

Primer on Semiconductors

Unit 1: Material Properties

Lecture 1.4: Properties of common semiconductors

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Semiconductors

																		column IV						
Period																								
1	1 H																	2 He						
2	3 Li	4 Be																	5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg																	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr						
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe						
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn						
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo						
* Lanthanoids			57 La	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							
** Actinoids			89 Ac	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							

http://en.wikipedia.org/wiki/Periodic_table

III-V semiconductors

																		Col. Col.						
																		III		V				
Period																								
1	1 H																	2 He						
2	3 Li	4 Be															5 B	6 C	7 N	8 O	9 F	10 Ne		
3	11 Na	12 Mg															13 Al	14 Si	15 P	16 S	17 Cl	18 Ar		
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr						
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe						
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn						
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo						
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http://en.wikipedia.org/wiki/Periodic_table

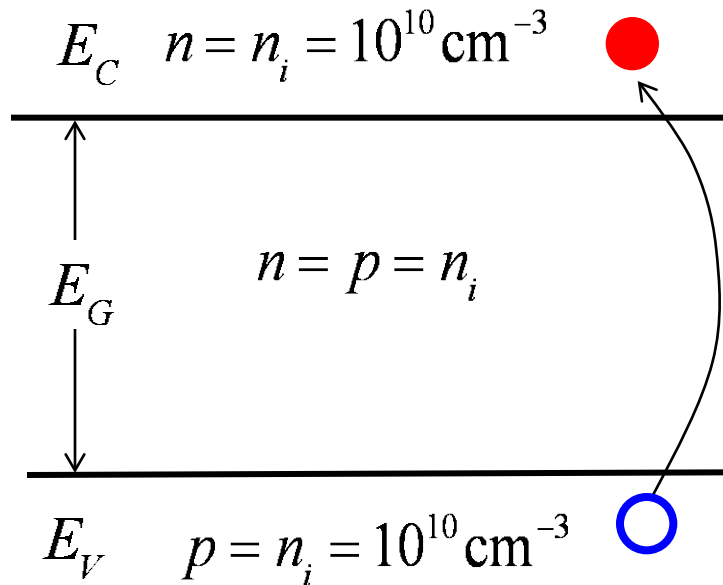
II-VI semiconductors

Col. II																		Col. VI									
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18									
1	1 H																	2 He									
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne									
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar									
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr									
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe									
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7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo									
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http://en.wikipedia.org/wiki/Periodic_table

Two key numbers

Intrinsic Si



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

$$n_i(\text{Si}) = 1 \times 10^{10} \text{ cm}^{-3} \quad (T = 300 \text{ K})$$

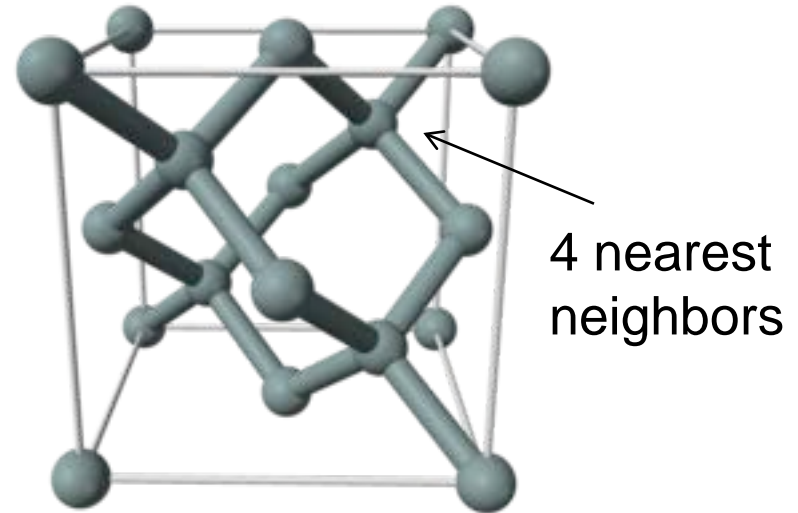
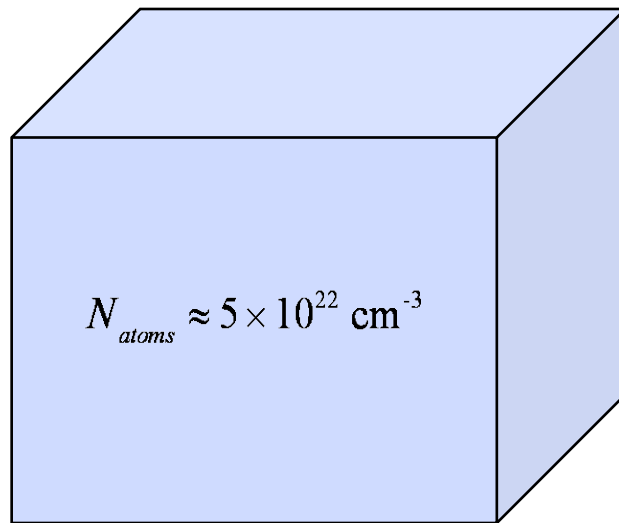
$$n_i \propto e^{-E_G/2k_B T}$$

A few common semiconductors

Semiconductor	Band gap (eV)	intrinsic density
Ge	0.663	$2.0 \times 10^{13} \text{ cm}^{-3}$
Si	1.125	$1.0 \times 10^{10} \text{ cm}^{-3}$
InP	1.344	
GaAs	1.422	$2.3 \times 10^6 \text{ cm}^{-3}$
CdTe	1.5	
6H SiC	2.99	
4H SiC	3.26	
GaN	3.4	

Later, we will learn how to calculate n_i .

