Thermoelectricity

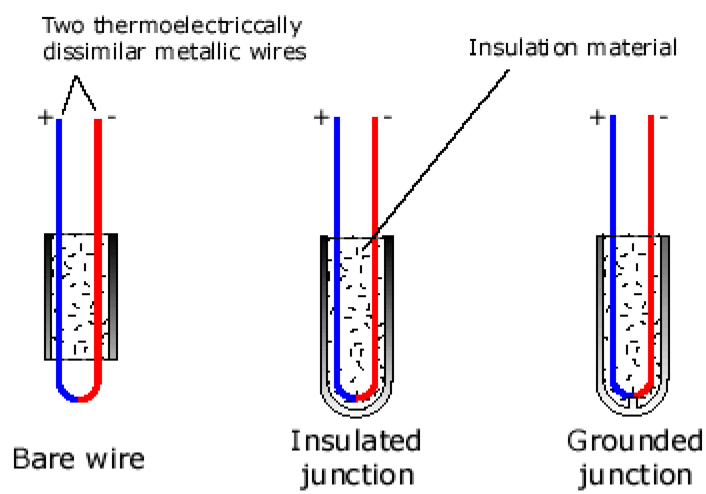
Arthur Franklin

What IS thermoelectricity?

- Conversion of heat to electricity, and vice versa.
- Most well known concept “Thermocouple”

Thermocouple

- Two differing conductors with ends connected when at different temperatures a small voltage arises allowing for current flow.



$$E_{AB} = \int_{T_t}^{T_j} \sigma_{AB}\, dT$$

Couple physics

- Seebeck effect- manifestation of a voltage due to temperature gradient along a conductor.
- σ- Seebeck coefficient (based on material)
- Voltage E_{12} – EMF measured from temp point 1 to 2.
- m & B, based on material properties
- ΔE_{12} change in Emf
- ΔT_2 Change in temperature

$$E_{12} = \bar{\sigma}(T_2 - T_1)$$

$$V(x) = mT(x) + B$$

$$E_{12} + \Delta E_{12} = \bar{\sigma}(T_2 - T_1) + \sigma(T_2)\Delta T_2$$

$$\sigma(T_2) = \frac{\Delta E_{12}}{\Delta T_2}$$

$$E_{AB} = \int_{T_t}^{T_j} \sigma_A \, dT + \int_{T_j}^{T_t} \sigma_B \, dT$$

http://web.cecs.pdx.edu/~gerry/epub/pdf/thermocouple.pdf

Pros

- Free Energy- Kind of, use of natural heated materials through conduction can generate voltages that can contribute power.
- Efficiency of 14% competitive on feasible alternative energy market.
- Output peak around 75 watts.
- Great for charging batteries.

Negs

- High efficiency conmibations, Pb, Sn, Bi,Te can get heavy.
- Best temperature effeciency conversion in ΔT ranges 300K-800K
- Long term degradation of metal junction can limit usable lifetime. (Months –years)

Power/ Effeciency

- Limited by temperature difference
- Large internal resistance minimizes Power
- Low temp effeciency peak ~15%
- For human temp difference ~ 12° C effeciency ~ 4%

$$Power = \frac{1}{R_g}\left(\frac{\alpha \times (T_h - T_c)}{\sqrt{(1+ZT_a)}+1}\right)^2$$

