Thermoelectric Effect

Muhammad Shamaas
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Thermoelectric Effect

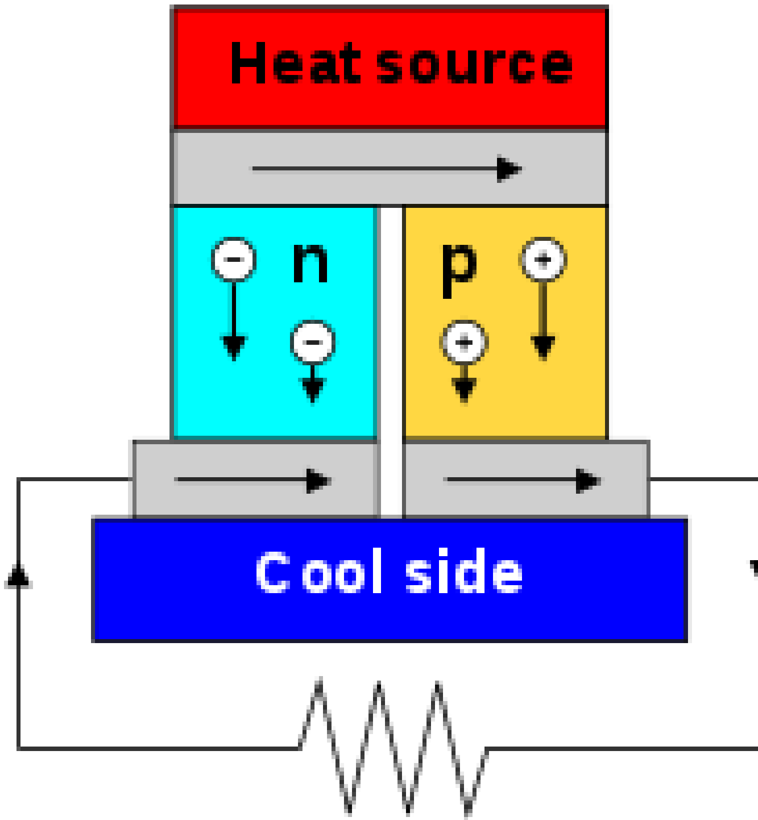
- Thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa using a thermoelectric device.
- It encompasses three separately identified effects:
  1. **Seebeck effect**
  2. **Peltier effect**
  3. **Thomson effect**.

Seebeck Effect

- Seebeck Effect explains the conversion of heat directly into electricity at the junction of different types of conductors.
- $E_{EMF} = -S.\nabla T$

  S = Seebeck Coefficient

  ∇T = Temperature Gradient



Thermoelectric Generators (Seebeck Effect)

Thermoelectric generators are compact, expensive, inefficient and have no moving parts.

1. **Power Recycling:** Used in power plants for converting waste heat into additional electrical power.
2. **ATEG:** Automotive thermoelectric generators increase fuel efficiency by reusing waste heat.
3. **Space probes:** Radioisotopes are used in thermoelectric generators for heating.
4. **Devices:** Stove fans, body-heat powered lighting and smart watch, thermocouples, thermopiles and thermogalvanic cells.