Why is Si so common in electronics?

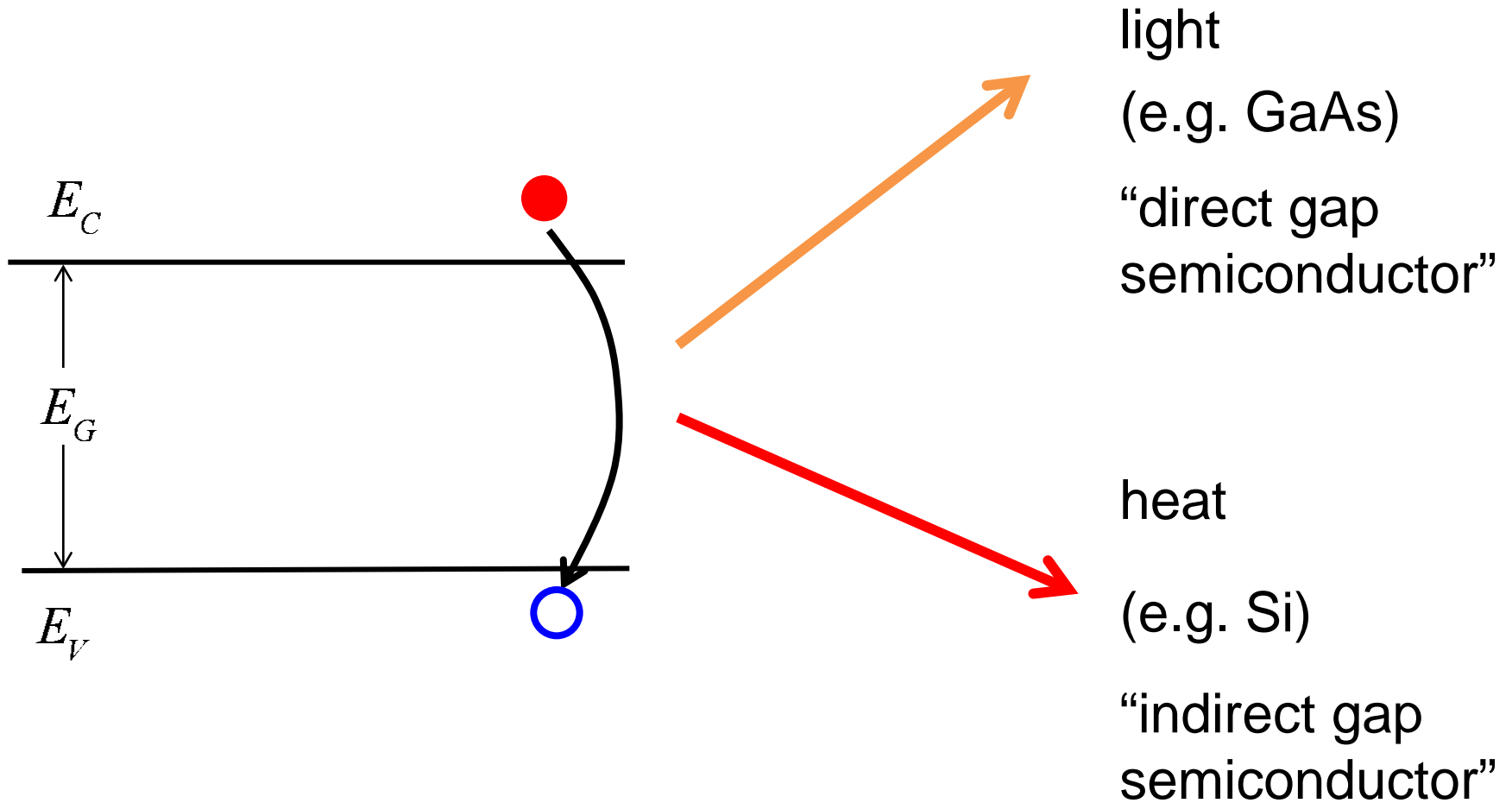


Inside the crystal, each atom has four nearest neighbors and all bonds are satisfied.

Surfaces are defects with many “dangling bonds”.

Silicon has a “native oxide” (SiO_2) that ties up dangling bonds and “passivates” the surface.

Recombination



Other properties

How fast do charge carriers move (mobility)?

What is the thermal conductivity?

At what electric field does the semiconductor “break down”?

Effective mass?

etc.

Summary

Silicon is the most commonly used semiconductor because it has a native oxide that passivates the surface.

Other semiconductors are used when Si isn't suitable (e.g. to make light-emitting devices).

The **bandgap and intrinsic carrier concentration** are two key (related) parameters for a semiconductor. We will encounter several other important parameters later.