# Scope of Electrical and Electronic Materials

- Scope of application of electrical materials is very vast.
- These materials find utilities in not only electrical engineering machines, equipments, devices etc. but are also used as components, circuits and other auxiliaries related to electronics, computers, and instrumentation fields.
- Their importance is also realized in cable networking, wireless networking, satellites, optical devices etc.
- They find very useful applications even in medical, mechanical, nuclear, biotechnological fields.
- The details given below focuses upon the scope of electrical materials in numerous applications.

# Scope of Electrical and Electronic Materials

- *In Consumer Items*

- Bulb fi laments
- Heaters
- Remote control devices
- Telephone
- Domestic wiring
- Tape record
- Switches
- Iron press
- Television
- Invertors
- Radio
- Microwave ovens, etc.

# Scope of Electrical and Electronic Materials

- In Electrical Engineering

- Contacts
- Cables
- Magnets
- Alternators
- Motors
- Voltage Dividers
- Conductors
- Dielectrics/Insulators
- Piezoelectrics
- Transformers
- Capacitors
- Bus Bars, etc.

# Scope of Electrical and Electronic Materials

- In Electronics

- Amplifiers
- Integrated Circuits
- Antenna
- Broadcasting Systems
- Printed Circuits
- Rectifiers
- Filters
- Regulators
- Satellite
- Photoconductive Cell
- Transistors
- Modulators, etc.

# Scope of Electrical and Electronic Materials

✓ *In Robotics*

- Sensors
- Controls
- Manipulators
- Grippers
- Actuators
- Processors
- Encoders
- Pendants, etc.

✓ *In Computer Engineering*

- Hardware
- Monitors
- Peripherals
- Floppy
- Printers
- Memory devices
- Ports
- Display devices
- Hard disk
- CDs, etc.

# Scope of Electrical and Electronic Materials

✓ *In Instrumentation*

- *Transducers*
- *Signal generators*
- *Microprocessors*
- *Strain gauges*
- *Cathode ray oscilloscope*
- *Recorders*
- *Thermistors*
- *Energy meters, etc.*

✓ *In Information Technology*

- *Networking cables*
- *Web camera*
- *Cam corder*
- *Multimedia devices*
- *Routers*
- *Optical fibres, etc.*

✓ In Mechanical Engineering

- Furnace
- Thermocouples
- Arc welding set
- Electrically heated ovens
- X-ray systems, etc.

# Scope of Electrical and Electronic Materials

✓ *In Biotechnology and Medical Sciences*

- Electro-cardiography
- Fibre-optic endoscopy
- Electronic photography
- Magnetic resonance imaging, etc.

# Requirements of Engineering Materials

- ✓ *In Materials technology does not mean just knowing the physics and chemistry of materials, their behaviour and properties.*
- ✓ *It is also essential to know as to how a material can be suitably and economically put to practical uses under wide range of conditions.*
- ✓ *These conditions may relate to operation, to fabrication, or to stability of materials.*
- ✓ *An electrical engineering material is used in one or all of the following areas.*
- ➢ *Machines (as motor, alternator, robots etc.)*
- ➢ *Structures (as transformer, cathode ray tube, antenna etc.)*
- ➢ *Devices (as strain gauge, integrated circuit, control switch, thermistor, bimetal gauge etc.)*
- ➢ *Instruments (as multimeter, transducers, thermocouples etc.)*

# Requirements of Engineering Materials

- ✓ *Each material possesses several properties. Some important properties are*
- ➢ ***Electrical** : resistivity, conductivity, dielectric constant, dielectric strength, relaxation time, loss angle, power factor.*
- ➢ ***Magnetic** : hysteresis, retentivity, permeability, susceptibility, coercive force, reluctivity.*
- ➢ ***Electronic** : semi-conduction, drift , diffusion, concentration, energy gap, Fermi energy, mobility, carrier density, ionization energy, effective mass, density of state, rectifying action.*
- ➢ ***Optical :** reflection, refraction, transmission, fluorescence, lustre, luminescence. Physical density, melting point, colour, shape, size, finish, porosity.*
- ➢ ***Thermal:** expansion, conductivity, specific heat, thermal fatigue, thermal stress, thermal shock, latent heat of fusion.*

