Room Temperature Superconductivity

Why in news?

Recently, two South Korean researchers claimed that a lead-based compound (LK-99) had shown superconducting properties at room temperature under normal pressure conditions.

What is a superconductor?

> *The phenomenon of superconductivity was first discovered in 1911 by Heike Kamerlingh Onnes, which earned him the 1913 Nobel Prize in physics.*

- A superconductor is a material that can conduct electricity or transport electrons from one atom to another with no resistance.
- Superconductivity refers to a state in which a material offers zero, or near-zero, resistance to electric current.
- **Superconductive**- No heat, sound or any other form of energy would be released from the material when it has reached critical temperature (Tc), or the temperature at which the material becomes superconductive.
- **Critical temperature**- It is the temperature at which the electrical resistivity of metal drops to zero in superconductor.
- Example- Aluminium, niobium, magnesium diboride, etc.,

What are the properties of superconductors?

- **Meissner Effect (Expulsion of Magnetic Field)** - A Superconductor, when it is cooled below the critical temperature Tc), expel the magnetic field and doesn't allow the magnetic field to penetrate inside it. This phenomenon in superconductors is called Meissner effect.
- In a solid material, this is called ***diamagnetism***, and a perfect conductor would be a perfect diamagnet.
- **Infinite Conductivity/ Zero Electric Resistance-** In the superconducting condition, the superconducting material illustrates the zero electric resistance.
- When the material is cooled under its transition temperature, then its resistance will be reduced to zero suddenly.
    - Example-Mercury shows zero resistance under 4k.
- **Critical Temperature/Transition Temperature** - Critical temperature of a superconducting material is the temperature at which the materials changes from normal conducting state to superconducting state.
- This transition from normal conducting state (phase) to superconducting state (phase)

is sudden / sharp and complete.

- **Josephson Current-** If the two superconductors are divided with the help of thin-film in insulating material, then it forms a junction of low resistance to found the electrons with copper pair.
- It can tunnel from one surface of the junction to the other surface. The current, due to flow of such cooper pairs, is called Josephson Current.
- **Critical Current**- When a current is passed through a conductor under superconducting state, a magnetic field is developed.
- If the current increase beyond certain value the magnetic field increased up to critical value at which conductor returns to its normal state. This value of current is called critical current.

What are the applications of superconductor?

- **Medical** - MRI (Magnetic Resonance Imaging), Magneto-encephalography (MEG) and Magnetic Source Imaging (MSI), Magneto-cardiography (MCG) etc.
- **Electric field** - Generators, motors, transformers, relays, magnetic energy storages (SMES), superconducting magnets, HTS Induction Heater, Fusion etc.
- **Electronics** - SQUIDS (superconducting quantum interference device), High Speed computing, Quantum computing, Sensors, filters, circuitry, radar etc.
- **Transportation** - Magnetically levitated trains, Marine Propulsion (magneto-hydrodynamic), Marine Propulsion (motor) etc.
- **Physics** - Particle Accelerators, Magnets, Plasma / fusion research etc.

What are the limitations of superconductor?

- **Operating at room temperatures -** Superconducting materials are active only when they are kept at low temperatures. Every superconducting material has a temperature below which it becomes active.
- **Use of cryogenics**- Keeping them below the transition temperature involves a lot of expensive cryogenic technology.
- Even the most sophisticated ones like copper oxide-based ceramic materials work only below −140°C.
- Hence, superconductors still do not show up in most everyday electronics.

Why room temperature matters?

- **Room-temperature superconductors-** A material that can display superconductivity at room temperature which is usually considered to be between 20 and 25 degree Celsius.
- It is the one which conducts electricity with zero resistance without the need of special cooling mechanism.
- **Zero resistance-** A superconducting power grid would not lose energy through resistance, so it would save the energy lost to resistance in the electricity grid.
- **Affordable MRI scans-** It would make magnetic resonance imaging (MRI) much more affordable because it would no longer require liquid helium to cool the scanner’s huge detecting tube.
- **Improve efficiency-**It would enable ultra-fast and energy-efficient computer

chips and long-lasting batteries and lamps etc.,

- **Cost effective-**
  - Electrical power grids would be at least 20% more efficient,
  - Maglev trains could run further at lower cost and
  - Particle accelerators and nuclear fusion devices could operate much more cost-effectively.

References

1. Indian Express- Why room temperature superconductor
2. India today- LK 99 a holy grail

