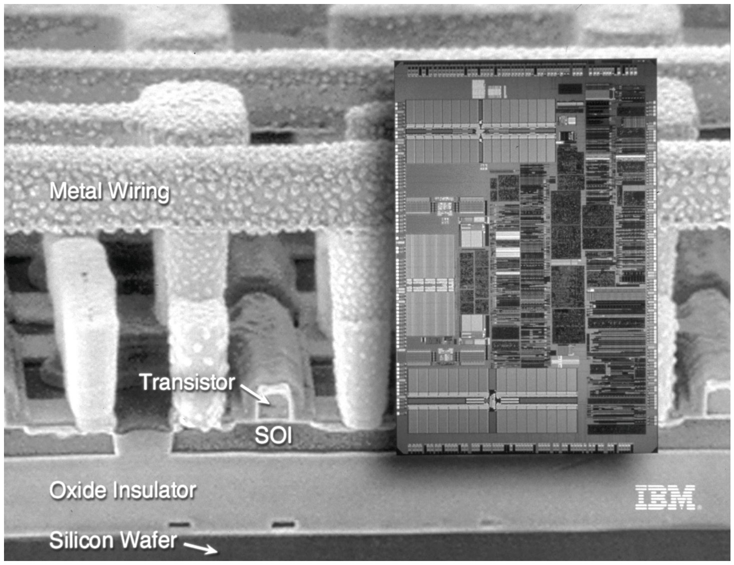
5.1 Intrinsic (pure) semiconductors

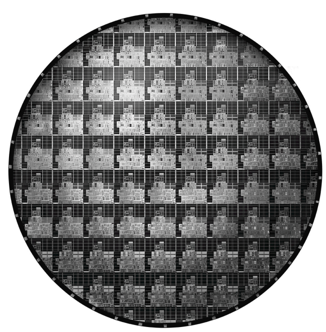
A few things:

- EASTER BREAK:
  - No class Friday 4/22 and Monday 4/25.
- LAB 4/26:
  - Lab report #2 due!
  - Please do NOT wear sandals or shorts, and preferably long sleeves.
- NO CLASS: Friday 4/29



200 mm and 300 mm Si wafers.

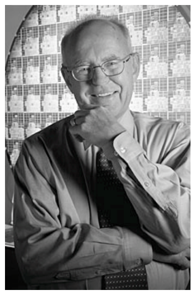
|SOURCE: Courtesy of MEMC, Electronic Materials, Inc.



Wafer of Intel Itanium® processors

http://www.intel.com/pressroom/kits/events/moores_law_40th/index.htm

Moore's Law:
The number of transistors on a chip
will double every two years.



Gordon Moore,
Co-founder Intel Corp.
Source: Intel

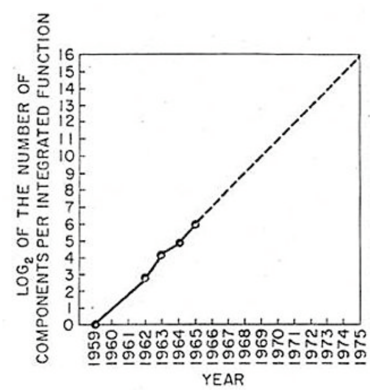


Fig. 2 Number of components per Integrated function for minimum cost per component extrapolated vs time.

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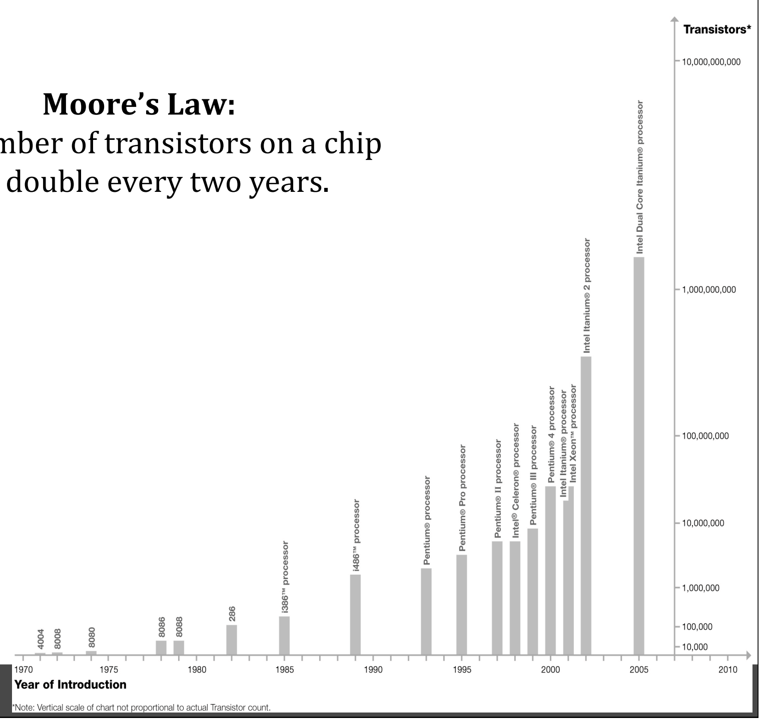


