Activity (R): The activity of any radioactive nuclide is the rate at which the nuclei of its constituent atoms decay. If N is the number of nuclei present in the sample at a certain time, its activity R is given by

$$R = -\frac{dN}{dt}$$

SI unit of activity is Becquerel (Bq).

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Traditional unit of activity is curie (Ci)

1Ci= 3.7×10^{10} Bq= 37GBq

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probability per unit time that a nucleus of radionuclide will decay

Half life: $\frac{1}{2} R_o = R_o e^{-\lambda T_{1/2}}$, $e^{\lambda T_{1/2}} = 2$, $\lambda T_{1/2} = \ln 2$, $T_{1/2} = \frac{0.693}{\lambda}$

$\lambda \rightarrow$ probability per unit time

$\lambda dt \rightarrow$ probability that a nucleus will decay in time interval dt

$N \rightarrow$ initially present nuclei (undecay)

$dN \rightarrow$ no. of nuclei that decay in time dt

$dN = ?$

$$dN = -\lambda N\,dt$$

(-) sign N decreasing with time t.

$$\int_{N_0}^{N} \frac{dN}{N} = \int_0^t -\lambda\,dt$$

$$\ln N - \ln N_0 = -\lambda t$$

$$\ln \frac{N}{N_0} = -\lambda t$$

$$\boxed{N = N_0 e^{-\lambda t}}$$

Radioactive decay

<u>Mean</u> <u>lifetime</u> $(\overline{T})$ Reciprocal of its decay probability per unit time

$$\overline{T} = \frac{1}{\lambda}$$

$$\overline{T} = \frac{T_{1/2}}{0.693} = 1.44\,T_{1/2}$$

1) A piece of radioactive material is initially observed to have 1,000 decays/sec. Three hours later, you measure 125 decays / second. The half-life is
   1) ½ hour
   2) 1 hour
   3) 3 hours
   4) 6 hours

2) Radium was isolated by Marie Curie in 1898. It has a half-life of 1,600 years and decays by alpha-emission. The resulting element is
   1) Polonium (84 electrons)
   2) Thorium (90 electrons)
   3) Radon (86 electrons)

alpha= ${}^{4}_{2}He$

3) The 14C:12C ratio in a fossil bone is found to be 1/8 that of the ratio in the bone of a living animal. The half-life of 14C is 5,730 years. What is the approximate age of the fossil?
   1) 7640 years
   2) 17200 years
   3) 22900 years
   4) 45800 years

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$$T_{1/2} = \frac{0.693}{\lambda}$$

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Nuclear Physics: What have we learnt so far?

- Few terms
- Radioactive decay
- Binding Energy
- Binding Energy per nucleon curve
- Liquid drop and Shell model

