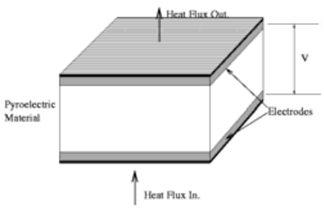
Pyroelectric Effect.

Generation of electric change by a crystalline material when subjected to a heat flow.



Closely related to Piezoelectricity.

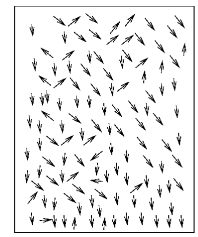
$BaTiO_3$, PZT and PVDF all exhibit Pyroelectric effects

Primary Pyroelectricity.

Temperature changes shortens or elongates individual dipoles.

This affects randomness of dipole orientations due to thermal agitation.

Hotter



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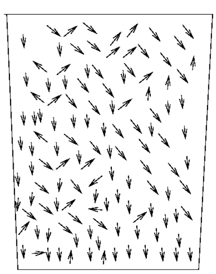
Differential Dipole Moment

Secondary Pyroelectricity

Hotter



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Differential temperature Induces a strain Causing Piezoelectricity

Quantitative Pyroelectricity.

Pyroelectric crystals are transducers: they convert thermal to electrical energy.

The Dipole moment of the bulk pyroelectric is: $M = \mu A h$

Where μ is the dipole moment per unit volume, A is the sensor area and h is the thickness

From standard dielectrics, charge on electrodes, $Q = \mu A$

The dipole moment, μ, varies with temperature.

$P_Q = \frac{dP_S}{dT}$ Is the pyroelectric charge coefficient, and P_s is the "spontaneous polarisation"

The generated charge is $\Delta Q = P_Q A \Delta T$

$P_v = \frac{dE}{dT}$ is the pyroelectric voltage coefficient and E is the electric Field.

The generated voltage is $\Delta QV = P_v h \Delta T$ (h is the thickness)

The relation between charge and voltage coefficients follows directly from Q = CV

$$\frac{P_Q}{P_V} = \frac{dP_S}{dE} = \varepsilon_r \varepsilon_0$$

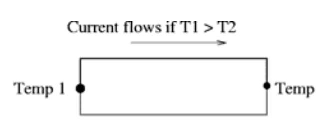
Seebeck and Peltier Effects.

Seebeck effect: Thermally induced electric currents in circuits of dissimilar material.

Peltier effect: absorption of heat when an electric current cross a junction two dissimilar materials

The dissimilar materials can be different species, or the the same species in different strain states.

The Peltier effect can be thought of as the reverse of the Seebeck effect



Seebeck effect

Free electrons act as a gas. If a metal rod is hot at one end and cold at the other, electrons flow from hot to cold.

So a temperature gradient leads to a voltage gradient:

$$\frac{dV}{dx} = \alpha \frac{dT}{dx}$$

Where α is the absolute Seebeck coefficient of the material.

When two materials with different α coefficients are joined in a loop, then there is a mis-match between the temperature-induced voltage drops.

The differential Seebeck coefficient is: $\alpha_{AB} = \alpha_A - \alpha_B$

Thermocouples

The net voltage at the junction is $dV_{AB} = \alpha_{AB} dT$

So the differential Seebeck coefficient is also $\alpha_{AB} = \frac{dV_{AB}}{dT}$

This is the basis of the thermocouple sensor

Thermocouples are not necessarily linear in response. E.g. the T – type thermocouple has characteristics

$$V = a_0 + a_1 T + a_2 T^2$$

Where the a's are material properties:

$$V = -0.0543 + 4.094 \times 10^{-2} T + 2.874 \times 10^{-5} T^2$$

The sensitivity is the differential Seebeck coefficient

$$\alpha_{AB} = \frac{dV_{AB}}{dT} = a_1 + 2a_2 T = 4.094 \times 10^{-2} + 5.748 \times 10^{-5} T$$

Independent of geometry, manufacture etc. Only a function of materials and temperature.

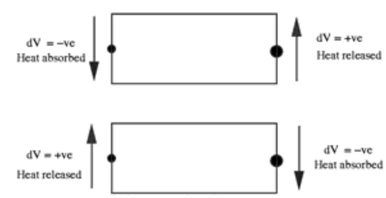
Seebeck effect is a transducer which converts thermal to electrical energy.

Can be used as solid state thermal to electrical energy converter (i.e. engine)as well as an accurate temperature sensor.

Seebeck engines are currently not very efficient but are much more reliable than heat engines. They are used by NASA for nuclear powered deep-space probes.

Peltier Effect.

If electric current is passed through a dissimilar material junction, then the heat may be generated or *absorbed.*



The change in heat dQ =±p I dt

(where p is the Peltier constant (unit of voltage))

Can be used to produce heat or *cold* as required.

Eg. Cooling high performance Microprocessors.

Table 3-8 Characteristics of some thermocouple types

Junction Materials	Sensitivity µV/°C (@ 25°C)	Temperature Range (°C)	Applications	Designation
Copper/Constantan	40.9	-270 to +600	Oxidation, reducing, inert, vacuum. Preferred below 0°C. Moisture resistant	T
Iron/Constantan	51.7	-270 to +1000	Reducing and inert atmosphere. Avoid oxidation and moisture	J
Chromel/Alumel	40.6	-270 to 1300	Oxidation and inert atmospheres	K
Chromel/Constantan	60.9	-200 to 1000		E
Pt (10%)/Rh-Pt	6.0	0 to 1550	Oxidation and inert atmospheres, avoid reducing atmosphere and metallic vapors	S
Pt (13%)/Rh-Pt	6.0	0 to 1600	Oxidation and inert atmospheres, avoid reducing atmosphere and metallic vapors	R