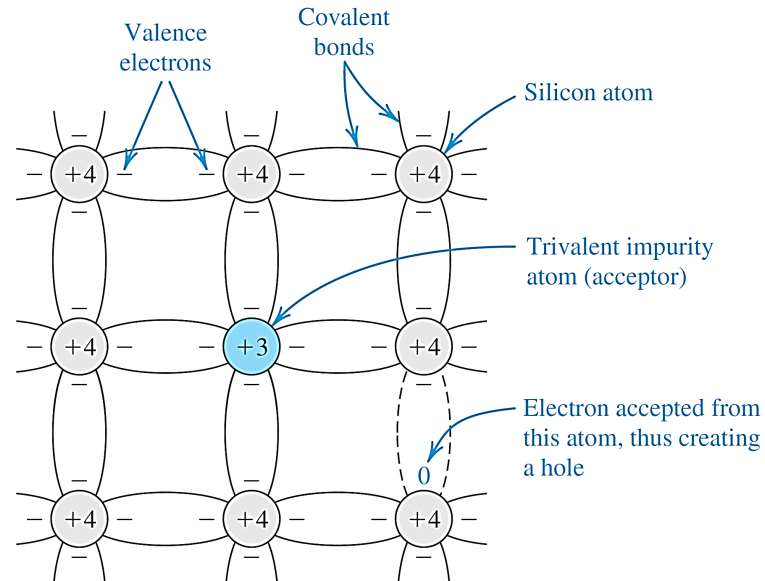
- Increasing the concentration of holes (p) — Doping with an element having a valence of 3 such as boron

silicon is ~~p-type~~

- Boron atom has three electrons in its outer shell.
- Accepting an electron from a neighboring atom
- The result is a hole in the neighboring atom
- Boron impurity is called an **acceptor**.
- Generating holes without electrons being generated.**
- Holes: majority carrier while electrons: minority carrier

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Semiconductor Materials and Properties



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Semiconductor Materials and Properties

Current Flow in Semiconductors



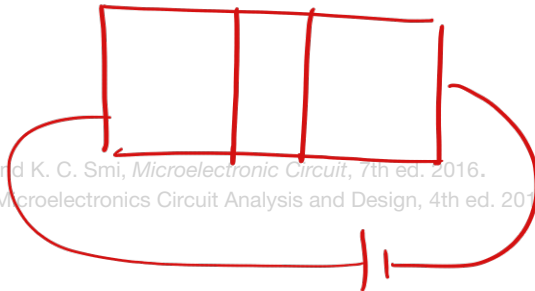
- Two different mechanisms for the movement of charge carriers (current flow in semiconductors):

Drift and Diffusion

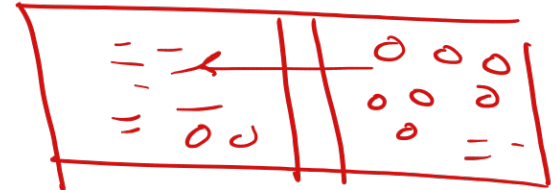


Movement caused by electric fields

الحمل الكهربي



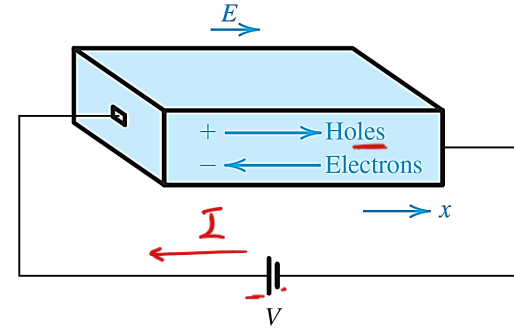
Flow caused by variations in the concentration