Properties of materials

1. Electrical
2. Thermal
3. Mechanical

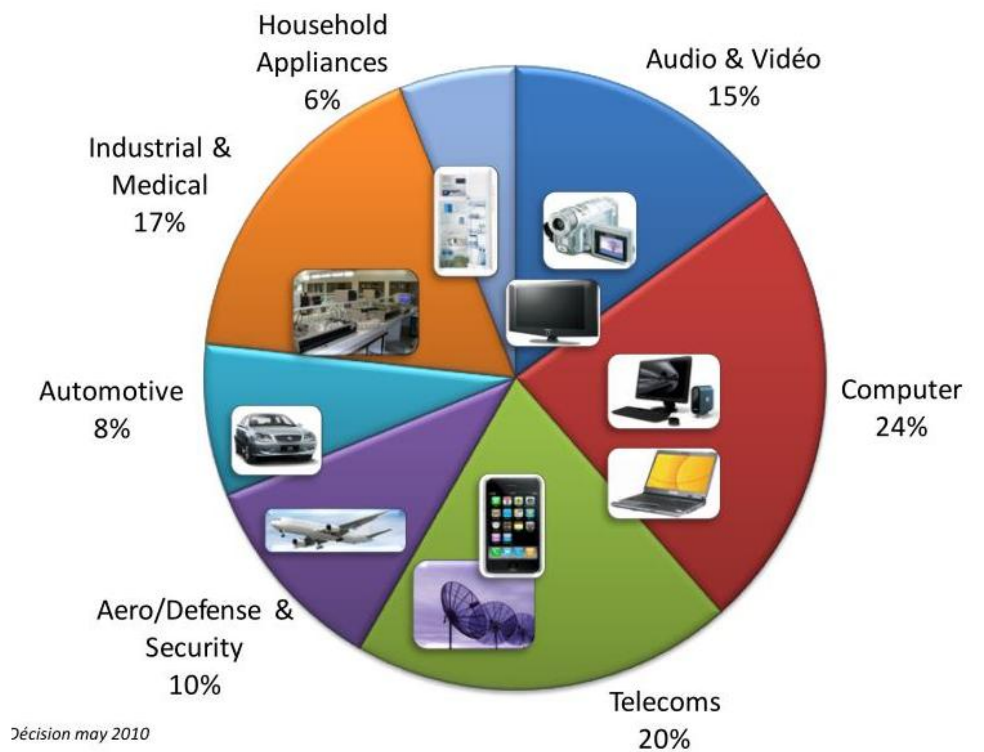
Electrical conductivity

Electrical conductivity: the ease with which charge carriers (electrons or hole) move with applied electric field.

1. Why important to study electrical conductivity?

   Design and study electrical devices

   Semiconductors are everywhere



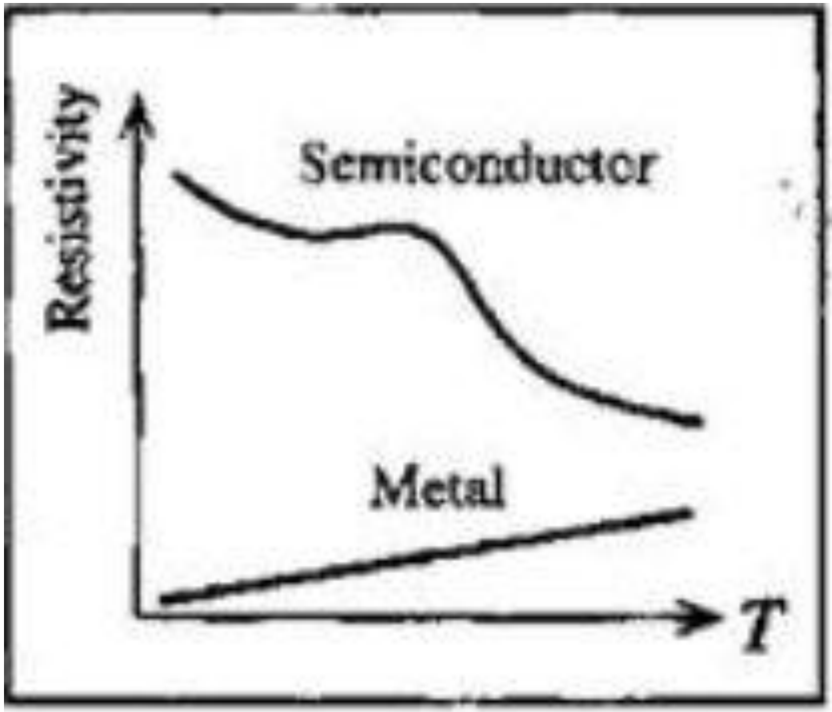
Electrical conductivity

1. Conductor/metals: Copper, Brass, Steel, Gold, and Aluminium
2. Insulator-Glass, Air, Wood, Plastic and Rubber
3. Semiconductor – Silicon, Germanium, GaAs, GaN

