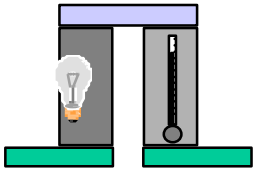

Thermoelectric Power Generation

DARPA Palm Power Workshop
November 14-15, 2000
Fort Lauderdale, FL

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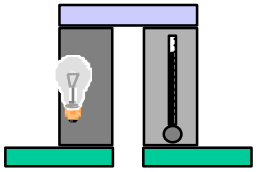
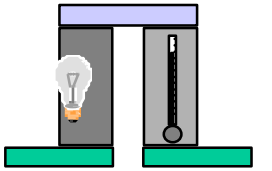
Benefits of Thermoelectric Cooling/Power Generation



- High reliability (>250,000 hrs.)
- Low noise
- No vibrations
- Small
- Lightweight
- Decreased life cycle costs
- Very efficient at low cooling power
- No compressed gases or chemicals
- Environmentally green

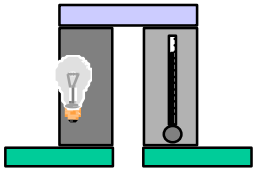


Impact

Thermoelectrics

- Factor of 2-4 increase in FOM will provide power generation (waste heat recovery) and environmentally benign cooling for DoD and civilian applications.
  - **Payoff**: Environmental compliance to future international bans/restrictions on coolants; Reduction in cost/maintenance of cooling systems.

- Spot-cooling for improved performance/durability of high power electronic devices.
  - **Payoff**: Increased lifetime and decreased maintenance of electronic/optical processing and communications equipment.



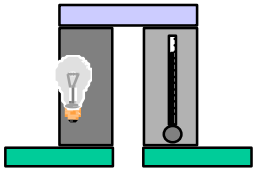
Impact

Thermoelectrics

Cooling and temperature stabilization in lasers:

- Future telecommunications will require reduction in wavelength spacing between channels from 100 GHz to 25 GHz which will need 0.1ºC temperature stabilization!
- Temperature increase from 25ºC to 50ºC reduces lifetime by factor of 4.
- 100ºC cooling of mid-IR laser medium can increase pulse width from <10 ns (room temperature) to cw operation (DARPA).
  - **Payoff**: Increased lifetime and decreased maintenance of electronic/optical processing and communications equipment.

Advanced Thermoelectric Materials and Devices



Objective: To create new classes of thermoelectric materials and devices for cooling and power generation by synthesizing novel materials and structures, and offering at least an order of magnitude enhancement in performance (ZT~ 4)

