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Number 727 #1, April 14, 2005 by Phil Schewe and Ben Stein

A New Kind of Equilibrium

Normally heat will flow from a hot place to a neighboring cold place. In a new form of thermoelectric refrigerator, proposed by Tammy Humphrey (University of Wollongong, Australia) and Heiner Linke (University of Oregon), temperature imbalances can be held at bay by electrochemical imbalances. The implications? Possibly much more efficient forms of no-moving-parts electric refrigerators.

Heat and electricity are two forms of energy, and in a special circuit, made from thermoelectric materials, a temperature difference can generate electricity and, conversely, a voltage difference can bring about a temperature difference. A thermoelectric circuit usually consists of two semiconductors joined at two junctions. One of the semiconductors is of the p type with a surplus of holes, the other of the n type with a surplus of electrons.

Here's how you can generate heat or electricity in contrary phenomena. In the Peltier effect, a voltage imbalance will pull electrons and holes out of one of the junctions, thus cooling that junction and warming the other junction. In the Seebeck effect, things work in reverse: a temperature imbalance between the junctions will set electrons and holes in motion, thus constituting an electric current. The Peltier effect is at work, for example, in on-chip cooling of critical microcircuitry. The Seebeck effect is used in powering spacecraft (too far from the sun for photocells to be of use), where the heat from a radioactive source is used to make electricity. What keeps thermoelectric devices from greater applicability is the poor efficiency, typically 10%.

One of the main problems is that some of the heat (applied at one junction) used to drive a current through the circuit is carried by electrons to the other junction, reducing the thermal gradient and therefore sapping the process of generating electricity. What one needs is a circuit good for electric conduction but poor for thermal conduction by electrons. And this is what Humphrey (tammy.humphrey@unsw.edu.au) and Linke's proposed circuit would do (see figure at www.aip.org/png).

The p-leg and n-leg parts of the circuits would consist not of bulk matter but of quantum dots, nanoscopic pieces of matter in which only select electron energies are allowed. Engineer the dots to discourage the higher-energy electrons carrying thermal energy, heat leakage will drop, and the overall efficiency will go up. The best thermoelectric efficiencies are about 10%. If efficiencies could be pushed to 50%, the thermoelectric approach (silent, less bulky, no refrigerant, long lived) would compete to take over even bulk household refrigeration, Humphrey says. (Physical Review Letters, 11 March 2005; lab website www.humphrey.id.au, http://darkwing.uoregon.edu/~linke/

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