# Requirements of Engineering Materials

- ***Mechanical:*** *creep, fatigue, toughness, hardness, impact, ductility, malleability, resilience, brittleness.*
- ***Chemical*** *: corrosion resistance, passivity, atomic number, molecular weight, acidity, alkalinity, oxidation.*
- ***Cryogenic :*** *ductile-brittle behaviour, low temperature impact behaviour, very low temperature phase changes, superconductivity.*
- ***Acoustical*** *: sound reflection, absorption, damping, transmission.*
- ***Structural:*** *strength, stiff ness, elasticity, plasticity.*
- ***Surface*** *:friction, abrasion, wear, erosion.*
- ***Metallurgical :*** *phase rule, solid solution, crystallization rate, diffusion.*
- ***Technological:*** *weldability, machinability, formability, castability, fabricationability, hardenability.*
- ***Aesthetic:*** *feel, texture, appearance, lustre.*
- ***Nuclear:*** *half-life period, decay constant, radiation absorptivity.*

# Important Terminology

- ***Porosity*** *is a desired requirement in intrinsic semiconductor for doping, but is undesired in insulators exposed to moist air.*
- ***Thermal expansion*** *of unequal values are desired in bimetallic strips of dissimilar materials for use in thermostatic controls and thermocouples.*
- ***Fatigue resistance*** *is a desired property in lamp fi laments against fluctuation of voltage, otherwise the life of fi laments will decrease. Corrosion resistance is desired in all the materials against environmental effects.*
- ***Damping*** *is a desired property for various components of an electrical instrument to prevent against mechanical shocks and vibrations, and against the effects of external magnetic and electrical fields.*

# Important Terminology

- **Strength** is very essential for the casing of alternators and motors.
- **Elasticity and ductility** are also needed in cables, wires and coils.
- **Abrasion resistance** is an important requirement for contact materials which are subjected to sparking of arc, such as in electrodes.
- **Wear resistance** is desired in contacts which are subjected to physical/ mechanical rubbings.
- **Diffusion** is desired for doping of silicon and germanium elements. It is also needed in making of binary (metal) alloy systems such as CuZn, Cu-Ni etc.
- **Weldability** is desired in the construction of laminated core of transformer.
- **Appearance** of any machine, equipment, or device provides

# Operational Requirements of Electrical and Electronic Materials

- Electrical materials have to satisfy widely varying needs of different operational parameters.
- These parameters are voltage, current, temperature, frequency, polarization, remanence, resistivity, emission etc.
- Accordingly, the materials have to be suitable for meeting the following requirements.
- • high and low voltage applications
- • high and low conduction applications
- • high and low temperature services
- • high and low frequency services
- • high and low resistivity devices
- • high and low emission applications, etc.

# High and Low Temperature (Service) Materials

- Temperature measurement of furnaces and ovens in industrial applications is essentially required for a proper process control.
- The measurement may have to be done well above the melting point of the metal in many instances.
- It may be a high value of 3410°C for tungsten (W) and 2454°C for iridium (Ir), a medium range value of 1769°C for platinum (Pt) and 1083°C for copper, or a low value of 30°C for gallium (Ga) and -220°C for fluorine (F).
- For low-temperature measurement, various nickel based cryogenic steels are used.
- These are:

| Percentage of nickel | 3.5 | 5.0 | 9.0 |
|---|---|---|---|
| Service temperature (°C) | –100 | –120 | –190 |

# High Voltage (Service) Materials

- With increasing demand of electricity, the generation and transmission requirements of voltages are on increase.
- It is because at high voltage, the line losses are relatively reduced and the power system becomes economical.

**Table 1.1** High voltage materials

| Equipments | Materials |
|---|---|
| • Overhead live conductors | ACSR (Aluminium conductor reinforced with steel) |
| • Underground cables | Nitrogen gas filled pressure cables in conjunction with oil-treated paper insulation |
| • Insulators | Highly purified benzene, hexane, silicone oil; ferroelectrics, mica, vacuum |
| • High frequency coils | Powdered metals |
| • Circuit breakers | Pd-Rh and W-Pt contacts, Petroleum oil as insulation |
| • Low-loss capacitors | Ferroelectrics, vacuum as insulation |

# Classification of Solids on the Basis of Energy Gap

- Solids (or materials) are broadly classified into following categories on the basis of their energy gap which is an important electronic behavior.

1. Conductors,
2. Semiconductors, and
3. Dielectrics or insulators.

- Conductors are mainly metals and alloys. Their electrical resistivity ρ (reciprocal of electrical conductivity) is the least.
- Semiconductors have properties in-between the conductors and dielectrics. They are widely used for making solid state devices.
- Dielectrics have the highest values of resistivity. They are used as insulators and capacitors etc.