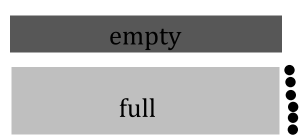
Year	Processor name	Transistor count	Minimum feature size
1971	4004	2300	10 micron
1974	8080	6000	6 micron
1978	8086	29000	3 micron
1982	80286	134,000	1.5 micron
1989	Intel486	1.2 million	1 micron
1993	Pentium	3.1 million	800 nanometer
1997	Pentium II	7.5 million	350 nanometer
1999	Pentium III	28 million	180 nanometer
2006	Core 2 Duo	291 million	65 nanometer
2008	Xeon 7400	1900 million	45 nanometer
2011	Xeon Westmere-EX	2600 million	32 nanometer

Source: Intel

2013: 14 nanometer

Semiconductor:

Half way in between a conductor and an insulator.



Small gap to empty levels, shallow pit.

Today's questions:

What is a "big" gap vs a "small" gap?

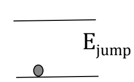
What is a significant vs insignificant amount of doping impurities?

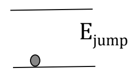
(and how pure does a semiconductor have to be to use it in electronics?)

If the band gap is **3 eV**, what is probability that an electron will jump to higher energy level due to thermal energy
(*no other electrons filling that level*)?

At T=0 K ?

A. large
B. small
C. zero
D. need more info





T = 0 K ?   C. zero

Probability is high if the thermal energy is greater than the “jump” energy

$$P(E_{jump}, T) \sim e^{-E_{jump}/kT}$$

At room temperatrue, if the band gap is 3 eV, how many electrons can get up into the conduction band and can move?

Assume that the number of electrons (per unit volume) near the top of the valence band is $10^{22}/cm^3$

A. $\sim 10^{22}$ electrons/cm^3
B. $\gg 10^{22}$ electrons/cm^3
C. $\ll 10^{22}$ electrons/cm^3

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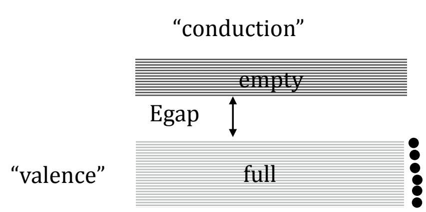


What if 0.3 eV band gap?

$P = e^{-0.3/(1/40)} = e^{-12}$

Electrons in conduction band = $e^{-12}\, 10^{22}/cm^3$
$= 10^{-5}\, 10^{22} = 10^{17}$ electrons/cm^3

Not great conductor, good conductor.

If we were to dope a semiconductor with a material with one extra electron (such as doping Si with P), we would need to introduce 10^{17} impurity atoms to match the 10^{17}electrons/cm^3 in the conduction band of previous question.

What must be the initial purity of the (Si) sample?

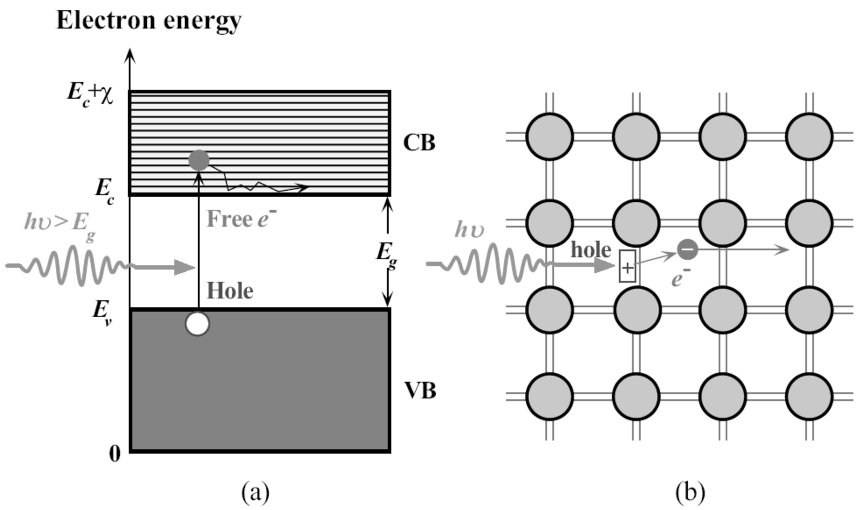
Initial sample must have:

