Thermoelectric materials are 1 key to energy savings

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Breathing new life into an old idea, MIT Institute Professor Mildred S. Dresselhaus and co-workers are developing innovative materials for controlling temperatures that could lead to substantial energy savings by allowing more efficient car engines, photovoltaic cells and electronic devices.

Novel thermoelectric materials have already resulted in a new consumer product: a simple, efficient way of cooling car seats in hot climates. The devices, similar to the more-familiar car seat heaters, provide comfort directly to the individual rather than cooling the entire car, saving on air conditioning and energy costs.

The research is based on the principle of thermoelectric cooling and heating, which was first discovered in the early 19th century and was advanced into some practical applications in the 1960s by MIT professor (and former president) Paul Gray, among others.

Dresselhaus and colleagues are now applying nanotechnology and other cutting-edge technologies to the field. She'll describe her work toward better thermoelectric materials in an invited talk on Monday, Nov. 26, at the annual meeting of the Materials Research Society in Boston.

Thermoelectric devices are based on the fact that when certain materials are heated, they generate a significant electrical voltage. Conversely, when a voltage is applied to them, they become hotter on one side, and colder on the other. The process works with a variety of materials, and especially well with semiconductors — the materials from which computer chips are made. But it always had one big drawback: it is very inefficient.

The fundamental problem in creating efficient thermoelectric materials is that they need to be very good at conducting electricity, but not heat. That way, one end of the apparatus can get hot while the other remains cold, instead of the material quickly equalizing the temperature. In most materials, electrical and thermal conductivity go hand in hand. So researchers had to find ways of modifying materials to separate the two properties.

The key to making it more practical, Dresselhaus explains, was in creating engineered semiconductor materials in which tiny patterns have been created to alter the materials' behavior. This might include embedding nanoscale particles or wires in a matrix of another material. These nanoscale structures — just a few billionths of a meter across — interfere with the flow of heat, while allowing electricity to flow freely. "Making a nanostructure allows you to independently control these qualities," Dresselhaus says.

She and her MIT collaborators started working on these developments in the 1990s, and soon drew interest from the US Navy because of the potential for making quieter submarines (power generation and air conditioning are some of the noisiest functions on existing subs). "From that research, we came up with a lot of new materials that nobody had looked into," Dresselhaus says.

After some early work conducted with Ted Harman of MIT Lincoln Labs, Harman, Dresselhaus, and her student Lyndon Hicks published an experimental paper on the new materials in the mid 1990s. "People saw that paper and the field started," she says. "Now there are conferences devoted to it."

Her work in finding new thermoelectric materials, including a collaboration with MIT professor of Mechanical Engineering Gang Chen, invigorated the field, and now there are real applications like seat coolers in cars. Last year, a small company in California sold a million of the units worldwide.

OTHER POTENTIAL APPLICATIONS

The same principle can be used to design cooling systems that could be built right into microchips, reducing or eliminating the need for separate cooling systems and improving their efficiency.

The technology could also be used in cars to make the engines themselves more efficient. In conventional cars, about 80 percent of the fuel's energy is wasted as heat. Thermoelectric systems could perhaps be used to generate electricity directly from this wasted heat. Because the amount of fuel used for transportation is such a huge part of the world's energy use, even a small percentage improvement in efficiency can have a great impact, Dresselhaus explains. "It's very practical," she says, "and the car companies are getting interested."

The same materials might also play a role in improving the efficiency of photovoltaic cells, harnessing some of the sun's heat as well as its light to make electricity. The key will be finding materials that have the right properties but are not too expensive to produce.

Dresselhaus and colleagues are continuing to probe the thermoelectric properties of a variety of semiconductor materials and nanostructures such as superlattices and quantum dots. Her research on thermoelectric materials is presently sponsored by NASA.

Source: Massachusetts Institute of Technology