Promising new material that could improve gas mileage

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With gasoline at high prices, it's disheartening to know that up to three-quarters of the potential energy you are paying for is wasted. A good deal of it goes right out the tailpipe instead of powering your car.

Now a Northwestern University-led research team has identified a promising new material that could transform a technology that currently cools and heats car seats -- thermoelectrics -- into one that also efficiently converts waste heat into electricity to help power the car and improve gas mileage.

The researchers discovered that adding two metals, antimony and lead, to the well-known semiconductor lead-telluride, produces a thermoelectric material that is more efficient at high temperatures than existing materials. The results are published online in the journal *Angewandte Chemie*.

"We cannot explain this 100 percent, but it gives us a new mechanism -- and probably new science -- to focus on as we try to raise the efficiency of thermoelectrics," said Mercouri G. Kanatzidis, Charles E. and Emma H. Morrison Professor of Chemistry in the Weinberg College of Arts and Sciences and the paper's senior author.

Current thermoelectric technology is only used in niche markets, such as solid-state refrigeration and cooling, because the materials are not very efficient. With new materials and increased efficiency, devices based on thermoelectrics could find widespread use in the automotive industry, solar energy conversion and the conversion of waste heat from nuclear reactors, smokestacks and industrial equipment.

"It's a big accomplishment to recover some of the heat or energy that would otherwise be lost and convert it into useful energy," said Kanatzidis. "That's what thermoelectrics can do, but we need to make them more efficient to really be practical."

Thermoelectric materials are only 5 to 6 percent efficient today, but a new generation of materials based on recent discoveries including this one at Northwestern, could produce devices with 11 to 14 percent efficiency, says Kanatzidis. The long-term goal is to reach 20 percent.

Thermoelectric materials convert heat into electricity by taking advantage of temperature differences. Electrons move from the hot end of the material to the cold end, creating positive and negative electrodes and an electrical voltage.

A thermoelectric device, for example, could be attached to a car's tailpipe. The side of the material in contact with the tailpipe would be the hot side, and the side exposed to the air would be the cold side. The temperature difference would be enough to generate electricity, which would be returned to the car's engine for additional torque. Such devices also could be used in large industrial plants, such as those for power, chemical production and glass making.

Car companies are working on the thermoelectrics problem as part of their strategy to raise the overall gas mileage of vehicles, says Kanatzidis. They hope to raise mileage by 5 to 10 percent per gallon using thermoelectrics, which would be significant.

A superior thermoelectric material needs to have these properties to work: high electrical conductivity (to transfer a lot of power), low thermal conductivity (to maintain the temperature difference and prevent equilibrium) and the ability to generate a large voltage for as small a temperature difference as possible.

A material with all three properties is difficult to find, but Kanatzidis and his team found it -- in an unexpected way.

Four years ago, Kanatzidis and his research group discovered a class of materials based on lead-telluride that doubled the efficiency performance of existing materials. They were able to lower the thermal conductivity without changing its electrical properties by putting nanodots -- small particles of silver-antimony-telluride between two and 10 nanometers in diameter -- inside the lead-telluride.

For the new work reported in Angewandte Chemie, Kanatzidis and graduate student Joseph Sootsman decided to add two different materials -- the metals lead and alimony, also in the form of nanodots -- to lead-telluride to see if they could lower the thermal conductivity even more. They were surprised when they saw the results.

"The thermal conductivity was not any lower than our earlier results, but we discovered a net gain in electrical conductivity at high temperatures that we didn't expect," said Kanatzidis. "This means we had a net gain in power coming out of the material that we didn't have before. This was very surprising."

Interestingly, the researchers also discovered that adding lead or antimony alone to the lead-telluride did not produce an improvement. Lead and antimony both had to be present in the lead-telluride to produce the electrical conductivity gain. The electrons scatter less and move faster with the two inclusions than with just one or none.

"This phenomenon will stimulate new scientific inquiries and generate new ideas on how to design even more efficient thermoelectric materials in the future," said Kanatzidis.

Source: Northwestern University

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