Reciprocal of electrical conductivity is electrical resistivity

$$\sigma = \frac{1}{\rho}$$

σ – conductivity
ρ – resistivity

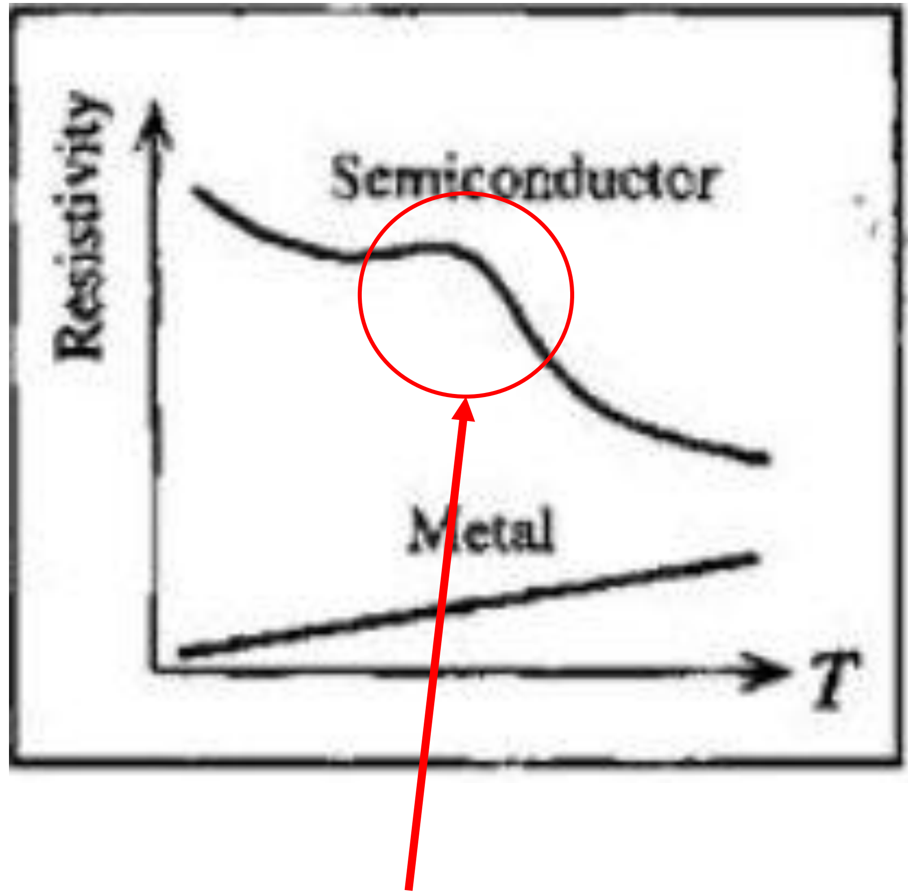


σ=neu

n -> carrier concentration

e-> electronic charge

u -> mobility (how easily an electron moves in an applied electric field)



Depend on doping

Metal: Increase in temperature, increase lattice vibration and decrease mobility of electron; thus conductivity decrease and hence resistivity increases

Semiconductor : carrier concentration and mobility of semiconductor increases with increase in temperature and thus conductivity of semiconductor increases with temperature. Resistivity of semiconductor decrease with increase in temperature in semiconductor

Thermal property

Which material has the highest thermal conductivity?
What causes a glass baking dish to break if it is cooled too quickly after being removed from oven?
Why this occurred?

How heat energy is transferred?

Phonons and electrons

Phonons- quanta of lattice vibration

1. **Heat Capacity**: The energy required to change the temperature of the material one degree is the *heat capacity*. When the energy required to change the temperature of one mole of a material by one degree, then it is *specific heat capacity*.
(Heat capacity at constant pressure) C_p= 3R
Why not heat capacity at constant volume?
solids volume don't expand on heating
2. **Thermal expansion:** an atom that gains thermal energy and begins to vibrate behaves as though it has a larger atomic radius. The average distance between atoms and therefore overall dimension of material changes. Change in dimensions of the material Δl per unit length is given by linear coefficient of thermal expansion α.

$$\alpha = \frac{\Delta l}{l_o \Delta T} = \frac{l_{f-}l_i}{l_o(T_{f-}T_i)}$$

3. **Thermal conductivity (k):** It is a measure of the rate at which heat is transferred through a material.

$$\frac{Q}{A} = -k\frac{\Delta T}{\Delta x}$$

Negative sign tells heat flux is from higher temperature to lower temperature regions so that $\frac{\Delta T}{\Delta x}$ is negative.

Ref.-The Science and Engineering of Materials- Askeland and Wright

Thermal property

- Which material has the highest thermal conductivity?
- <u>Diamond (2000 W/mK)</u>

- What causes a glass baking dish to break if it is cooled too quickly after being removed from oven?
- Thermal shock

- Why this occurred?
- <u>Thermal expansion</u>

Thermal shock: failure of a material due to sudden change in temperature.