Power Generation

Army, DARPA-MAV
- Waste heat recovery
- Engine Exhaust

AF - Satellite Power

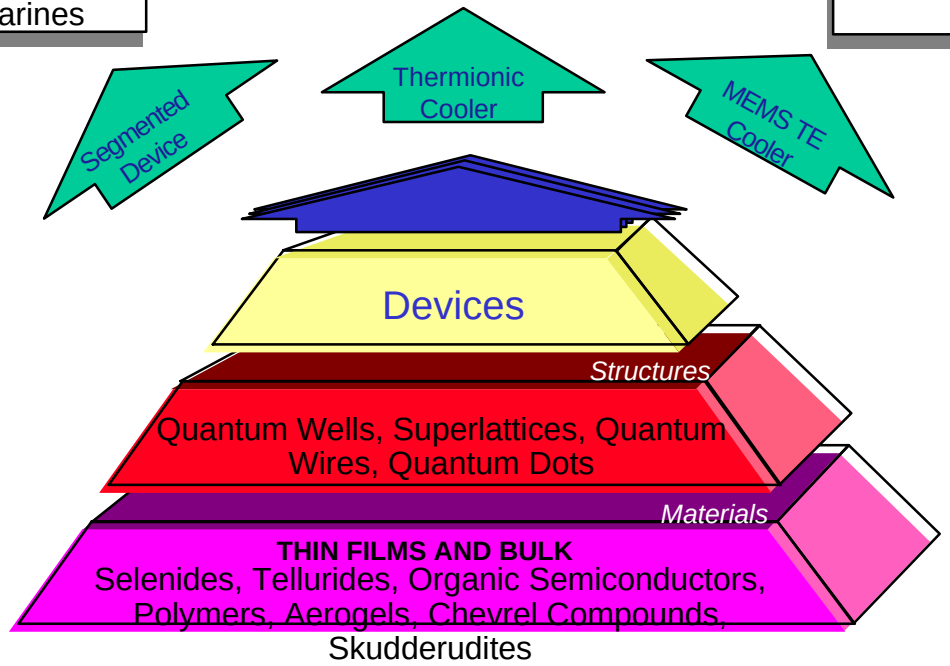
Cooling

Army - Man Portable Coolers
- IR Detectors
- Vehicle Environmental Control

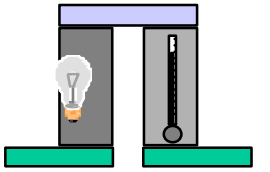
Navy -Air Conditioning/Submarines

General

Tri-Service - Thermal Management and Cooling of Electronics



$$ZT = \frac{S^2 T \sigma}{\kappa}$$



Thermoelectric effects

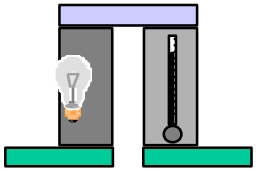
Seebeck effect:

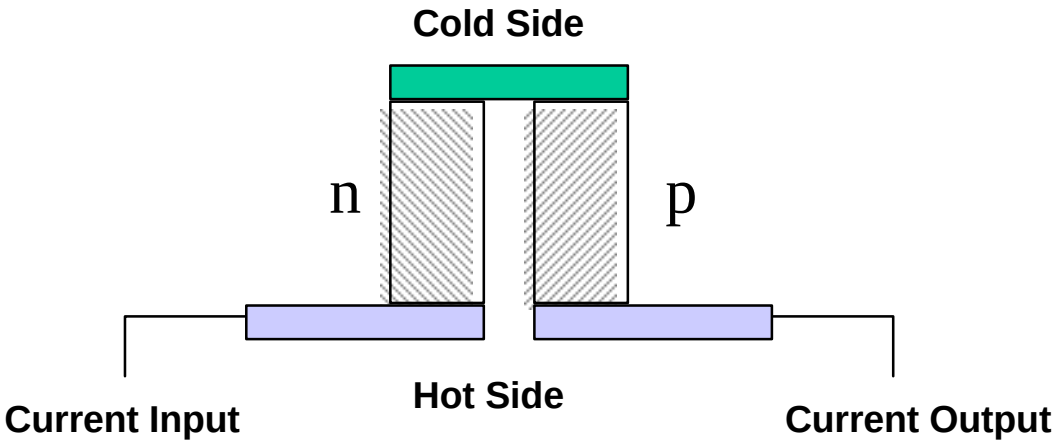
- an induced emf (voltage) in the presence of a temperature gradient
- used for power generation

Peltier effect:

- cooling/heating effect occuring at the junction of dissimilar materials in the presence of an electrical current
- used for cooling/thermal management

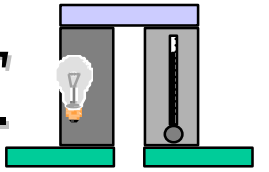
Thermoelectric Devices





- P-type and N-type Semiconductors connected in series
- Electrons gain energy from surroundings as they move over the barrier at the n-p junction

Thermoelectric Figure-of-Merit, ZT



$$ZT = \frac{s\ S^2\ T}{k}$$

σ = Electrical Conductivity
S = Seebeck Coefficient
κ = Thermal Conductivity

Difficult to increase ZT!

⇨ For simple materials, an increase in S leads to a decrease in σ
⇨ An increase in σ usually results in an increase in κ

Materials with potential for high ZT:

- Highly doped semiconductors with narrow bandgap
- Large unit cells with scattering centers
- Engineered structures
  - phonon scattering
  - enhanced electrical properties

New Structures

- thin films
  - porous Bi
  - skutterudites
  - ***superlattices***
    - ***PbTe/PbSeTe***
    - ***Bi_2Te_3/Sb_2Te_3***
- opal templates