Indications of the origin of the Spin Seebeck effect discovered

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The recovery of waste heat in all kinds of processes poses one of the main challenges of our time to making established processes more energy-efficient and thus more environmentally friendly. The Spin Seebeck effect (SSE) is a novel, only rudimentarily understood effect, which allows for the conversion of a heat flux into electrical energy, even in electrically non-conducting materials.

A team of physicists at Johannes Gutenberg University Mainz (JGU), the University of Konstanz, TU Kaiserslautern, and the Massachusetts Institute of Technology (MIT) have now succeeded in identifying the origin of the Spin Seebeck effect. By the specific investigation of the material- and temperature-dependence of the effect, the German and American researchers were able to show that it exhibits a characteristic length scale attributable to its magnetic origin. This finding now allows for the advancement of this long-time controversial effect in terms of first applications. The resulting research paper was published in the scientific journal *Physical Review Letters*, with a fellow of the JGU-based Graduate School of Excellence "Materials Science in Mainz" (MAINZ) as first author.

The Spin Seebeck effect represents a so-called spin-thermoelectric effect, which enables the conversion of thermal energy into electrical energy. Contrary to conventional thermoelectric effects it also enables the recovery of heat energy in magnetic insulators in combination with a thin metallic layer. Owing to this characteristic, it was assumed that the effect originates from thermally excited magnetic waves. The currently employed method of measurement, which makes use of a second metallic layer converting these magnetic waves into a measurable electrical signal, has so far not been able to allow for a distinct assignment of experimentally detected signals.

By measuring the effect for different material thicknesses in the range of a few nanometers up to several micrometers as well as for different temperatures, the scientists have found characteristic behavior. In thin films the signal amplitude increases with increasing material thickness and eventually saturates after exceeding a sufficient thickness. In combination with the detected enhancement of this critical thickness at low temperatures, the agreement with the theoretical model of thermally excited magnetic waves developed at Konstanz could be demonstrated. With these results, the researchers were able for the first time to reveal a direct relation between the assumed thermally excited magnetic waves and the effect.

"This result provides us with an important building block of the puzzle of the comprehension of this new, complex effect, unambiguously demonstrating its existence," said Andreas Kehlberger, Ph.D. student at Johannes Gutenberg University Mainz and first author of the publication.

"I am very pleased that this exciting result emerged in a cooperation of a doctoral candidate out of my group at the Graduate School of Excellence 'Materials Science in Mainz' together with co-workers from Kaiserslautern and our colleagues from Konstanz, with whom we collaborate within the Priority Program 'Spin Caloric Transport' funded by the German Research Foundation (DFG)," emphasized Professor Mathias Kläui, director of the MAINZ Graduate School of Excellence based at Mainz University. "It shows that complex research is only possible in teams, for instance with funding by the German Federal Ministry of Education and Research (BMBF) through the Mainz-MIT

Seed Fund."

The MAINZ Graduate School of Excellence was originally approved as part of the Federal and State Excellence Initiative in 2007 and received a five-year funding extension in the second round in 2012 – a tremendous boost for the Mainz-based materials scientists and for the sponsorship of young researchers at JGU. The MAINZ Graduate School consists of work groups at Johannes Gutenberg University Mainz, the University of Kaiserslautern, and the Max Planck Institute for Polymer Research in Mainz. One of its focal research areas is spintronics, where cooperation with leading international partners plays an important role.

More information: A. Kehlberger et al., Length Scale of the Spin Seebeck Effect, *Physical Review Letters* 115, 9:28, 28. August 2015. [DOI: 10.1103/PhysRevLett.115.096602](http://dx.doi.org/10.1103/PhysRevLett.115.096602)

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