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# The spin degree of freedom in thermoelectrics


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## ABSTRACT:


The recent decade has seen a doubling of the efficiency of thermoelectric converters through the use of various band structure engineering techniques and nanotechnology. Here we add the spin degree of freedom to research on thermal solid-state energy converters, based on the recently discovered spin-Seebeck effect [SSE, 1,2]. In SSE, a temperature gradient applied to a spin-polarized material creates a spin flux that is driven into an adjacent material (Pt) where it gives rise to a voltage by the inverse spin-Hall effect via spin/orbit interactions. The thermal spin flux can be carried by either magnons or spin-polarized electrons. The magnon thermal conductivity in ferromagnets gives, under a temperature gradient, a magnon heat flux that is directly proportional to a spin flux [3]. Spin-polarized electrons can also sustain a spin flux: the effect can then be as large as the highest thermoelectric voltages in semiconductors [4]. In fact, even in diamagnetic solids under a magnetic field, the atomic motion due to phonons modulates the local diamagnetic moment (phonon-induced diamagnetism, [5]) enough to generate measurable changes in the anharmonicity and lattice thermal conductivity. The talk will conclude with a review of the potential to use spin fluxes in solid-state heat-to-electricity energy converters. The magnon-drag thermopower, first identified on Fe [6], can be seen as a self-spin-Seebeck effect, eliminating the need for an interface between a ferromagnet and a normal metal. Magnetism can now be considered as a new design tool that adds to thermoelectrics research. The engineering advantages of spin-Seebeck based devices over conventional thermoelectric generators will be described. Conversely, we will also show how phonon anharmonicity can be affected by magnetic fields, even in diamagnetic systems [7]. The local atomic displacements corresponding to the phonons locally modulate the valence band, which in turn creates a very small local modulation of the local diamagnetic susceptibility. In the presence of an external magnetic field, this exerts a local magnetic force on the atoms, which affects the Grueneisen parameter and thus phonon-phonon interactions. The effect on the lattice thermal conductivity of InSb is measurable, and modeled by the theory without any adjustable parameter.


## BIOGRAPHY:

Heremans joined the faculty of the Ohio State University as an Ohio Eminent Scholar and Professor in the Departments of Mechanical and Aerospace Engineering, Materials Science and Engineering, and Physics. He is a member of the National Academy of Engineering, and fellow of the American Associations for the Advancement of Science and the American Physical Society. He graduated from the Catholic University of Louvain (Belgium) with Ph.D. in Applied Physics (1978). Prior to joining OSU, he had a 21-year career at the General Motors Research Labs, and later at Delphi, as researcher and research manager. His research interests focus on the experimental investigation of electrical and thermal transport properties and on the physics of narrow-gap semiconductors, semimetals and nanostructures. In the last decade his group focuses on fundamental aspects of thermoelectric and thermal spin transport.