Mechanical property

1. Elasticity: The property of a substance by which it regains its original shape and size when the deforming force is removed.
2. Stress: When we apply an external deforming force on an object, the particles of the object, in turn, apply a restoring force in the opposite direction to the deforming force. This restoring force per unit area is termed as stress.
   The magnitude of the stress = F/A

3. Strain: When stress is applied, a certain deformation is created. i.e, the particles are displaced from their original position. This displacement of particles on the application of stress is known as strain. It is expressed as the ratio of change in dimension to the original dimension.

$$\text{Strain} = \frac{\text{Change in length}}{\text{Original length}}$$

or

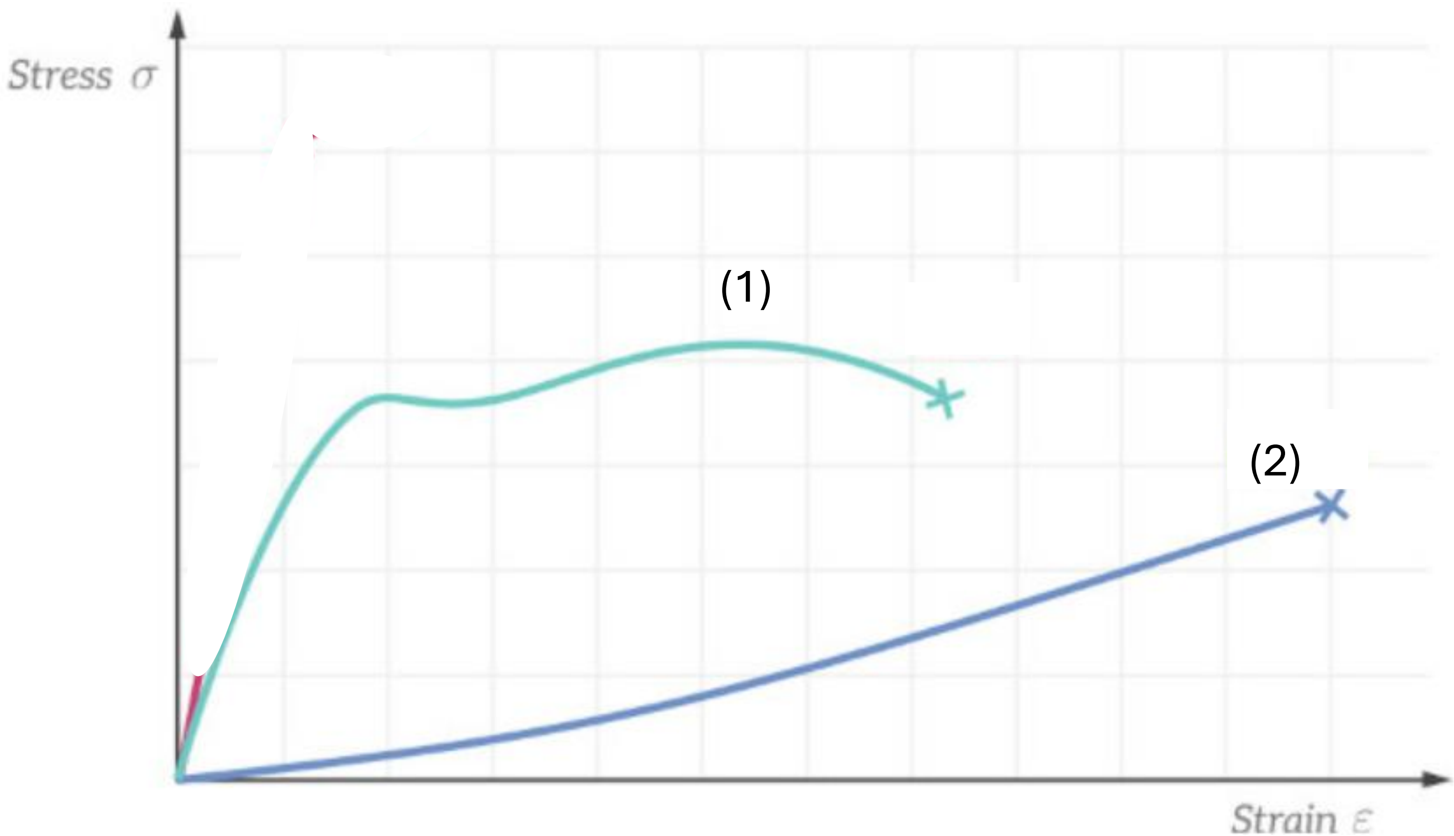
$$\varepsilon = \frac{\Delta L}{L}$$

4. **Hooke's Law**: It is the relationship between stress and strain. According to Hooke's law, stress is directly proportional to strain.

stress = k × strain

K here is proportionality constant and is known as modulus of elasticity.

