Low resistivity material and their application

1. Copper

1. Copper is widely used because of its high conductivity (i.e low resistivity)
2. It is a non magnetic metal and has remarkable physical, chemical and electrical properties.
3. Copper is reddish in colour and can be available in hard
4. drawn or annealed form.
4. Its mechanical properties are different for hard drawn and annealed copper.
5.

Hard drawn copper	Annealed Copper
1. Hard drawn copper is hard and has high tensile strength than annealed copper	(1) → Annealed copper is soft and has less tensile strength than hard drawn copper.
2. Hard drawn copper is obtained by drawing copper bars or rods in cold condition.	(2) → Annealing process is involved by heating the metal at specific temperature and then cooling.
3. Hard drawn copper is springy.	(3) → Annealed copper is flexible.
4. Its conductivity is lesser than annealed copper	→ Its conductivity is higher than hard drawn copper.
5. The resistivity of hard drawn copper is $1.72 \times 10^{-8}\ \Omega m$ at 20°C.	→ The resistivity of annealed copper is $1.72 \times 10^{-8}\ \Omega m$ at 20°C.
6. Density and melting point are 8.93 and 1084°C.	→ Density and melting point are 8.89 and 1084°C

6. Copper can be drawn into very thin wires
7. Sheets and bars of various thickness can be made.

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8. Copper offers high resistance to corrosion.
9. When exposed to atmosphere copper oxide layer is formed on it which acts as a protective layer and prevents corrosion.
10. The tensile strength of copper varies from 8.15 to 4.72 tonnes / cm^2.
11. Copper can be easily soldered and welded which is very necessary in electrical wiring.
12. To remove the oxide layer formed on the surface of copper some solvent (flux) is necessary for better soldering.
13. Copper joints offer low contact resistance as the oxide film formed on it also has conducting property.
14. It has poor resistance to oxidation which lowers its efficiency.

Application :-

1. Hard drawn copper are used in overhead conductors, high voltage underground cables and bus bars because of its high mechanical strength.
2. Annealed Copper is used for insulated copper conductors in low voltage power cables, winding wires for electrical machines and transformers, flexible wires and in making coils for many purposes.
3. Due to its high electrical conductivity and thermal conductivity it is commonly used as a contact material for control relays, motor starter switches and tap changers.

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2. Silver

→ Pure silver has high electrical conductivity and corrosion resistance.
→ It is used where high wear resistance is not required.
→ In oder to make it harder 15% of copper is added into it.

Application

→ It is used in commutator segment of small d.c motors as alloy of silver copper containing 40% of copper is used.
→ For brushes and collector ring of d.c motors silver graphite alloy containing a small percentage of graphite is used to provide sliding lubrication.

3. Gold

→ It is the best electrical conductor.
→ It has density of 19.3 times that of water at 20°C.
→ It melts at 1063°C and boils at 2700°C.
→ It is malleable and ductile and can be easily beaten into translucent sheets as thin as 0.00001 mm.
→ It is used as alloy to make coins and jewellery.
→ It good corrosion resistance.
→ Its alloy is also used as corrosive resistant brazing material.

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4. Aluminium

→ Its resistivity is 2.8×10^{-8} Ω m, i.e about 1.6 times higher than copper.

→ Its density is 2.68 which means it is much lighter than copper

→ Its melting point is 655°C

→ It can be easily rolled and drawn hard.

→ It can be drawn into thin wires.

→ Aluminium is a soft metal but when alloyed with some other material like magnesium, silicon or iron, it acquires higher mechanical strength and can be used for overhead transmission lines.

→ When Aluminium exposed to atmosphere it forms an oxide layer over its surface which prevents the material from further oxidation and acts as a resistance layer to corrosion.

→ The oxide layer ~~over its~~ of copper over its surface has conducting property but the aluminium oxide layer when formed on surface has insulating property because aluminium oxide has relativity higher resistivity.

→ The contact resistance of copper is very low but the contact resistance of aluminium is very high.

→ It is a soft material so there is possibility of loose contacts.

→ Due to the insulating property of aluminium oxide formed on the surface, it is difficult to solder aluminium wires for this reason the aluminium wire is not used in house wiring.

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→ The tensile strength of aluminium wires have tensile strength varying from 0.95 to 1.57 tonnes/cm^2 which is much lower than that of copper due to which there is tendency in the breaking of the wire. Its resistivity is higher compared to copper the wire has to have a thicker cross section to keep the I^2R losses low. The winding will occupy more space and the machine size increases. For this reason aluminium winding is not used in electrical machines and transformer. It is difficult to substitute aluminium in place of copper.

Application of Aluminium conductor

It is used for flexible wires, overhead transmission lines, bus-bars, squirrel cage induction motor rotor bars and many other application.

As aluminium weighs about 1/3.5 times as much as copper, its resistance per unit weight is less than of copper although the resistivity is higher. For economic reasons aluminium has replaced copper in many fields.

