Researchers Spot a Ferron

Experimental measurements of a quasiparticle called a ferron indicate that ferrons could be used to turn ferroelectric materials into thermal switches, devices that can be used to control heat flow in engines.

By **Allison Gasparini**

Gasoline power plants, vehicle combustion engines, and spacecraft jets convert heat energy from a burning fluid into mechanical energy. The efficiency of this process lies between around 15 and 50%, depending on the fluid and the engine type, making it a relatively poor energy-conversion mechanism. Predictions indicate that switching the heat-generation process with one that involves a solid-state material could increase energy-conversion efficiency by 10%. Now, experiments designed to detect the ferron, a previously only theorized quasiparticle, may have found such a material [**1**].

The ferron is thought to carry polarization. As such, it is akin to the magnon, the quasiparticle that propagates spin currents in magnetic systems, and, like their magnetic cousin, the ferron is predicted to carry heat. But prior to these new experiments, the ferron had yet to be experimentally observed.

Engines that generate energy by producing heat with solids rather than by burning fluids are predicted to have significantly higher energy-conversion efficiencies.
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In their experiments Brandi Wooten of Ohio State University and her colleagues studied a ferroelectric ceramic material called lead zirconium titanate. They applied an electric field to the material and then made various measurements to probe the system's thermal properties and its heat carrying particles.

Ramping the field from 0 to 1,000,000 V/m, the team measured a 2% increase in the ferroelectric's thermal conductivity. This increase is 4 times greater than that reported for ferroelectrics in previous experiments but matches that predicted by a model that assumes that the heat is carried by ferrons. The thermal conductivity change is reversible, something that the team says could allow researchers to turn the heat flow on and off. When on, a heat engine could convert the incoming heat from this thermal switch into mechanical energy.

The finding is interesting and unexpected, says Patrick Woodward a chemist also at Ohio State University. He notes, however, that it remains to be seen if it's possible to use ferroelectric materials to achieve a heat-flow change that is substantial enough to make a practical thermal switch. Wooten agrees that this question has yet to be answered—the maximum thermal conductivity they measured for lead zirconium titanate is too low for applications. But she says that this demonstration is still an important proof of concept. Most known solid-state heat switches operate at very low temperatures, while this new one operates at room temperature. That makes it very special, she says.

The team is now studying other ferroelectric materials that they think should have the needed thermal conductivity properties for applications. Woodward says that he is interested to see how these more chemically complex materials behave. The team's current goal is to find a ferroelectric with a thermal conductivity that increases by 15–20% when an electric field is applied. "It would be a magical thing to have a [ferroelectric] heat switch," says Joseph Heremans of Ohio State University and the lead researcher on this study. "It could revolutionize the world of heat engines."

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REFERENCES

1. B. L. Wooten *et al.*, "Electric field–dependent phonon spectrum and heat conduction in ferroelectrics," **Sci. Adv. 9 (2023).**