Scientists achieve major breakthrough in thin-film magnetism

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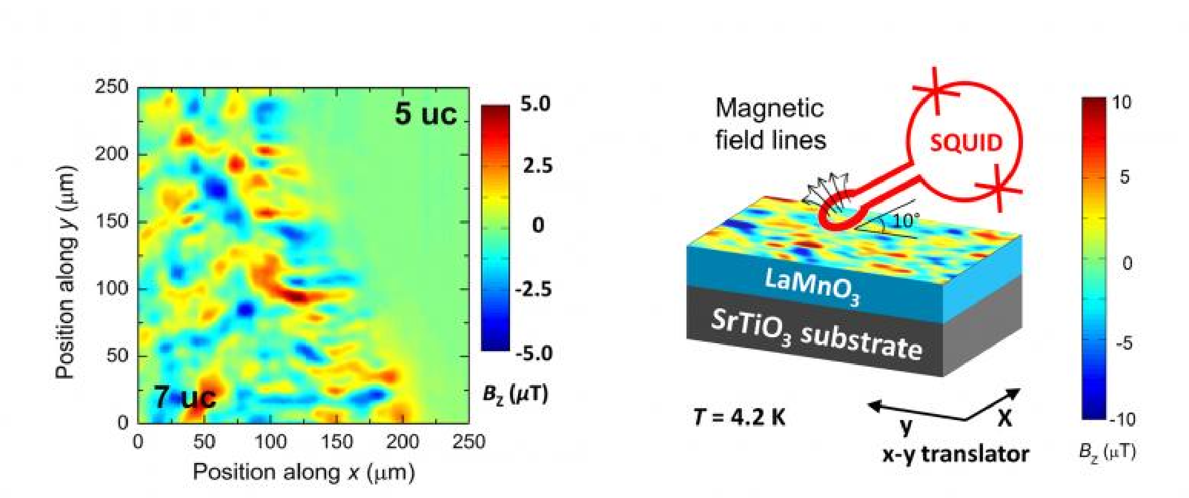

Image of the magnetic fields recorded by scanning a tiny superconducting coil over the surface of a $LaMnO_3$ film grown on a substrate crystal. The magnetic left-hand side is seven $LaMnO_3$ blocks thick (about 3 nm), while the nonmagnetic right-hand side is only five (2 nm). The measuring setup is shown on the right. Credit: NUS

Magnetism in nanoscale layers only a few tens of atoms thick is one of the foundations of the big data revolution – for example, all the information we download from the internet is stored magnetically on hard disks in server farms dotted across the World. Recent work by a team of scientists working in Singapore, The Netherlands, USA and

Ireland, published on 14 August 2015 in the prestigious journal, *Science*, has uncovered a new twist to the story of thin-film magnetism.

The team from the National University of Singapore (NUS) - Mr Li Changjian, a graduate student from the NUS Graduate School for Integrative Sciences and Engineering, Assistant Professor Ariando and Professor T Venky Venkatesan – led to the discovery of this new magnetic phenomenon by growing perfectly-crystalline atomic layers of a manganite, an oxide of lanthanum and manganese {LaMnO3}, on a substrate crystal of nonmagnetic strontium titanate using a method – pulsed laser deposition – developed many years ago for high-temperature superconductors and multicomponent materials by Prof Venkatesan, who now heads the NUS Nanoscience and Nanotechnology Institute (NUSNNI).

The manganite is an antiferromagnet when it is atomically thin and shows no magnetism. The new discovery is that its magnetism is switched on abruptly when the number of Manganese atomic layers changes from 5 to 6 or more. The conjecture is that this arises from an avalanche of electrons from the top surface of the film to the bottom, where the electrons are confined near the substrate. This shift of electric charge occurs as the manganese atomic layers form atomically charged capacitors leading to the build-up of an electric field, known as 'polar catastrophe', inside the manganite. As a consequence of this charge transfer, the manganite layer switches to a strongly ferromagnetic state, as could be visualised by a magnetic microscopy technique called Scanning SQUID Microscopy. This was conducted by Dr Xiao Renshaw Wang, who is a PhD graduate from NUSNNI, working with Professor Hans Hilgenkamp at the MESA+ Institute of the University of Twente in The Netherlands. The work validates the polar catastrophe model, and it shows how the addition of just one extra atomic layer can transform the magnetism.

The team plans to use local electric fields to controllably turn on/off the magnetism of its 5-layer films, and explore potential applications in microwave devices and magnetic recording. With magnetic memory elements approaching nano dimensions, this technique promises new approaches in magnetic recording and computing.

More information: "Imaging and control of ferromagnetism in $LaMnO_3/SrTiO_3$ heterostructures." *Science* 14 August 2015: Vol. 349 no. 6249 pp. 716-719 DOI: 10.1126/science.aaa5198

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