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Magneto-Seebeck effect and thermal torques in magnetic tunnel junctions[1]

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Creating temperature gradients in magnetic nanostructures has resulted in a new research direction, i.e., the combination of magneto- and thermoelectric effects. Magnetic tunnel devices, known for application as magnetic sensor in hard disc drives or magnetic random access memories (MRAM) show large magnetoresistance. We show that in nanoscale magnetic tunnel junctions, the Seebeck voltage in a heat gradient can be controlled via the magnetization. The Seebeck coefficient changes during the transition from a parallel to an antiparallel magnetic configuration in a tunnel junction – the magneto-Seebeck effect. In that respect, it is the analog to the tunneling magnetoresistance and thus is called tunneling magneto-Seebeck effect (or tunneling magnetothermopower). The change in Seebeck coefficients is in the order of the voltages known from the charge-Seebeck effect in semiconductors (up to 100 μV/K). Their size and sign can be delicately controlled by the composition of the electrodes' atomic layers adjacent to the barrier and the temperature and we observe a characteristic sign change from positive to negative magneto-Seebeck effects as theoretically predicted. It is known that generally strong electronic asymmetry at around the Fermi level results in a large Seebeck effect. Here the magnetization dependence of the charge-Seebeck coefficients varying up to >100% for the parallel and the antiparallel originates from the half-metallic like transmission of the tunnel junction. Using heating with ultrafast laser pulses, these thermal gradients can be of up to 20 K across the tunnel barrier. We demonstrate that we can achieve the parameters predicted, where by thermal torques magnetization switching is expected. This allows to conceptually think of MRAM's driven by heat gradients only.

[1] M. Walter, et al. Nature Mater. 10, 742 (2011).

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