Antiferromagnetic Insulatronics: Spintronics without magnetic fields

Mathias Kläui[1,2,3,*]

([1]Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany)
([2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany)
([3]Centre for Quantum Spintronics, NTNU, 7034 Trondheim, Norway)
(*IEEE Magnetics Society Distinguished Lecturer)

While known for a long time, antiferromagnetically ordered systems have previously been considered, as expressed by Louis Néel in his Nobel Prize Lecture, to be "interesting but useless". However, since antiferromagnets potentially promise faster operation, enhanced stability with respect to interfering magnetic fields and higher integration due to the absence of dipolar coupling, they could potentially become a game changer for new devices. The zero net moment makes manipulation using conventional magnetic fields challenging. However recently, these materials have received renewed attention due to possible manipulation based on new approaches such as photons [1] or spin-orbit torques [2]. In this talk, we will present an overview of the key features of antiferromagnets to potentially functionalize their unique properties. This includes writing, reading and transporting information using antiferromagnets.

We recently realized switching in the metallic antiferromagnet Mn2Au by intrinsic staggered spin-orbit torques [3,4] and characterize the switching properties by direct imaging. While switching by staggered intrinsic spin-orbit torques in metallic AFMs requires special structural asymmetry, interfacial non-staggered spin-orbit torques can switch multilayers of many insulating AFMs capped with heavy metal layers.

We probe switching and spin transport in selected collinear insulating antiferromagnets, such as NiO [5-7], CoO [8,9] and hematite [10,11]. In NiO and CoO we find that there are multiple switching mechanisms that result in the reorientation of the Néel vector and additionally effects related to electromigration can obscure the magnetic switching [5,7,9]. For the spin transport, spin currents are generated by heating as resulting from the spin Seebeck effect and by spin pumping measurements and we find in vertical transport short (few nm) spin diffusion lengths [6,8].

For hematite, however, we find in a non-local geometry that spin transport of tens of micrometers is possible [10,11]. We detect a first harmonic signal, related to the spin conductance, that exhibits a maximum at the spin-flop reorientation, while the second harmonic signal, related to the Spin Seebeck conductance, is linear in the amplitude of the applied magnetic field [10]. The first signal is dependent on the direction of the Néel vector and the second one depends on the induced magnetic moment due to the field. We identify the domain structure as the limiting factor for the spin transport [11]. We recently also achieved transport in the easy plane phase [12], which allows us to obtain long distance spin transport in hematite even at room temperature [12]. From the power and distance dependence, we unambiguously distinguish long-distance transport based on diffusion [10,11] from predicted spin superfluidity useful for logic [13].

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