5. Stress-Strain Curve: It is a graph showing the relationship between stress and strain of a given material under a given deforming force. The graph shows different behavior for different materials.



Which is more elastic- rubber or steel?

Optical property

Transmittance:

-- Aluminum oxide may be transparent, translucent, or opaque depending on the material's structure (i.e., single crystal vs. polycrystal, and degree of porosity).

single crystal

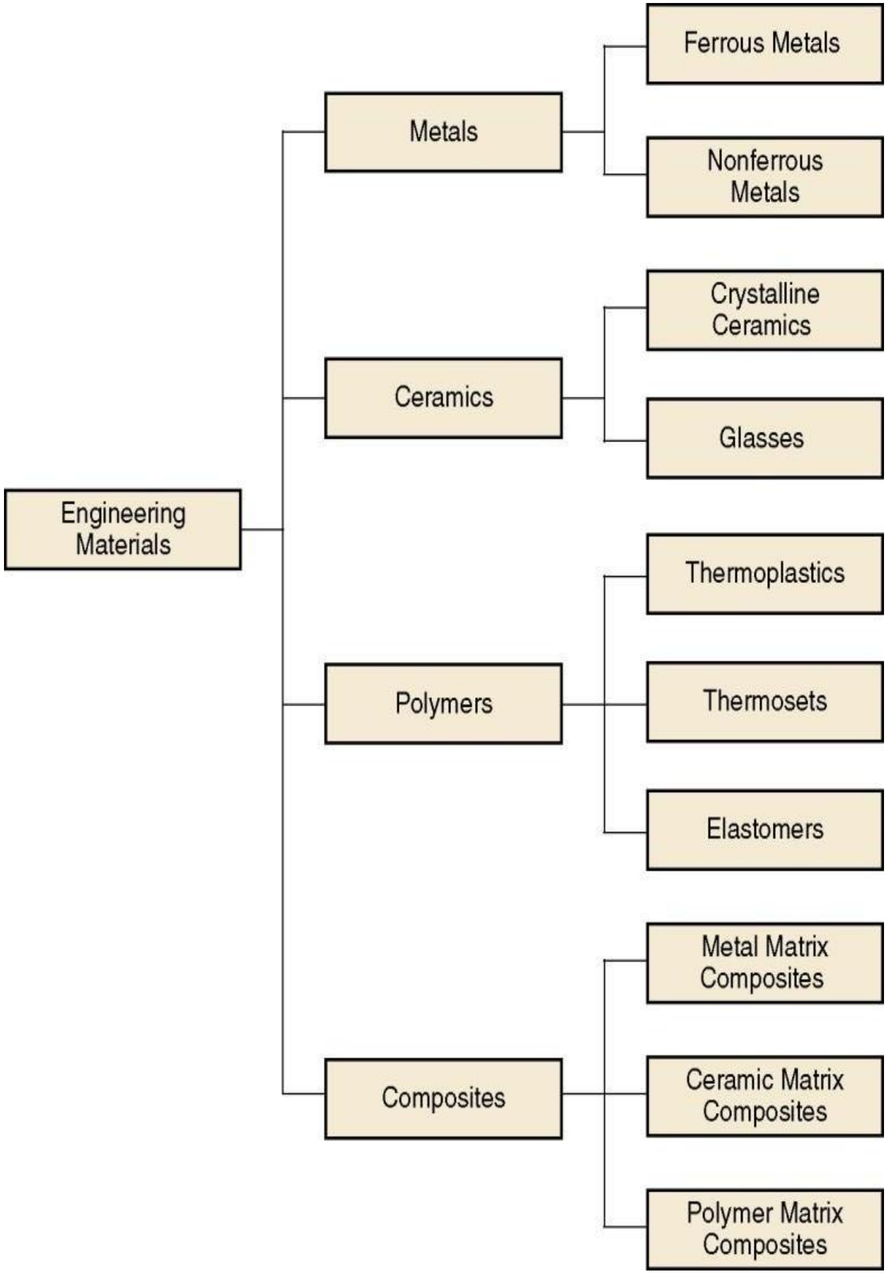
polycrystal: no porosity

polycrystal: some porosity

Fig. 1.2, *Callister & Rethwisch 9e.* (Specimen preparation, P.A. Lessing)