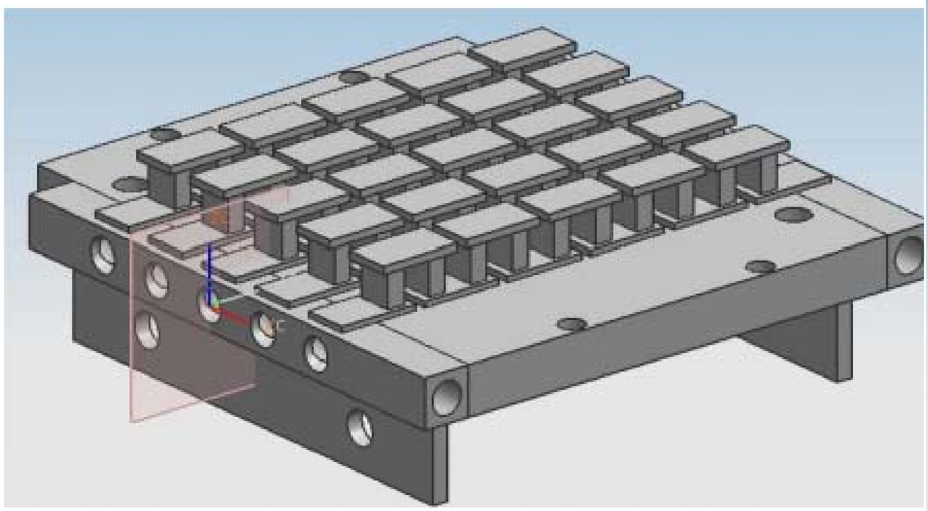
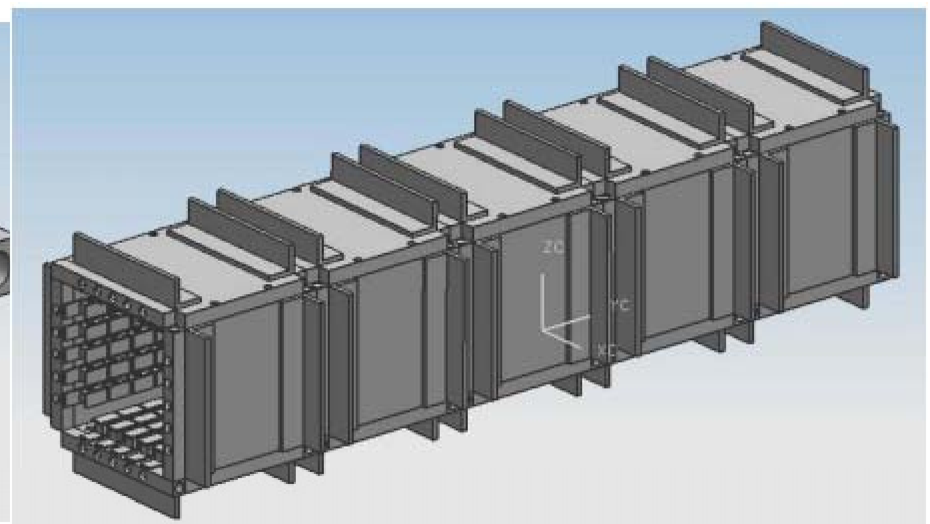
Electrical Resistivity (ρ)	$1.2 \times 10^{-5} \Omega M^{-1}$
Seebeck Coefficient (α)	$243 \mu V K^{-1}$
Thermal Conductivity (λ)	$0.97 W m^{-1} K^{-1}$
Figure of Merit: Z.T	2.37
Temperature at hot end (T_h)	350K
Temperature at cold end (T_c)	300K
Average Temperature (T_a)	325K
Silicon wafer height (L)	$5 \times 10^{-4} M$
Via Area (A)	$1 cm^2$

$$Carnot = \frac{(T_h - T_c)}{T_h}$$

http://www.cs.columbia.edu/~simha/cal/pubs/pdfs/cat_warmer.pdf

TEG

- Metallic coating (Bismuth Telluride)
- Placed on/under chips on circuits
- Nets about 2-6% conversion with ΔT >20k

http://www.cs.columbia.edu/~simha/cal/pubs/pdfs/cat_warmer.pdf

Low-band Photovoltaics

- Rare materials
- Large dependence on conventional metal combinations
- Expensive!

Resources

- http://www.infoplease.com/ce6/sci/A0848443.html "Thermoelectricity“
- "The Encyclopedia of Alternative and Sustainable Living" http://www.daviddarling.info/encyclopedia/T/AE_thermocouple.html
- http://www.cs.columbia.edu/~simha/cal/pubs/pdfs/cat_warmer.pdf
- http://www.efunda.com/DesignStandards/sensors/thermocouples/thmcple_intro.cfm
- http://web.cecs.pdx.edu/~gerry/epub/pdf/thermocouple.pdf