MA 26: Focus Session: Unconventional Thermoelectric Phenomena and Materials (joint session MA/TT)

Thermoelectric effects have been discussed for several decades and have found widespread applications. This Focus Session, a joint venture of the divisions MA (Magnetism) and TT (Low Temperature), will thematise recent developments, namely “unconventional” thermoelectric phenomena and materials [see, e.g., K. Uchida and J. P. Heremans, Joule 6, 2240 (2022)]: these include transverse thermoelectric effects, such as the ordinary and anomalous Nernst effects, where the generated charge current is perpendicular to the temperature gradient. The latter – similar to the anomalous Hall effect – relies on the spin-orbit interaction or on canted spin textures, and ensuing topological electronic structures. Transverse thermoelectricity can be found even without a magnetic field, namely in goniopolar materials (e.g., $NaSnAs_2$). Finally, nano-structured coherent quantum hybrid systems, containing dots as well as normal-conducting and superconducting elements, show remarkable – generally nonlocal – thermoelectric properties.

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Time: Wednesday 15:00–17:45 Location: H 1058

Invited Talk MA 26.1 Wed 15:00 H 1058

Enhanced Nernst effect in van der Waals tellurides — M. Behnami[1], M. Gillig[1], S. Aswartham[1], G. Shipunov[1], D. Efremov[1], B. R. Piening[1], I. V. Morozov[1], K. Ochkan[1], J. Dufouleur[1], V. Kocsis[1], C. Hess[1,5], M. Putti[4,6], F. Caglieris[1,4], B. Büchner[1,2], and •H. Reichlova[1,2,3] — [1]IFW Dresden, Germany — [2]IFMP, Technische Universität Dresden, Dresden, Germany — [3]Institute of Physics ASCR, Praha, Czech Republic — [4]CNR-SPIN, Genova, Italy — [5]Fakultät für Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, Germany — [6]Department of Physics, University of Genova, Italy

The increase in the Nernst effect and its anomalous component in magnetically ordered materials is actively researched, and I will start the talk with a brief overview of these efforts. Subsequently, I focus on layered van der Waals materials, which have garnered significant attention in current research due to their distinct properties not inherent in bulk compounds. Particularly intriguing are the topologically non-trivial telluride van der Waals type-II Weyl semimetals with substantial spin-orbit coupling. I will present a systematic exploration of the Nernst effect in this family of materials. We identified a large linear segment of the Nernst coefficient that scales with mobility; however, it does not conform to the previously reported Fermi liquid framework.

Invited Talk MA 26.2 Wed 15:30 H 1058

Hybrid transverse magneto-thermoelectric cooling in artificially tilted multilayers — •Ken-ichi Uchida — National Institute for Materials Science, Tsukuba, Japan

In artificially tilted multilayers comprising two different conductors that are alternately and obliquely stacked, transverse thermoelectric conversion occurs, in which charge and heat currents are interconverted in the orthogonal direction. Although transverse thermoelectric conversion also occurs in homogeneous materials as intrinsic transport phenomena owing to the effects of magnetic fields, magnetization, and spins on conduction carriers, such magneto-thermoelectric effects have been investigated independently of thermoelectrics for artificially tilted multilayers. Here, we show that the synergy of these different principles improves the performance of transverse thermoelectric conversion. Using lock-in thermography techniques, we visualize transverse thermoelectric conversion processes in artificially tilted multilayers and experimentally clarify how nonuniform charge currents are converted into orthogonal heat currents. Through the measurements of temperature change under magnetic fields, we quantify the contributions of the magneto-thermoelectric effects in the artificially tilted multilayers and demonstrate magnetically enhanced hybrid transverse thermoelectric cooling. By replacing one of the conductors in the multilayer with permanent magnets, the same functionality is obtained even in the absence of magnetic fields, paving the way for the creation of thermoelectric permanent magnets. This study provides a new material design guideline for transverse thermoelectrics.

