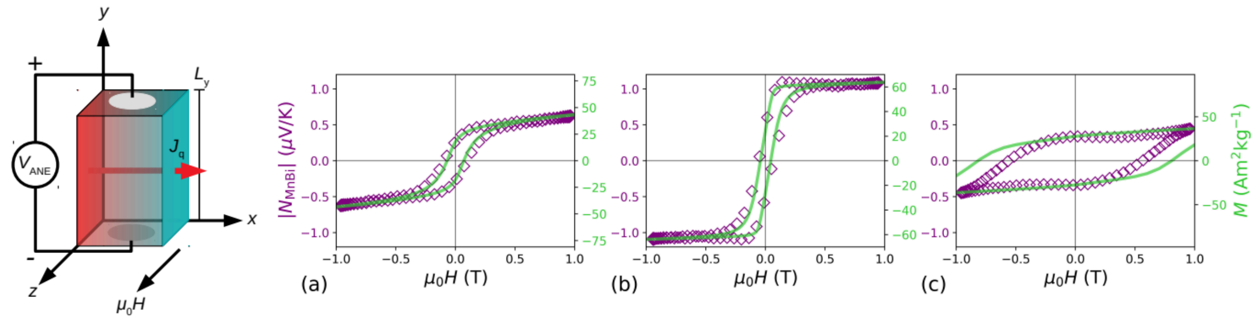
Heat flux sensors based on Nernst effects

The need to increase the efficiency in processes like thermal cycles, computing and energy storage and transportation has recently increased the focus on heat management, extending the field of interest to the reduced dimensions. In this framework, the design of thermal sensors based on new concepts towards higher versatility and reliability is of great interest for research and industry and has to be supported by metrological traceability. As a heat flux sensor, thermoelectric thermopiles represent an optimal choice in terms of sensitivity. However there are several drawbacks related to these devices, namely, they are rigid structures, their sensing area has geometrical constraints and the miniaturization of devices is limited. A promising way to overcome these limitations is the realization of active sensing surfaces based on transverse thermoelectric effects [1], in particular the Nernst effect of metals and semimetals [2] and the anomalous Nernst effect (ANE) of ferromagnets [3]. Although the Nernst effect is smaller than the Seebeck effect, its geometry permits the realization of a sensor based on a single layer of active material instead of junctions. The Nernst geometry, in which the thermoelectric voltage is perpendicular to the heat flux, simplifies the architecture of thermoelectric generators and therefore allows for higher integration towards the design of nanostructured devices and MEMS. A further advantage is the use of ANE materials, i.e. ferromagnets such as MnBi [4], whose properties like the magnetic remanence and coercivity can be tuned in polycrystalline sample [5], as shown in the following figure.



Geometry of the ANE measurements: (purple poins) ANE thermopowers as a function of the applied magnetic field of MnBi samples with different microstructure: (green lines) comparison with the magnetization curve for each sample.

Moreover, the possibility of using magnetic nano-particles and thin films as active elements allows the realization of flexible sensors, nano-structured devices and heat-sensitive coatings for sensors and energy harvesting devices.

The main objectives of the research on transverse thermoelectric effects are the optimization of the properties of materials for the preparation of devices, the experimental investigation of their transverse thermopower and the development of models related to the experimental findings.

These activities are in close relation with more fundamental studies like the role of topology [6] and Berry curvature [7] whose investigation can support the research on transverse thermoelectric effects.

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