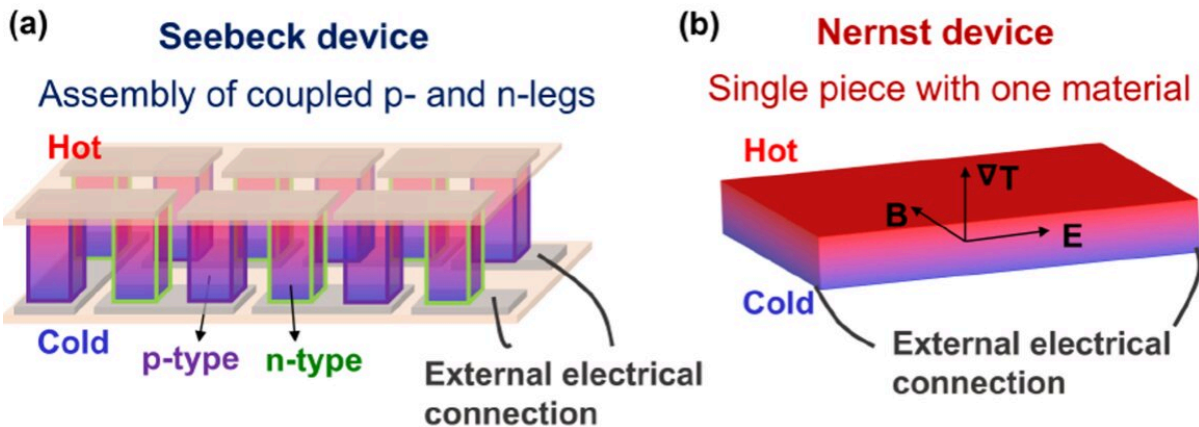


A new way to generate electricity from waste heat: Using an antiferromagnet for solid devices

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Schematics of thermoelectric devices based on the Seebeck effect (a) and Nernst effect (b). The Nernst device needs only one material and eliminates the complex electrical connections required in the Seebeck device, especially at the hot side. B, magnetic field; E, electrical field; ∇T , temperature gradient. Credit: MPI CPfS

Forcing electrons to flow perpendicularly to a heat flow requires an external magnetic field—this is known as the Nernst effect. In a permanently magnetized material (a ferromagnet), an anomalous Nernst effect (ANE) exists that can generate electricity from heat even without a magnetic field. The anomalous Nernst effect scales with the magnetic

moment of the ferromagnet. An antiferromagnet, with two compensating magnetic sublattices shows no external magnetic moment and no measurable external magnetic field and therefore should not exhibit any ANE.

However, we have recently understood that by the new concept of topology can be applied to achieve large Nernst effects in magnets. In particular, we have learned that the quantity known as the Berry phase is related to the ANE and can greatly increase it. However, the ANE in antiferromagnets is still largely unexplored, in part because the ANE was not thought to exist. Remarkably, a joint research team from the Max Planck Institute for Chemical Physics of Solids in Dresden, Germany, together with collaborators at the Ohio State University and the University of Cincinnati, has found a large anomalous Nernst effect, larger than is known in almost all ferromagnets in YbMnBi_2 , an antiferromagnet.

The ANE that has been observed is likely a result of topology, the high spin-orbit coupling, and the complex and not fully compensated magnetic structure of YbMnBi_2 . The canted spin structure in YbMnBi_2 breaks time reversal symmetry and provides a non-zero Berry curvature. At the same time, the large spin-orbit coupling of the heavy bismuth element helps to produce a large extrinsic contribution. Based on this recipe, a certain class of antiferromagnets with a non-collinear spin structure and with large spin-orbit coupling can exhibit a large anomalous Nernst effect. The researchers were surprised when they observed such a large ANE in YbMnBi_2 , reaching 6 mV/K, which is a record value for antiferromagnets and as high as those values previously observed for the best ferromagnets.

For [practical applications](#), one could use this new phenomenon to make simple energy converters: a transverse thermoelectric device where the voltage is generated perpendicular to the heat flow. The device consists

of only one block of material. The commercially available thermoelectric generators based on the Seebeck effect are complex assemblies built from small blocks of n- and p-type semiconductor materials. Unlike ferromagnets, which often suffer from low carrier mobility, antiferromagnets can also exhibit higher mobilities and therefore show better electrical conductivity. Together with [low thermal conductivity](#), an anomalous thermoelectric figure of merit (zT) is achieved in YbMnBi_2 , which is an order of magnitude higher than that of all known ferromagnets.

"Although the ANE value is surprisingly large and the zT value is much higher than that of ferromagnets, the overall thermoelectric performance still needs to be improved for practical applications," says Yu Pan, group leader in the department of Solid State Chemistry at the MPI CPfS in Dresden. She continues, "Nevertheless, this study shows the great potential of antiferromagnets for thermoelectric applications, as they have much better performance than ferromagnets. We believe our work is just the beginning of the discovery of even more interesting thermoelectric materials in the future."

More information: Yu Pan et al, Giant anomalous Nernst signal in the antiferromagnet YbMnBi_2 , *Nature Materials* (2021). [DOI: 10.1038/s41563-021-01149-2](#)

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