# Classification of Solids on the Basis of Energy Gap

- The order of electrical resistivity of solids vary between 10^–9 for good conductors to10^+17 for best quality insulators.
- The classification of solids on the basis of their electrical resistivities are shown in Table 1.2.

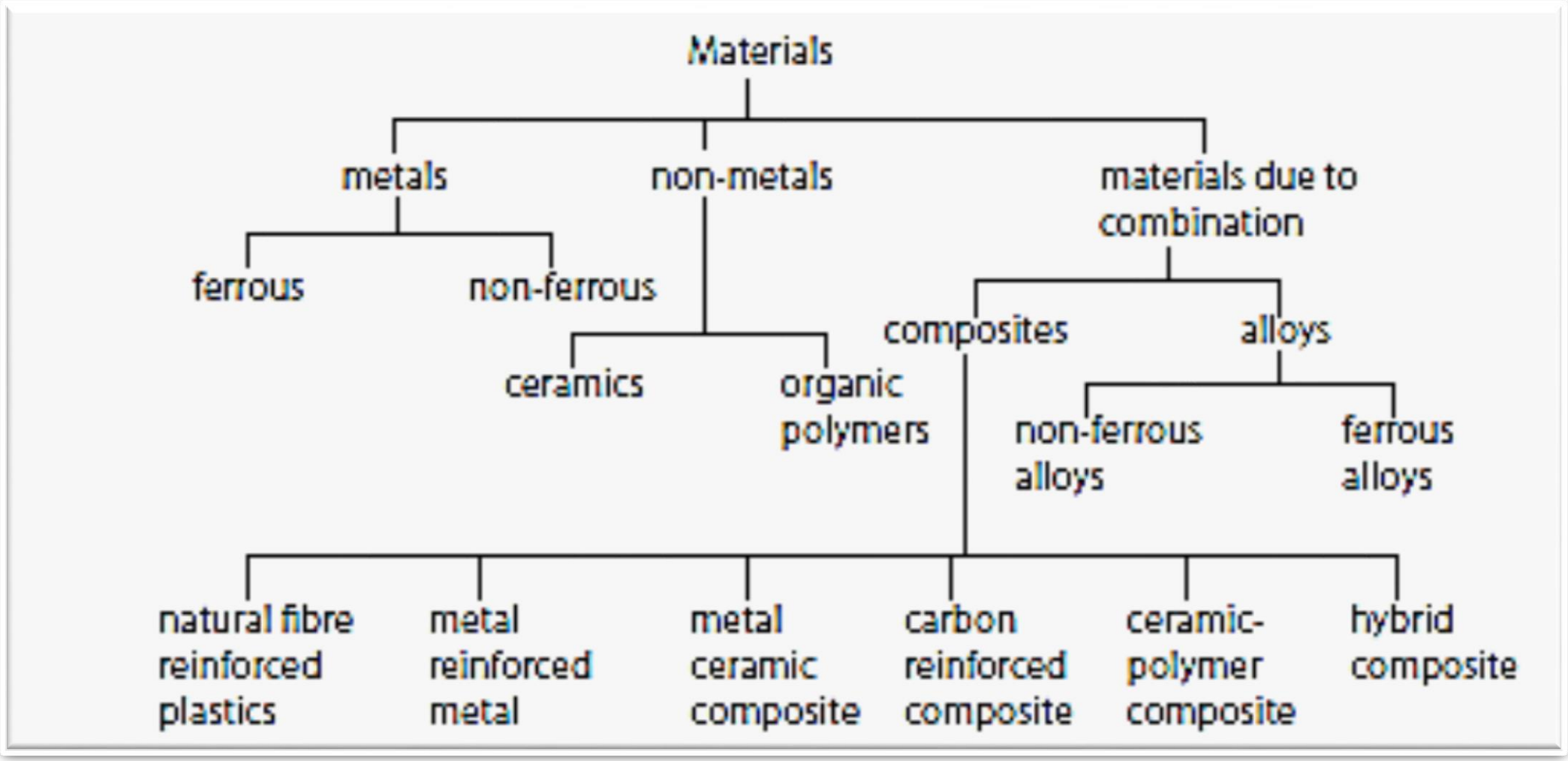
**Table 1.2** The electrical resistivity of solids at room temperature