A. S. Sedra and K. C. SMI, *Microelectronic Circuit*, 7th ed. 2016.

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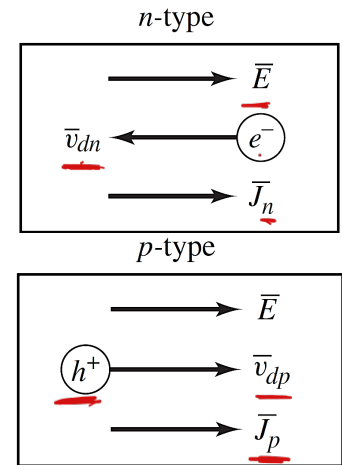
Semiconductor Materials and Properties



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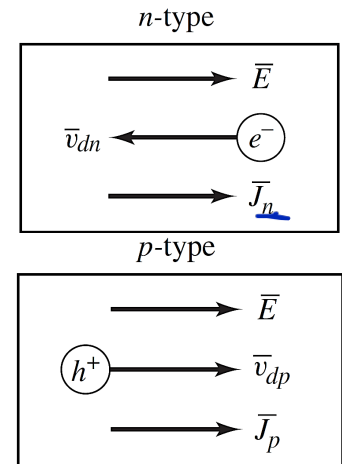
Semiconductor Materials and Properties



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Semiconductor Materials and Properties



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Semiconductor Materials and Properties



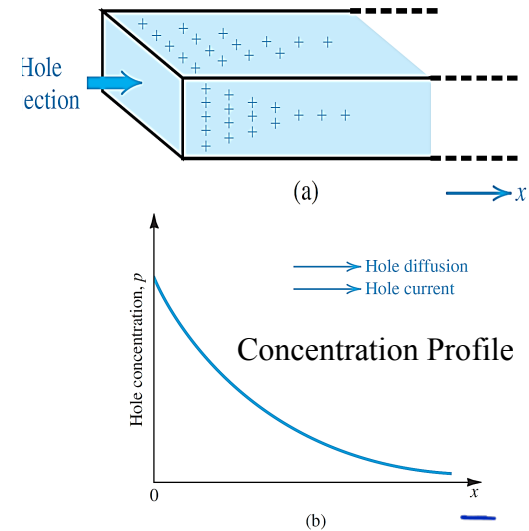
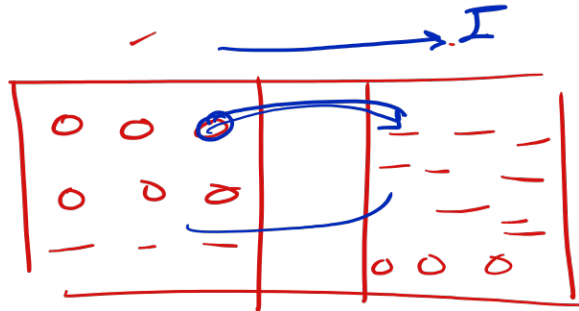
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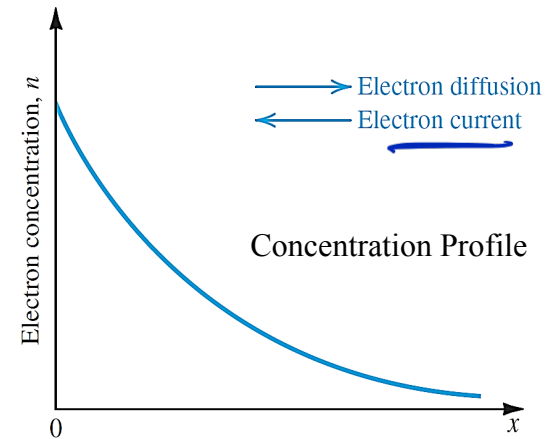
Semiconductor Materials and Properties

Diffusion Current

- Carrier diffusion occurs when the density of charge carriers in a piece of semiconductor is not uniform.
- Ex: hole concentration is made higher in one part of a piece of silicon than in another, then holes will diffuse from the region of high concentration to the region of low concentration.



Semiconductor Materials and Properties



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Semiconductor Materials and Properties



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