Peltier Cells

Physics 590B Spring 2019

John Wilde
Seebeck effect

Discovered by Thomas Seebeck around 1820.

Heat applied to the junction of two dissimilar conductors will create a voltage difference between the ends.

\[ J = \sigma \nabla V - \sigma S(T) \nabla T \]

Steady state solution,
\[ J = 0 \]
\[ \nabla V = S(T) \nabla T \]

\( J \): Current density
\( \sigma \): electrical conductivity
\( V \): Voltage
\( S \): Seebeck Coefficient
\( T \): Temperature
Peltier effect

Discovered by Jean Charles Athanase Peltier in 1834.

Electric current applied to a thermoelectric circuit made of two dissimilar materials will either heat or cool the junction.

\[ \dot{Q} = \Pi(T) I \]

so at the junction,

\[ \dot{Q} = (\Pi_P - \Pi_N)I \]

\( \Pi \): Peltier coefficient

\( I \): Electric current

\( \dot{Q} \): Heat current

Related to Seebeck effect: \( \Pi = ST \)

Doesn’t account for the following:

- Resistive heating: \( P = I^2R \)
- Thomson Effect: effect of \( \nabla T \) within the material
- Dynamic effects
Peltier Cell
Peltier Cell

Single-stage

Multistage

Thermoelectric Cooling

Parts:
- Ceramic plate
  - Good thermal conductance ($k$)
  - Electrically insulating
  - Mechanically strong
- Conductor
  - Thin film copper
  - Low resistance
- Semiconductor
  - Figure of merit $ZT$ (~1 is excellent)

Pros:
- No moving parts
- No refrigerants
- Current controlled
- Small footprint

Cons:
- Inefficient
- Small heat flux

Pros: Cons:
- No moving parts  • Inefficient
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Figure of Merit: $ZT = \frac{S^2 \sigma T}{k}$

Rule of Thumb: $\Delta T_{max} = \frac{1}{2} ZT_0^2$

$\sigma$: Electrical conductivity
$k$: Thermal conductivity
$T_0$: Cold-side temperature (K)
Figure of Merit Comparison

Applications

Lab Applications
- Cold Plates
- Cooling system in tight spaces
  - Power supplies
  - Computer chips
- Reduce dark current
  - CCD, IR, spectrometers
- Precision temperature control
- Redistribute heat over satellites

Fun Applications
- Climate control in jackets
- Camping cooler
- Ice-cream makers
- Wine coolers
- A fashion statement
Standard Specifications

For Heatsink temperature = 50 C in normal atmosphere
Thanks