| Solid | Electrical resistivity (ohm m) | Solid | Electrical resistivity (ohm m) |
|---|---|---|---|
| *Metals* | | *Semiconductors* | |
| Silver | $10^{-9}$ | Doped germanium | $10^{-3}$ |
| Gold | $10^{-9}$ | Pure germanium | $10^{-1}$ |
| Copper | $10^{-9}$ | Pure silicon | $10^{-2}$ to $10^{-3}$ |
| Aluminium | $10^{-8}$ | *Insulators* | |
| Nickel | $10^{-7}$ | Glass | $10^{5}$ |
| Iron | $10^{-6}$ | Fireclay | $10^{8}$ |
| Antimony | $10^{-5}$ | Bakelite | $10^{9}$ |
| Bismuth | $10^{-4}$ | Alumina, diamond, rubber, polyethylene | $10^{11}$ |
| *Alloys* | | | |
| Brass | $10^{-7}$ | Mica, PTFE | $10^{13}$ |
| Constantan | $10^{-3}$ | PVC | $10^{15}$ |
| Nichrome | $10^{-2}$ | Pure silica | $10^{17}$ |

# Comparison among Conductors, Semiconductors and Insulators

| Description | Conductors | Semiconductors | Insulators |
|---|---|---|---|
| • Conductivity | High to very high | Low to medium | Nil to very low |
| • Resistivity | Low to very low | Medium to low | Very high to high |
| • Temperature coefficient of resistance | Always positive | Always negative | May be positive or negative |
| • Energy band | Overlapping or unfilled | Filled | Filled |
| • Forbidden zone | Nil or very small | Small | Large |
| • Current carriers | | | |
| – without external energy | Free electrons | Nil | Nil |
| – with external energy | Free electrons | Electrons and holes | Electrons |
| • Behaviour at low temperatures | Near absolute zero, they become super-conductors | In lower range, they become dielectrics | $\varepsilon_r$ drops sharply |
| • Effect of increas-ing temperature on conductivity | Conductivity decreases | Conductivity increases | Conductivity increases |
| • Effect of high electrical voltage on breakdown | No breakdown | They breakdown | They generally breakdown |
| • Bonding nature of valence electrons with their parent atom | Very loosely (feebly) bound | Loosely bound | Very tightly bound |
| • Ionization energy | Much less | Less | Very large |

# Different Types of Engineering Materials



# Different Types of Engineering Materials

**Metals:**

- Metals are elemental substances capable of changing their shape permanently.
- They are good conductors of heat and electricity.
- These may be of ferrous or non-ferrous type.
- The behaviour and properties of ferrous metals depend on the percentage and the form (phase and constituents) of carbon present in them.
- The difference between steel and iron, and their specific names according to percentage of carbon

**Non-Ferrous Metals:**

- *Non-ferrous metals* do not contain Fe and C as their constituents.
- Aluminium, copper, silver, nickel, zinc, tin, chromium etc. are some examples.
- Al, Cu, Ag and Au are good conductors of electricity; Ag is most malleable, Au is most ductile, and chromium is corrosion resistant.
- Zinc is used in the metals plating, tin is used to make bushes, and nickel imparts strength and creep resistance.

# Different Types of Engineering Materials

**Ceramics:**

- *Ceramics* are generally metallic or non-metallic oxides. Physically separable and chemically homogeneous constituents of materials consisting different phases are also ceramics.
- Rocks, glasses, fireclay and firebricks, cements and limes are ceramics.
- Ferrites, garnets, ferroelectrics and ceramic superconductors are the latest developments in this area.

**Organic Polymers:**

- *Organic polymers* are relatively inert and light, and generally have a high degree of plasticity.
- These are derived mainly from the hydrocarbons.
- These consist of covalent bonds formed by carbon, chemically combined with oxygen and hydrogen.
- The word ‘mer’ in Greek means a unit, ‘mono’ means one and ‘poly’ means many.
- Thus, polymers are obtained from monomers bonded by a chemical reaction (a process called polymerization).
- In this process, long molecular chain having high molecular weight is generated.
- Bakelite, polyethylene, nylon, teflon are some examples.

# Different Types of Engineering Materials

**Alloys :**

- An *alloy* is a combination of two or more metals.
- They possess properties quite different from those of their constituent metals.
- An alloy is prepared for a specific purpose to meet the particular requirement of an application.
- Alloys may be ferrous-alloy or non-ferrous depending on the base metal used.

**Composites:**

- *Composites* may be inorganic or organic.
- They have two or more constituents of dissimilar properties.
- The two major constituents may be metals and ceramics, or metals and polymers, or ceramics and polymers or other combinations.
- Alloys may also be used instead of metals to make composites.
- One of the constituent (called reinforcing constituent) may be in particulate form, fibrous form, or flake form.
- Fibrous composites are more common in present day applications.
- Whisker reinforced composites are likely to be the future material.