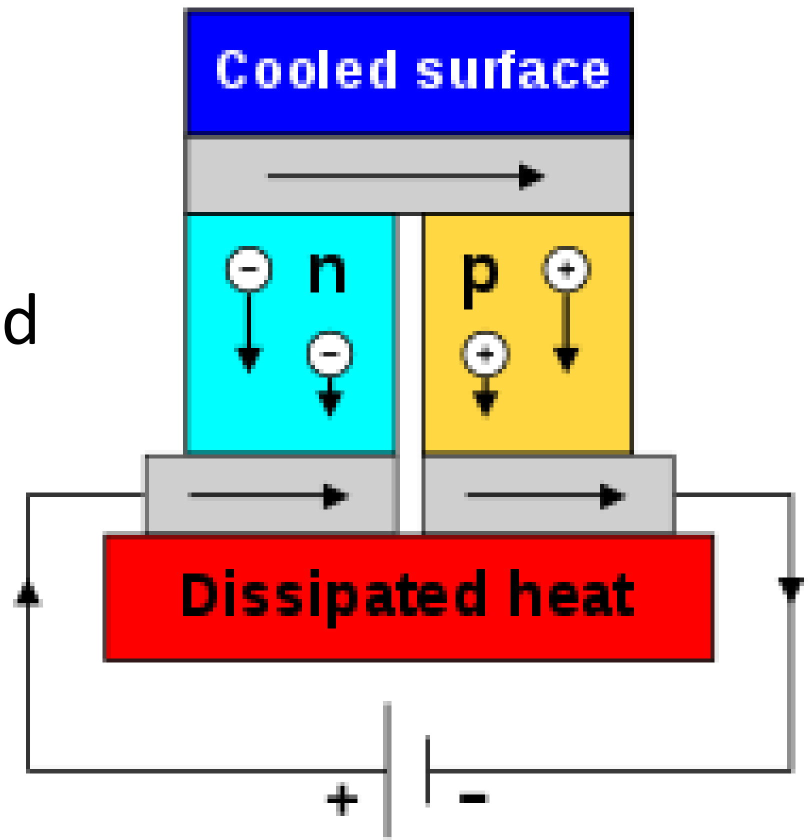
Peltier Effect

- Peltier Effect explains the presence of heating or cooling at an electrified junction of two different conductors.
- $\frac{dQ}{dt} = (\Pi_A - \Pi_B).I$

  Q = Thermal Energy Produced

  I = Current

  $\Pi = TS$ = Peltier Coefficient of Medium



Thomson Effect

- Thomson Effect describes the heating or cooling of a current-carrying conductor with a temperature gradient.
- $\frac{dQ}{dt} = -KJ\nabla T$

  Q = Heat Produced

  K=Thomson Coefficient

  J=Current Density

  ∇T=Temperature Gradient
- It is a continuous version of the Peltier effect to account for a change in Seebeck coefficient with temperature.

