Clean Energy Breakthrough Converts Waste Heat to Electricity

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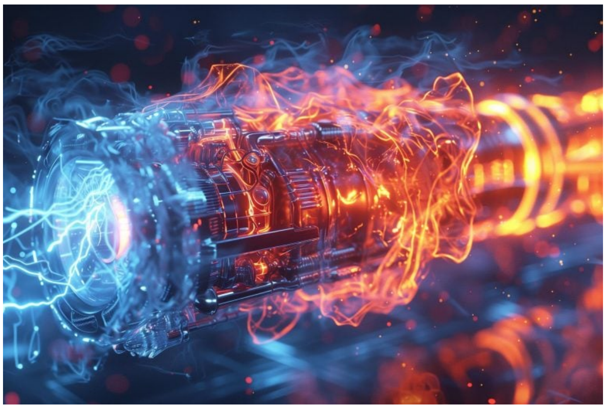
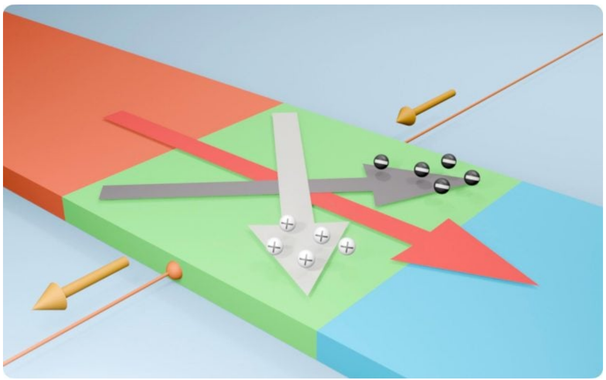


Courtesy of SynEvol
Credit: Tokyo University of Science

In order to capture waste heat and turn it into useful power, thermoelectric materials—which turn heat into electricity—are essential. These materials improve energy efficiency by producing more power, which is especially helpful in industries and automobiles where engines generate a lot of waste heat. Additionally, they have potential for portable power applications where conventional power sources might not be practical, including satellites and remote sensors.

The voltage produced by conventional thermoelectric devices, sometimes referred to as parallel thermoelectric devices, follows the direction of heat flow. P-type and n-type parallel materials, which generate voltages in opposite directions, provide the basis for these devices. They provide a higher voltage when connected in series, but this arrangement adds more contact points, which raises electrical resistance and energy loss.

Conversely, transverse thermoelectric devices provide a clear advantage by producing electricity perpendicular to the heat flow. These devices allow for more effective energy conversion with fewer contact points. Materials with "axis-dependent conduction polarity" (ADCP), commonly referred to as goniopolar conductors, are a potential class for these devices. These substances conduct n-type (negative) charges in one direction and p-type (positive) charges in another. But up until now, little research has been done on the transverse thermoelectric effect (TTE), despite its potential.



Courtesy of SynEvol
Credit: Ryuji Okazaki

According to this perspective, a Japanese research team led by Associate Professor Ryuji Okazaki of Tokyo University of Science's (TUS) Department of Physics and Astronomy, along with Mr. Shoya Ohsumi of TUS and Dr. Yoshiki J. Sato of Saitama University, achieved TTE in the semimetal tungsten disilicide (WSi2). WSi2 has ADCP, as demonstrated by earlier research, however trials have not found its source or the expected TTE.

As a new fundamental technology for sensors that can measure temperature and heat flow, transverse thermoelectric conversion is becoming more and more popular. There aren't many of these materials, though, and there aren't any set design standards. Prof. Okazaki says, "This is the first direct proof of the transverse thermoelectric conversion in WSi2.

Through a combination of computer models and practical testing, the researchers examined the characteristics of WSi2. At low temperatures, they investigated a WSi2 single crystal's thermopower, electrical resistivity, and thermal conductivity along its two crystallographic axes. They discovered that WSi2's distinct electronic structure, which includes mixed-dimensional Fermi surfaces, is the source of its ADCP. The existence of electrons and holes (positive charge carriers) in distinct dimensions is demonstrated by this structure.

The hypothesized geometrical surface that divides the occupied and unoccupied electronic states of charge carriers within a solid substance is known as a Fermi surface. In WSi2, holes create quasi-two-dimensional Fermi surfaces and electrons create quasi-one-dimensional ones. The TTE effect is made possible by the direction-specific conductivity produced by these special Fermi surfaces.

In line with earlier study, the researchers also noticed differences in these charge carriers' electrical conductivity between samples. The researchers demonstrated through first-principles simulations that these variances resulted from variations in the way charge carriers scatter as a result of flaws in the WSi2 crystal lattice structure. This realization is essential for improving the substance and creating dependable thermoelectric devices. By introducing a temperature differential along a certain angle with respect to both crystallographic axes, they also showed direct TTE creation in WSi2, producing a voltage perpendicular to the temperature differential.

"WSi2 is a

promising candidate for TTE-based devices, according to our results." We anticipate that this research will result in the identification of novel transversal thermoelectric materials and the creation of new sensors," Prof. Okazaki says.

This work advances the development of new materials that can more effectively convert heat into electricity, paving the way for a greener future by clarifying the mechanism of TTE generation in WSi2.