A. ~ 1 impurity per 10^{17} atoms
B. << 1 impurity per 10^{22} atoms
C. << 1 impurity per 10^{17} atoms
D. << 1 impurity per 10^{5} atoms

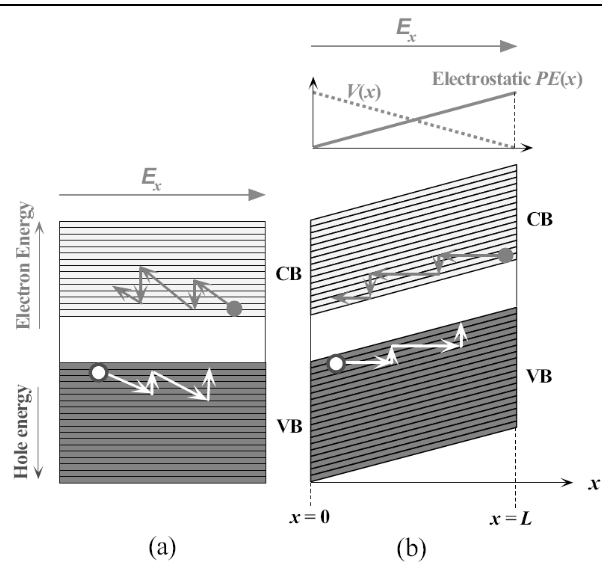
If we were to dope a semiconductor with a material with one extra electron (such as doping Si with P), how many impurity (P) atoms would we need to match the 10^{17} e^-/cm^3 in the conduction band of previous question?

10^{22} atoms/cm^3
10^{17} impurity atoms/cm^3
$10^{17}/10^{22}$ impurity atoms / atom = 10^{-5} impurities / atom

Initial sample must have << 1 impurity per 10^{5} atoms!



Electron energy
Ec+χ
CB
Ec
hυ > Eg
Free e-
Eg
Hole
Ev
VB
0
hυ
hole
+
e-
(a)
(b)



Ex
Electrostatic PE(x)
V(x)
Electron Energy
Hole energy
CB
VB
x
x = 0
x = L
(a)
(b)

The conductivity of metals decreases with increasing temperature due to electron collisions with vibrating atoms. In contrast, the conductivity of semiconductors increases with increasing temperature. What property of a semiconductor is responsible for this behavior?

A. Atomic vibrations decrease as temperature increases.
B. The number of conduction electrons and the number of holes increase steeply with increasing temperature.
C. The energy gap decreases with increasing temperature.
D. Electrons do not collide with atoms in a semiconductor.

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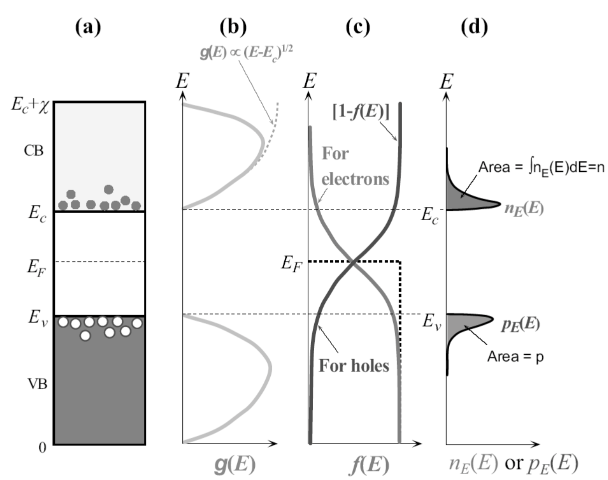
All materials obey Ohm's Law:

A. True
B. False



How do we calculate n and p?

Happy Easter!

Enjoy the break.

(but don't forget about your lab report)