Overhead transmission lines are now all made of aluminium conductors with steel reinforcement called ACSR conductor.

ACSR → Aluminium conductor with steel reinforcement

Steel reinforcement is made for giving higher strength to the overhead conductor.

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Steel

Steel contains iron with a small percentage of carbon added to it. Iron is very strong but when carbon is added it assumes very good mechanical properties.
With the addition of a small percentage of carbon tensile strength of steel increases but at the same time its ductility decreases.
If the carbon is too high the steel is brittle.
Steels are classified as follows →
1. Mild steel containing carbon about 0.25%.
2. Medium steel containing carbon about 0.45%
3. High Carbon steel containing carbon about 0.70% and above.

The resistivity of steel is 8 to 9 times higher than that of copper. Due to this reason steel is not generally used as conducting material because it has higher mechanical properties. and is easily available.
Aluminium conductors are steel reinforced to increase their tensile strength for use as overhead transmission line conductors. Steel is easily corroded when exposed to moisture.
When a zinc coating is provided on its surface (i.e when it is galvanised) it does not corrode.
Galvanised steel wires are used as overhead telephones wire and as earth wires.

Stranded Conductors –

When a single conductor of large cross section is used, it becomes rigid in construction and its has chances to break while handling. To avoid this conductors are made of a number of thin wires, bunched together called strands.

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Stranding makes the conductor flexible and eliminates to a large extent the risk of its breaking through the insulation. A standard stranding consist of 6 wires around 1 wire, then 12 wires around the previous 6, then 18 wires around the 12 then 24 wires around the 18 and so on. The number of layer to be provided will depend upon the number of wires to be provided. The central wire is not counted as a layer.

A stranded conductor is made by the twisting the wire (strands) together to form layers. Stranding is done in opposite directions for successive layers. If the wires of one layer are twisted in left hand direction, the next layer of wires will be twisted in the right hand direction and so on.

Bundle conductors

The adoption of bundled conductors in extra high tension power transmission enables stranded conductors to be used and gives an increased current carrying capacity compared with a single conductor of equivalent cross sectional area. Since the voltage stress at the conductor surface is reduced by using bundled conductors, corona loss is smaller and the line is less liable to cause radio interference.

Low resistivity copper alloys →

The copper becomes mechanically hard when it is drawn. The hardening of copper can also be done by alloying with other metals.

1. Brass → When copper is alloyed with zinc (60% Cu, 40% Zn) is called brass. Brass has high tensile strength but has lower conductivity than copper. It can be easily shaped by pressing and its lends itself to deep drawing. It can be easily welded and soldered and is fairly resistant to corrosion that is why brass is widely used as a current

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carrying and structural material in plug points, socket outlets switches, lamp holders, fuse holders, knife switches, sliding contacts for starters and rheostats etc.

Bronze

Copper when alloyed with tin 8% to 16% and a very small %amount of third element like Cadmium, Berylliim, Phosphorous, Silicon etc is called Bronze. Bronzes are given their name based on the third element which is added to copper and tin to form the alloy.

For eg:-
when the third element is phosphorous, the alloy is called phosphorous bronze. If the third element is silicon or bronze cadmium the alloy is called Silicon bronze or cadmium bronze respectively.

All Bronzes posses high mechanical strength as compared to copper but have lower conductivity.

Tin is more corrosion resistant than zinc. So bronzes are more free from corrosion than brasses.

Cadmium Bronzes is used for contacting conductor and commutator segments.

Beryllium Bronze whose mechanical strength is higher than. Cadmium Bronze is used for making current carrying springs, sliding contacts, knife switch blades etc.

Beryllium Copper alloy → The copper alloy containing beryllium also called bronze. It has high conductivity and mechanical strength. Its hardening and elasticity property can be changed by giving appropriate heat treatment. It is used for making current carrying springs, brush holders, bellows coil springs, sliding contacts and knife switch blades.

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High resistivity materials and their application

→ High resistivity materials are used for making resistance elements for heating devices, starters for electric motors, resistances for precision measurements, loading resistances (rheostats), filaments for incandescent lamps etc are all made of special high resistivity materials. They are generally alloys of different materials. Common eg → Manganin, Constantan, Nichrome, Tungsten etc.

→ High resistivity materials are also used in making wire wound precision resistance and shunts for measuring instruments, resistance boxes, coils for precision electrical measuring instruments. The material used for this purpose should have negligible temperature co-efficient of resistance. eg → Manganin (an alloy of Copper (86%) Magnese (12%) and Nickle 2%. The melting point of manganin is 1020°C. Manganin can be easily drawn into a thin wire.

→ High resistivity materials required in making heating element for electric irons, electric ovens, rooms heaters, electric furnaces et. Nichrome is the material suitable for these application because of its high maximum permissible working temperature 1100°C. Resistivity is 100×10^{-8} ohm-m at 20°C. Nichrome is an alloy of Manganese 1.5%, Nickel 75% to 78%, chromium 20% to 23% and a little percentage of Iron. It can be drawn into thin wires and is mechanically strong.

