Seebeck Effect: Century-Old Limit Surpassed

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Why in News?

Recently, Scientists from JNCASR, IISc & University of Sydney discovered a crystalline semiconductor that generates thermoelectric voltage far beyond the accepted limit.

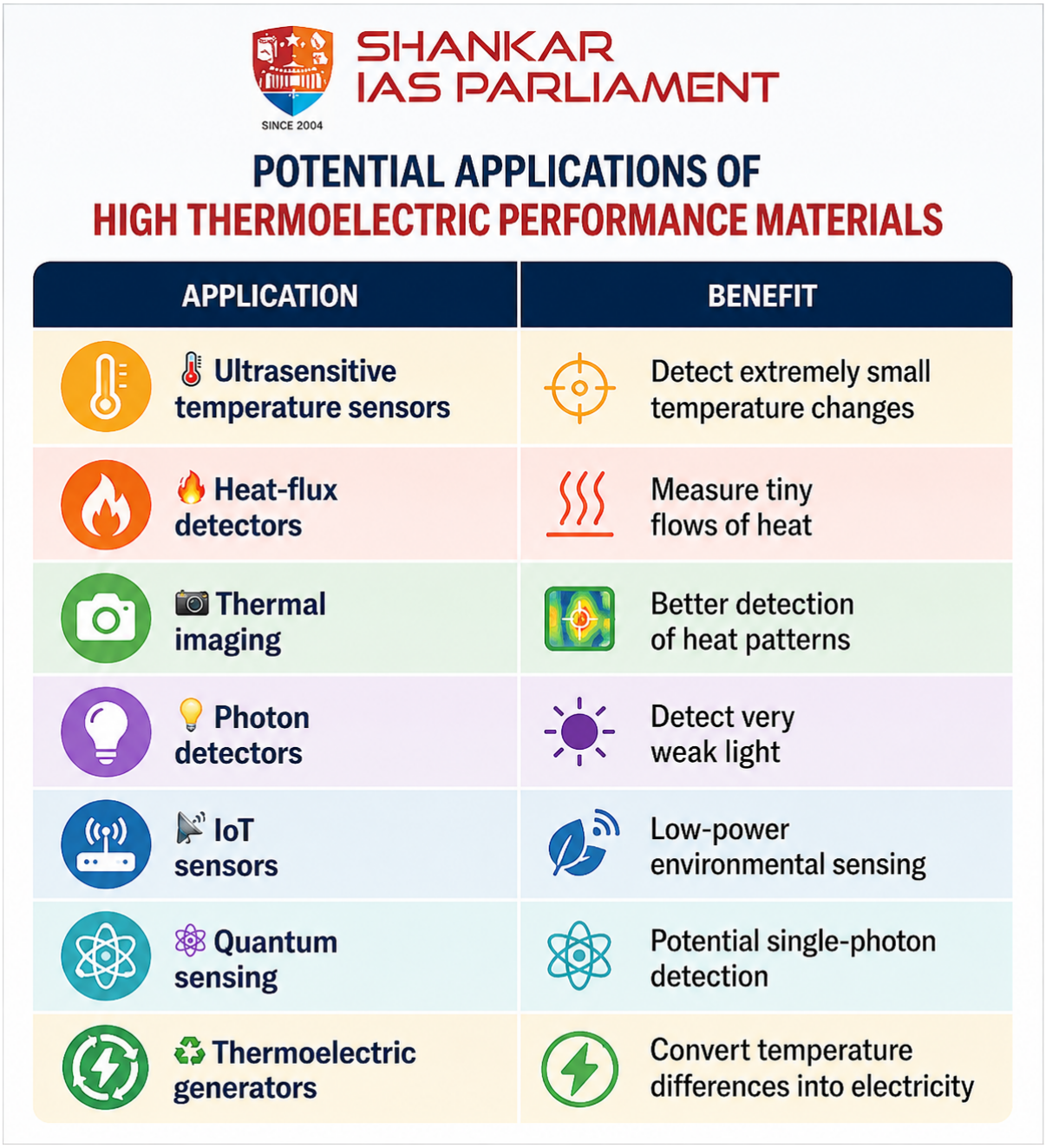
- **Seebeck effect –** It is the creation of an electrical voltage when two different metals or semiconductors have one end heated and the other end cooled.
- **Principle of Operation**
  - **Temperature Difference –** Heat is applied to one junction of two joined, dissimilar materials, while the opposite junction remains at a lower temperature.
  - **Electron Movement –** Free electrons within the materials acquire thermal energy and exhibit increased mobility at the heated junction.
  - **Voltage Generation –** These fast-moving electrons diffuse toward the cooler side, creating a charge separation and a measurable voltage, known as the Seebeck voltage.
- **Previous Scientific Limitations –** Historically, scientists considered the practical upper limit for crystalline solid materials to be only **a few millivolts per Kelvin**.
  - Metals – It typically exhibit Seebeck coefficients in the range of tens of microvolts per Kelvin (μV/K).
  - High-quality semiconductors – These are generally display Seebeck coefficients in the hundreds of microvolts per Kelvin (μV/K).
  - Certain liquid electrolytes and ionic systems – These can reach Seebeck coefficients in the millivolts per Kelvin (mV/K) range.
- **Recent Breakthrough –** Modified scandium nitride (ScN) has demonstrated a Seebeck coefficient exceeding the previously established limits:
- Specifically, **a value of −124.6 millivolts per Kelvin (mV/K)** was observed near room temperature.
- This value significantly surpasses the previously accepted upper limit for crystalline inorganic solids.

How was this scientific outcome achieved?

- The researchers utilized **Scandium Nitride (ScN)** as the base material.
- Magnesium dopants were intentionally introduced into the ScN.

Doping is the intentional introduction of a small quantity of another element to alter the electrical properties of a semiconductor.

- The combination of ScN and magnesium results in heavy doping and charge compensation.
- This process produces a material known as **HDHC (Heavily Doped, Highly Compensated)** semiconductor.



Reference

PIB | Century-Old Limit on Turning Heat into Electricity

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