Super conducting materials ;

One of the most interesting and unusual properties of solids is that certain metals and alloys exhibit almost zero resistivity (i.e. infinite conductivity) when they are cooled to sufficiently low temperatures. This phenomenon is called superconductivity.

Eg. : Pure mercury, Tin

General Features of superconductors ;

The temperature at which the transition from normal state to super conducting state takes place on coolling in the absence of magnetic field is called the critical temperature (T_c) or the transition temperature.

Features :

1. Superconductin elements, in general lie in the inner columns of the periodic table.
2. Superconductivity is found to occur in metallic elements in which the number of valence electron (z) lies between 2 and 8.
3. Transition metals having odd number of valence electrons are favourable to exhibit super conductivity while metals having even number of valence electrons are infavourable.
4. Materials having high normal resistivities exhibit super conductivity.
5. Materials for which $Z_p > 10^6$ (where Z is the number of valence electrons and p is the resistivity) show superconductivity.
6. Superconductivity is also favoured by small atomic volume, accompanied by a small atomic mass.
7. This transition temperature is different for different substances.
8. For a chemically pure and structurally perfect specimen, the superconducting transition is very sharp. For impure specimens and for those which are structurally imperfect, the transition range is broad (above one tenth of a degree)
9. For elements in a given row in the periodic table. T_c verus z^2 gives straight line.
10. Ferromagnetic and antiferromagnetic materials are not superconductors.
11. In addition to the drop in electrical resistivity to zero when cooled to transition temperature the following changes also occur.

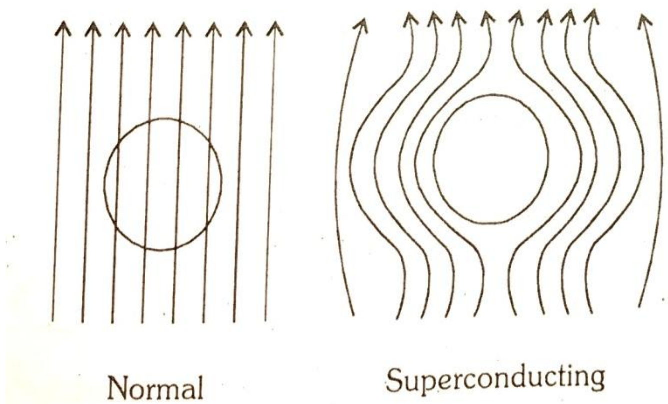
i) the magnetic flux lines are rejected out of the superconductor.

ii) there is a discontinuous change in specific heat.

iii) there are small changes in thermal conductivity and the volume of the material.

The Meissner effect :

When a weak magnetic field is applied to a superconducting specimen at a temperature below transition temperature T_c, the magnetic flux lines are expelled. The specimen



$T > T_c$ or $H > H_c$ $\quad$ $T < T_c$ or $H < H_c$

acts as an ideal diamagnet. This effect is called Meissner effect. This effect is reversible, i.e, when the temperature is raised from below T_c, at

$T = T_c$ the flux lines suddenly start penertrating and the specimen returns back to the normal state.

Critical magnetic field in superconductor :
For a given temperature T, when the strength of the applied magnetic field reaches a critical value H_c, the superconductivity disappears.

$$H_c(T) = H_c(O)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

where H_c (O) is the critical field at 0 K. H_c (O) and T_c are constant and characteristic of the material.

Isotope effect in superconductivity :
In superconducting materials the transition temperature varies with the average isotopic mass M of its constituents. The variation follows the general form.

$Tc \; \alpha \; M^{-\alpha}$

or $M^{\alpha} \; T_c$ = constant

where α is called the isoptope effect coefficient

High T superconductors :
Any superconductor with a transition temperature above 10 k is general called high T_c superconductor.

Examples :

$YBa_zCu_3O_7$	T_c = 92k
La_2-xSr_xCuO_4	T_c = 38k

Magnetci Levitation ;
Diamagnetic property of a super conductor, namely rejection of magnetic flux lines is the basis of magnetic levitation. A superconducting material can be suspended in air against the repulsive force from a permanent magnet. This magnetic levitation effect can be used for high speed transportation without frictional loss.

SQUIDS ;
SQUIDS – Superconducting Quantum Interference Device.

Types of Superconductors :
Superconductors are classified in accordance with their diamagnetic response.
Superconductors which exhibit a complete Meissner effect (perfect diamagnetism) are called type I Superconductors also known as soft superconductors. In this case, the diamagnetism abruptly disappears at the critical magnetic field H_c and the transition from superconducting to normal state is sharp.
On the other hand, in type II superconductors (also called hard superconductors). the diamagnetism starts disappearing gradually at a lower critical field H_{c1} and only at a upper critical field H_{c2} looses complete diamagnetism and becomes normal conductor.

metallic Glasses :
Metallic glasses are new type of engineering materials with high strength, good magnetic properties and better corrosion resistance. metallic glasses share the properties of both metals and glasses. They are morphous alloys with an atomic configuration similar to that of the molten liquid that has no translational symmetry. Metallic glasses are prepared by quenching the molten alloy very rapidly at the rate of 10^6 k/ second.

Use of metallic glasses :

Metallic glasses are ferromagnetic. They posses low magnetic losses, high permeability and saturation magnetization with low coercively. They also have extreme mechanical hardness, excellent initial permeability and zero magnetostriction. These properties make them useful as transformer core materials. Moreover power transformer made of metallic glass are smaller in size and efficient in their performance.

Nanophase materials ;

- Nanophase materials are materials with the grain size in the 1 to 100 nm range.
- Each grain contains only about 900 atoms each. They exhibit greatly altered physical, chemical and mechanical properties compared to their normal, large – grained counter parts with the same chemical composition.

Methods employed to produce Nanophase materials :'

i) Vapour condensation
ii) Chemical synthesis
iii) Mechanical deformation
iv) Thermal crystallization

Superplasticity :

The capability of some polycrystalline materials to exhibit very large textile deformations without necking or fracture is known as superplasticity.

Shape Memory Alloys (SMA)

SMA refer to group of metallic materials that demonstrate the ability to return to some previously defined shape or size when subjected to the appropriate thermal procedure.

MEMS

MEMS – Micro Electro Mechanical Systems is the integration of mechanical elements, sensors, actuators and electronics on a common silicon substrate through micro fabrication technology.

Cermets :

Cermets are large – particle composites containing between 80% to 90% ceramic and remaining % metal. These are materials which aim to blend the strength of ceramics with the ductility and toughness of metals.

Cermets have good high-temperature strength and creep resistance. They are sensitive to shock loading and thermal shock.

Ceramics ;

Industrial products that are in common use can be classified under three categories.

i) Metals such as iron, copper and aluminium
ii) Organic materials such as epoxy resins and rubber.
iii) Ceramics like porcelain, refractories and electronic wares.

The term 'ceramics' comes from ancient Greek word keramos which means fired clay.

Fine ceramics :

Usually ceramic are oxides or non – oxides composed of metallic and non-metallic elements (excluding carbon) Ceramics used as machine materials, electronic materials, optic materials, surgical replacement materials etc., cannot be obtained by simply pressing and sintering unrefined raw material; instead 'fine ceramics' is used.

Fine ceramics is synthesized using.
i) highly refined raw material
ii) regorously controlled composition and
iii) strictly regulated forming & sintering

Metallic – matrix composites (MMCs)

The concept of MMCs is based on using the best characteristics of two different materials. For example metallic matrices exhibit ductility and toughness whereas ceramic reinforcements have higher modulus and strength. A composites of these two have superior properties compased to unreinforced metals.