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Real-space magnetic topology in oxide/metal heterostructures

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Abstract

IT technology experts agree that the next phase of Moore's law will be based on energy efficiency rather than transistor density. Indeed, the energy efficiency of CMOS devices is 5-6 orders of magnitude worse that than of the human brain, which is at least 3 orders of magnitude away from the ultimate physical limits. Quantum materials (QM) will be crucial to achieve the ambitious goal of 1-10 aJ/operation; a number of promising concepts have been proposed, typically combining a 'write' element based on charge-to-spin conversion in a QM with a 'read' element based on spin-to-charge conversion in a metallic magnet with strong spin-orbit interaction. Magnetic interactions between dissimilar materials play an absolutely central role in these schemes. In this talk, I will describe what may become a classic example of this interaction: the transfer of topological charge between an antiferromagnetic insulator (α-Fe_2O_3) and a soft metallic magnet (Co). Using linear and circular X-ray photoelectron emission microscopy, we observed an unprecedented form of vortices/antivortices in antiferromagnetic haematite (α-Fe_2O_3) epitaxial films, in which the primary whirling parameter is the staggered magnetization. Remarkably, ferromagnetic topological objects with the same vorticity and winding number as the α-Fe_2O_3 vortices are 'imprinted' onto an ultra-thin Co ferromagnetic overlayer by interfacial exchange. Our data and micromagnetic simulations suggest that the ferromagnetic vortices are merons (half-skyrmions, carrying an out-of-plane core magnetization), and indicate that the vortex/meron pairs can be manipulated by the application of an in-plane magnetic field, giving rise to large-scale vortex–antivortex annihilation. I will also discuss the prospects of employing dense topological arrays in similar heterostructures to build prototypes of information storage devices.