Types of materials

Ref: Fundamentals of Modern Manufacturing materials: processes and systems, M.P. Groover, 5th edition, John Wiley & Sons Inc. (2007).



METALS

Metallic bonds

- Strong, ductile, resistant to fracture
- High thermal & electrical conductivity
- Opaque, reflective.

Familiar objects that are made of metals and metal alloys

CERAMICS

Ionic bonding

- –Brittle, glassy, elastic
- –Non-conducting (insulative to the passage of heat & electricity)
- –Transparent, translucent, or opaque
- –Some exhibit magnetic behavior (e.g. Fe_3O_4)

Familiar objects that are made of ceramic materials

POLYMERS/PLASTICS

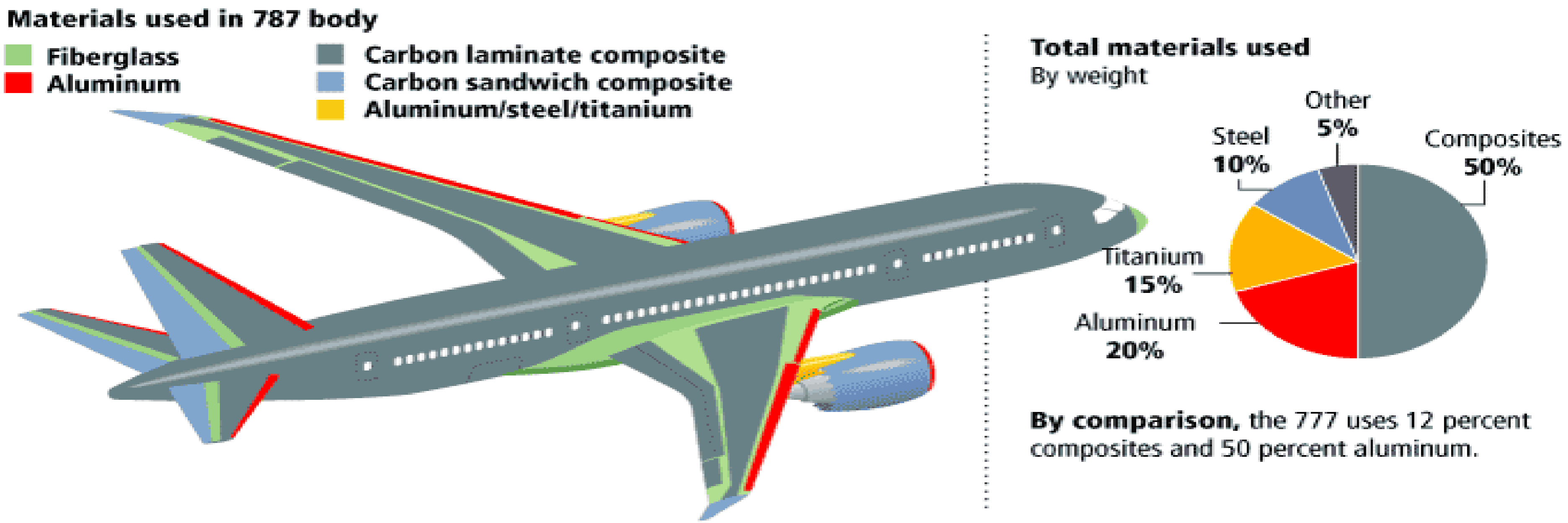
Covalent bonding- sharing of electrons

- –Soft, ductile, low strength, low density
- –Thermal & electrical insulators
- –Optically translucent or transparent.
- –Chemically inert and unreactive
- –Sensitive to temperature changes

Familiar objects that are made of polymeric materials

COMPOSITES

- Light, strong, flexible
- High costs



From previous class