Magnetic heat valve: controlling heat flow at the nanoscale using nanopillar magnetic/non-magnetic nanostructures

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The race towards energy efficient data storage and memory devices has intensified over the past decade largely due to the discovery of the giant magnetoresistance (GMR). Since then, the flow of spin-polarized charge currents, that is, imbalance in the density of spin up and spin down electrons accompanying the flow of charge current is demonstrated to exert a spin torque on a nanomagnet island and change its magnetization direction although at a large critical current density. Unwanted heat generation, due to the flow of electrons, is often considered a nuisance to the proper functioning of any electronic device. One can tap this waste heat and imagine of spintronic devices that utilize heat to perform read/write operations or efficiently control the heat flow using a magnetic heat valve. These effects, which mainly arise from spin or heat accumulation at an interface between a ferromagnet and non-magnet, are studied in the field of spin caloritronics—a merger between spintronics and thermoelectrics. In this talk, after a brief introduction to field of spin caloritronics, I will give three examples of such spin based device concepts that are accessible by standard device fabrication techniques utilizing the Raith eLine lithography system. I will show that the flow of heat through a ferromagnet also results in the flow of spin current, an effect dubbed spin (dependent) Seebeck effect. The reciprocal of this process called the spin (dependent) Peltier effect results in the heating/cooling of a nanomagnet by the flow of a spin current. Finally I show the possibility of controlling the flow of heat using a magnetic heat valve that operates exactly as the GMR devices, but in the heat sector.

Scanning electron microscope image of a multifunctional spin caloritronic device which was made using the Raith eLine lithography system and standard liftoff processes. To complete the device, one optical and eleven e-beam lithography steps were required. The nanopillar (black rectangle) is sandwiched between a Pt-bottom (grey contact 1) and Au-top contact (yellow contact 5) which are electrically separated by a cross-linked PMMA (blue).

References: