Research team discovers novel way of transferring magnetic information

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Part of the team members from NUS Nanoscience and Nanotechnology Institute: (from left to right) Dr Renshaw Wang, Dr Huang Zhen, Assistant Professor Ariando and Professor T. Venkatesan. They are looking at a four-inch wafer on which a multi-component oxide film has been deposited using the pulsed laser deposition process. Credit: NUS Nanoscience and Nanotechnology Institute

A team led by researchers from the National University of Singapore (NUS) has achieved a major breakthrough in magnetic interaction. By adding a special insulator, they make electrons "twirl" their neighbouring "dance partners" to transfer magnetic information over a longer range between two thin layers of magnetic materials. This novel technique enables magnetic information to make their way from one magnetic layer to another, synonymous to the encoding and transmission of data.

"The big data revolution relies on vast amount of digital information which are magnetically stored on hard disks in server farms across the planet. A bottleneck that stifles the progress of this emerging field lies in the demand for faster data transmission rates. The recent discovery by our team paves the way for the development of devices that operate in the terahertz frequency range, which makes encoding and transmission of data many times faster," explained Assistant Professor Ariando, who is from the NUS Nanoscience and Nanotechnology Institute (NUSNNI), and co-leader of the research team.

The findings were reported in the online edition of the journal *Nature Communications* on 16 March 2016.

Electron spin and magnetism

While many people are used to downloading data from the Cloud onto mobile devices, most do not know where the data comes from. Digital information is stored in minute magnetic dots written in layers that are only a few nanometers thick that cover the surface of millions of saucer-sized spinning disks. These hard disks are stacked by the thousands in server farms worldwide.

In recent years, the technology for growing uniform magnetic layers only ten to 100 atoms thick has been perfected. By combining them into complex stacks, these nanostructures form the foundation of 'spin electronics'. The 'spin' here refers to the resemblance between the electron and a spinning ball of electric charge, and the spin makes the electron into a tiny magnet.

When two magnetic layers are stacked close to each other, they couple together to exchange electrons with each other. The electrons carry across their spin, and the directions of magnetisation of the two layers are aligned. This coupling is broken if the two magnetic layers are separated by an insulating spacer that is more than a few atoms thick. The insulator is almost impenetrable for the free electrons.

A new magnetic interaction

As magnetic interactions are normally mediated by short-range exchange or weak dipole fields, the research team, which is co-led by Professor T Venky Venkatesan, Director of NUSNNI, sought to propagate the magnetic interaction over longer distances.

Dr Lü Weiming, a Research Fellow at NUSNNI and first author of the research paper, found that the use of polar oxide insulator enables the range of the magnetic coupling to jump from about one nanometer to ten, and its strength varies up and down with spacer thickness. This discovery is startling as no electrons could ever make their way across such an impenetrable layer. In addition, the range achieved would previously have required a metallic system to transmit the electrons across the magnetic layers.

To explain this unusual observation, Professor Michael Coey of Trinity College Dublin, who is a visiting faculty at NUSNNI, came up with a suggestion. "Instead of spin magnetism being carried across directly by messenger electrons, it is the orbital magnetism that is passed along from atom to the next across the insulator. The atomic electrons are engaged in a dance, each twirling their partners on the neighbouring atoms until the orbital motion reaches the other side," he explained.

Prof Coey's supposition was proven to be true by research team member Dr Surajit Saha, a Research Fellow at NUSNNI and the Department of Physics at the NUS Faculty of Science, who performed spectroscopic measurements on the new magnetic effect.

Applying discovery to next generation magneto optical devices

Now that the research team has provided the recipe for the insulator that allows the magnetic effect to occur, they intend to further investigate the effect to fully understand the mechanism, and to utilise their discovery to develop a new generation of magneto optical devices.

Prof Venkatesan said, "I believe we will soon discover a use for the phenomenon in the terahertz frequency regime. Unlike the time of French physicist Louis Néel, whose discovery of anti-ferromagnetism found an application 60 years hence, nowadays, it should not take 60 years to find an application for new discoveries in magnetism such as this."

Provided by National University of Singapore

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