Tungsten → It is a very hard metal. Resistivity of tungsten is about twice that of aluminium. Its melting point is the highest of all metals (3300°C). It can be drawn into very thin wires required for making filaments. The thinner the tungsten wire, the greater is the tensile strength.

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Tungsten is commonly used in incandescent lamps, as heater in electron tubes etc. In atmosphere of inert gas (Nitrogen, Argon) etc or in vaccum, tungsten can reliably work at temperature like 200°C and even higher.

It oxidises very quickly in the presence of oxygen even at temperature of a few hundred degree centigrade.

When tungsten is used as filament in incandescent lamps, the filament is made in straight, coiled or coiled-coil form.

Tungsten is used as filament material for the following reasons
→ it has the highest melting point amongst all metals, can be drawn into very thin wires, has very high tensile strength in its thinnest form. It does not become brittle at high temperature

2. Carbon

Carbon materials are widely used in the field of electrical engg. They are manufactured from graphite and other forms of carbon like coal etc.

They manufacturing process of carbon products consist of grinding of the raw carbon materials, mixing of the powdered carbon with a binding agent, moulding of the requisite component and lastly baking them.

To increase the conductivity of the carbon product, different kinds of additives like copper or bronze powder are mixed with the carbon moulding compound.

It has very high value of resistivity
negative temperature co-efficient of resistance.
Pressure sensitive (i.e electrical resistance of the carbon contact decreases as the pressure increases)
low surface friction.

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Carbon is used in application like brushes for electrical machines and apparatus, electrodes for electric arc furnaces, carbon pile resistances, non wire resistors, membranes and other component for telecommunication equipment, battery cell element, arc lamps, arc welding etc.

Carbon brushes for electrical machines and apparatus. Carbon brushes should possess mirror smooth surface and adequate conductivity. Carbon should not wear down rapidly and should not cause mechanical damage due to friction to the surface on which it is mounted.

Another application of carbon is as carbon resistors. It consist of a thin layer of carbon deposited on the surface of a ceramic rod. The resistance value required determines the thickness of the carbon film. Solid type carbon resistor consist of a solid rod of special material composed of carbon and binding agent.

→ film type
→ solid type (film type)

3. Platinum

→ It is a greyish white metal which is non-corroding. It is malleable and ductile and is resistant to most chemicals.
→ It is a heavy metal having specific weight of 21.4 gm/cm^2
→ Its melting point is 1775°C.
→ The resistivity of platinum is 0.1×10^{-6} Ω m and its temperature co-efficient is 0.00307 per degree C.
→ It can be drawn into thin wires and strips. It does not oxidize in air and has no tendency to arc.

Application
→ It is used as a heating element in laboratory ovens and furnaces.
→ Platinum rhodium thermocouple is used for measurement of temperatures upto to 1600°C.
→ It is used as electrical contact material

Platinum are highly resistant to corrosion and have a high melting point is used for making lightly loaded contacts.

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Platinum when used as material for contact deteriorate with time because of (i) corrosion and (ii) erosion

(i) Corrosion cause a film of oxide to be deposited on the contacts reducing the conductivity of the contact.

(2) Erosion is caused due to fusing and wear of the working surfaces of the contacts during operation. Erosion may cause growth to appear on one contact and cavity on the other.

Mercury → It is a silver white metal.
Its specific weight is 13.55 gm/cm². It is the only metal which is liquid at room temperature.
Its boiling point is 357°C.
Its resistivity and temperature co-efficient of resistance are respectively 0.95×10^{-6} Ω-m and 0.00027 per degree C.
Mercury is poisonous

Application

→ It is used in arc rectifiers, gas filled tubes, as liquid contact material in electrical switches etc.
→ It is used for making and breaking contact in Buchholz relay used for transformer protection.

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Superconductivity

The resistivity of most metals increases with increase in temperature There are some metals and chemical compounds whose resistivity becomes zero when their temperature is brought near 0° Kelvin (-273°C). At this stage such metals or compounds are said to have attained superconductivity.

The temperature at which the transition takes place from the state of normal conductivity to that of superconductivity is called transition temperature.

Super Conducting Material

Materials which can attain superconductivity are known as super conducting material or superconductors.

Superconductors are of two types Type I and Type II superconductors

Type I are soft superconductors and are pure metals.

Type II are hard superconductors and are usually alloys of metals with high value of resistivity in normal state.

Many metals and compounds have superconducting property at very low temperatures. It occurs in poorer metallic conductors such as tin, lead and tantalum and in better conductors such as gold, silver and copper.

Application of Superconductor Material

1. Superconductor material are used in electrical machines and transformers utilizing superconductivity.
2. Superconducting materials if used for power cables will enable transmission of power over very long distance using a diameter of a few centimeters without any significant power loss or drop in voltage.

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3. It is used as electro-magnets for use in laboratories and for low temperature devices like the maser.

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