HIDDEN POWER

THERMOELECTRICITY

How do heat and cold make electricity?

Question & Answer Fact Sheet

Can you explain the concept of thermoelectricity in more detail?

Thermo means “heat.” Therefore, thermoelectricity is the generation of electricity that results when a temperature difference is created across a given material (or materials). The reverse process is referred to as the thermoelectric effect, also known as Seebeck-Peltier effect, in which a temperature gradient results when an electric field is applied across the material.

Thermoelectricity originates from the fact that electrons in metals are freely able to move. The motion of electrons becomes even faster at higher temperatures (when heated). Interestingly, if a material becomes “hot” on one end and “cold” on the other, electrons respond by creating a net diffusion towards the cold end. This concentration of charge on one end compared to the other creates a potential difference that can then be used to generate electricity. In reverse mode, creating an electric potential across the material causes one end to become “hot” and the other end “cold”.

Note: The terms “hot” and “cold” are being used to describe temperature difference in a simple manner. In reality, both of the temperatures could be cold (or hot) compared to our everyday human experiences. The important factor is simply how far apart these two temperatures are from one another, not their value on the absolute scale.

When was the first thermoelectric generator created?

Thomas Johann Seebeck is credited with discovering in 1821 that electricity could be produced when one end of two connected dissimilar metals was heated within a circuit. This discovery became the basis for the development of the thermocouple (a device used to measure temperature) and the thermopile (a thermo-electric generator which could then be used to charge batteries).

Generators of this type were used ca. 1900 to charge storage batteries. The apparatus is in the collection of Hobart and William Smith Colleges in Geneva, New York.

Image source: http://physics.kenyon.edu/EarlyApparatus/Thermodynamics/Thermoelectric_Battery/Thermoelectric_Battery.html

What kinds of devices or applications currently, and in the future, utilize this scientific concept?

One obvious application of thermoelectricity is the thermoelectric generator, which converts heat to electricity. Such generators have already found wide uses by oil companies to power remote stations and by NASA to power spacecraft. However, the use of the thermoelectric generator among the general public has been limited until fairly recently. Thermocouples, which are an essential component of many electric thermometers and heating control devices, also use the thermoelectric effect.

Other applications take advantage of the reverse process of thermoelectricity, using electricity to heat up or cool down devices. Small heaters and refrigerators whose operation is based on this effect have been developed.

How will this scientific concept impact our society? What are the pros and cons of its usage?

An inherent problem with much of our current energy use is the tremendous amount of waste heat that is produced. Using thermoelectric devices, this unused waste heat (from car exhaust, industry and manufacturing processes, home and office heating systems, computers, lighting, etc.) could be harnessed and converted to electricity. Another advantage of thermoelectric devices is that they have no moving parts, they are quiet and reliable, and they can be very small and easily portable.

Unfortunately, the electric potential produced using thermoelectrics is currently very low. Therefore, in order to obtain a high enough total voltage to be usable, multiple thermoelectric generators must be connected in series together, which in turn greatly increases the electric resistance, causing much of the electrical energy created to be wasted as heat again. Thermoelectricity will only find widespread use when its efficiency can be improved.

What's happening on the cutting edge of research in this area right now?

In order to perform efficiently, thermoelectric materials must have the following two properties simultaneously:

1. High electrical conductivity (so that electrons can move freely through the material)
2. Low thermal conductivity (so that a large temperature difference (heat flow) can be created and maintained across the material)

Unfortunately, these properties are not unrelated to each other; therefore, improving one often conflicts with improving the other. Current research is looking at new ways to improve the efficiency of thermoelectric materials by manipulating these and other related properties. The methods being used require the use of nano-engineering and nano-technology to manipulate the molecular structures of thermoelectric materials at the nano-scale level.

One strategy used to decrease thermal conductivity involves adding extra atoms to the crystal (called "doping"). These atoms disrupt the transfer of heat by the lattice vibrations (which are called "phonons"), while still allowing the electrons to move through the crystal. Another way of lowering thermal conductivity involves introducing interfaces that prohibit the phonon heat transfer but still allow electrons to pass through.