Invited Talk MA 26.3 Wed 16:00 H 1058

Nonlocal heat engines with hybrid quantum dot systems — •Rafael Sánchez[1], Mojtaba S. Tabatabaei[2], David Sánchez[3], and Alfredo Levy Yeyati[1] — [1]Dep. Física teórica de la materia condensada and Ifimac, Universidad Autónoma de Madrid, Madrid, Spain — [2]Department of Physics, Kharazmi University, Tehran, Iran — [3]Institute for Cross-Disciplinary Physics and Complex Systems IFISC (UIB-CSIC), Palma de Mallorca, Spain

The energy absorbed by a conductor from a non-equilibrium environment can be rectified to generate finite electrical power. Typically, this depends on tiny energy-dependent asymmetries of the device, formed by e.g. a quantum dot [1]. We show that larger currents are expected in hybrid systems, where a superconductor hybridizes the even-parity states in the quantum dot [2]. We consider the environment to consist on a quantum dot Coulomb-coupled to the conductor and tunnel-coupled to a hot reservoir. Two main mechanisms contribute to the generation of power. On one hand, the non-equilibrium charge fluctuations in the second dot correlate with the Andreev processes, hence injecting Cooper pairs in the superconductor. This provides the necessary symmetry breaking energy transfer. On the other hand, this mechanism competes with quasiparticle contributions, which benefit from the sharp features of the superconducting density of states, and is able to increase the engine performance [3].

[1] H. Thierschmann et al., Nature Nanotech. 10, 854 (2015)
[2] S. M. Tabatabaei et al., Phys. Rev. Lett. 125, 247701 (2020)
[3] S. M. Tabatabaei et al., Phys. Rev. B 106, 115419 (2022)

15 min. break

Invited Talk MA 26.4 Wed 16:45 H 1058

Large anomalous Nernst thermoelectric performance in $YbMnBi_2$ — •Yu Pan[1,2], Congcong Le[2], Bin He[2], Sarah Watzman[3,4], Mengyu Yao[2], Johannes Gooth[2], Joseph Heremans[3], Yan Sun[2], and Claudia Felser[2] — [1]Chongqing University, Chongqing, China — [2]Max Planck Insitute for Chemical Physics of Solids, Dresden, Germany — [3]The Ohio University, Columbus, USA — [4]University of Cincinnati, Cincinnati, USA

The anomalous Nernst effect (ANE) have attracted increasing attention since the surge of topological semimetals, because the associated unique transverse geometry of ANE facilitates thermoelectric device fabrication. Topological ferromagnets with large Berry curvatures show large ANEs; however, they face drawbacks such as strong magnetic disturbances and low mobility due to high magnetization. Searching for materials with large ANE thermopower, low resistivity (high mobility), and low thermal conductivity are of great interest. It is found that $YbMnBi_2$, as a canted antiferromagnet, present a large ANE competitive to those of ferromagnets while with much lower resistivity and thermal conductivity. The canted spin structure of Mn guarantees a non-zero Berry curvature, but generates only a weak magnetization three orders of magnitude lower than that of general ferromagnets. The heavy Bi with a large spin-orbit coupling enables a large ANE and low thermal conductivity, whereas its highly dispersive $p_{x/y}$ orbitals ensure low resistivity. These results suggest $YbMnBi_2$ as an excellent candidate for transverse thermoelectrics.

Invited Talk MA 26.5 Wed 17:15 H 1058

A path to suistainable and scalable production of high-performance thermoelectric materials — •Maria Ibáñez — Institute of Science and Technology Austria, Am Campus 1, Klosterneuburg, Austria

Over the past few years, there has been a significant surge in interest surrounding solution-based techniques due to their cost-effectiveness and scalability in the production of high-performance thermoelectric materials. Herein, our primary focus will be on Ag_2Se, an important thermoelectric material for harnessing thermoelectricity at or near room temperature, an area where the selection of high-performing materials is currently limited. While Ag_2Se shows great promise, the main problems are the large discrepancy in the reported properties. These discrepancies often stem from the intricate control of defects within the material, such as vacancies, interstitial atoms, dislocations, grain boundaries, and precipitates. We will show that our solution-based synthesis method enables precise defect control, especially avoiding fluctuations in stoichiometry. Additionally, we will illustrate how we can fine-tune microstructural defects, including strain, dislocations, and grain boundary density, leveraging the characteristic phase transition of Ag_2Se during the sintering process. Our results will highlight that besides stoichiometry, the microstructure is crucial for tuning Ag_2Se transport properties. Furthermore, we will highlight the sustainability and scalability of our approach, where solvents can be reused and energy consumption minimized, contributing to a more environmentally friendly production process.