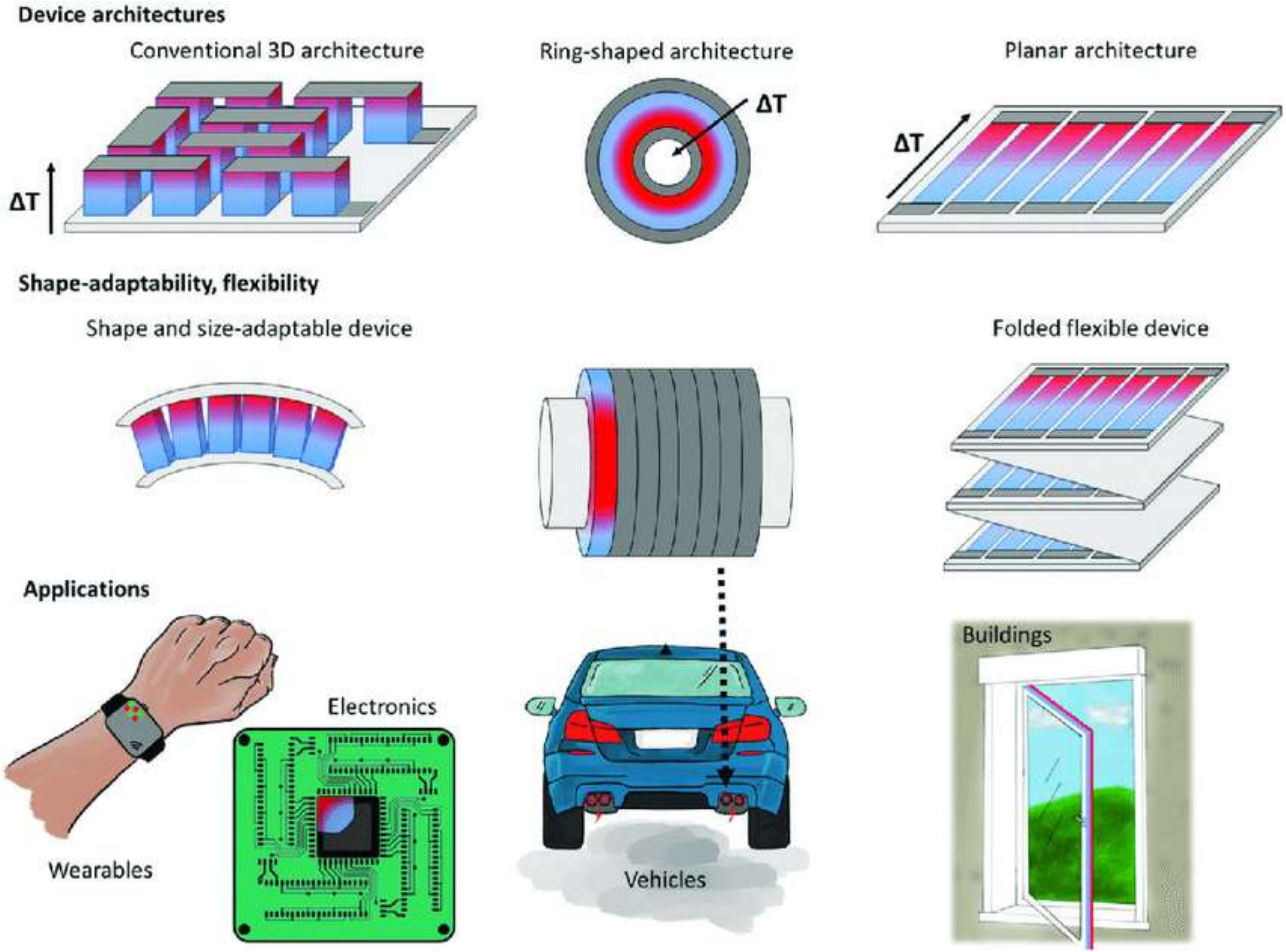
Thermoelectric Cooling (Peltier Effect)

1. **Thermoelectric refrigerators:** They are compact, have no circulating fluid or moving parts.
2. **Thermal cyclers:** Polymerase chain reaction (PCR) requires the precise, cyclic heating and cooling of samples to specified temperatures using Thermoelectric Coolers.

Manufacturing Thermoelectric devices

Material	Seebeck Coefficient
Selenium	900
Tellurium	500
Silicon	440
Germanium	330
Platinum	0
Nickel	-15
Constantan	-35
Bismuth	-72

62mm X 62mm X 4.1mm
-50 °C – 100 °C
8.4V, 480W Generator



Device architectures
Conventional 3D architecture
ΔT
Ring-shaped architecture
ΔT
Planar architecture
ΔT
Shape-adaptability, flexibility
Shape and size-adaptable device
Folded flexible device
Applications
Electronics
Wearables
Vehicles
Buildings

Challenges

1. **Inefficient:** Currently, ATEGs are about 5% efficient. To compete with current power generation methods, it must possess
$$ZT = S^2 \sigma T / \kappa$$
greater than 3. However, over past five decades the room temperature ZT of materials with best available technology has only slightly increased from 0.6 to about 1.0.
2. **Costly:** The cost of Thermoelectric materials like half heuslers, skutterudites, bismuth telluride and lead telluride has discouraged large-scale manufacturing.

Future of Thermoelectric Devices

1. **Utilization of waste heat:** Replacing the conventional electric generator with ATEGs means that the engine burns less fuel and releases fewer emissions. This could increase the fuel economy by up to 4%.
2. **Hi-Z Inc. ATEG:** The Generator produced 1 kW from a diesel truck exhaust system.
3. **Advancements in thin-film and quantum well technologies**: Low-cost production of tetrahedrite by Michigan State University, could increase efficiency up to 15% in the future.
4. **Same efficiency at all power levels:** More efficient than heat engines for low power applications (< 1kW).

References

[1]