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Magnetic dynamics studied by high-resolution electron spectroscopy and time-resolved electron microscopy.

RAJESWARI JAYARAMAN, EPFL - Lausanne

Future information technology requires an increased magnetically encoded data density and novel electromagnetic modes of data transfer. While to date magnetic properties are observed and characterized mostly statically, the need emerges to monitor and capture their fast dynamics. In this talk, I will focus on the spin dynamics i.e. spin wave excitations and the dynamics of a new topological distribution of spins termed "skyrmions". Wave packets of spin waves offer the unique capability to transport a quantum bit, the spin, without the transport of charge or mass. Here, large wave-vector spin waves are of particular interest as they admit spin localization within a few nanometers. By using our recently developed electron energy loss spectrometer, we could study such spin waves in ultrathin films with an unprecedented energy resolution of 4 meV. By virtue of the finite penetration depth of low energy electrons, spin waves localized at interfaces between a substrate and a thin capping layer can be been studied yielding information about the exchange coupling between atoms at the interface. The quantization of spin waves with wave vectors perpendicular to the film gives rise to standing modes to which EELS has likewise access. Such studies when carried out as function of the film thickness again yield information on the layer dependence of the exchange coupling. Magnetic skyrmions are promising candidates as information carriers in logic or storage devices. Currently, little is known about the influence of disorder, defects, or external stimuli on the spatial distribution and temporal evolution of the skyrmion lattice. In this talk, I will describe the dynamical role of disorder in a large and flat thin film of Cu_2OSeO_3, exhibiting a skyrmion phase in an insulating material. We image up to 70,000 skyrmions by means of cryo-Lorentz Transmission Electron Microscopy as a function of the applied magnetic field. In the skyrmion phase, dislocations are shown to cause the emergence and switching between domains with different lattice orientations, and the temporal fluctuation of these domains is filmed. These observations pave the way to the control of a large 2D array of skyrmions.