Scientists take a 'spin' onto magnetoresistive RAM

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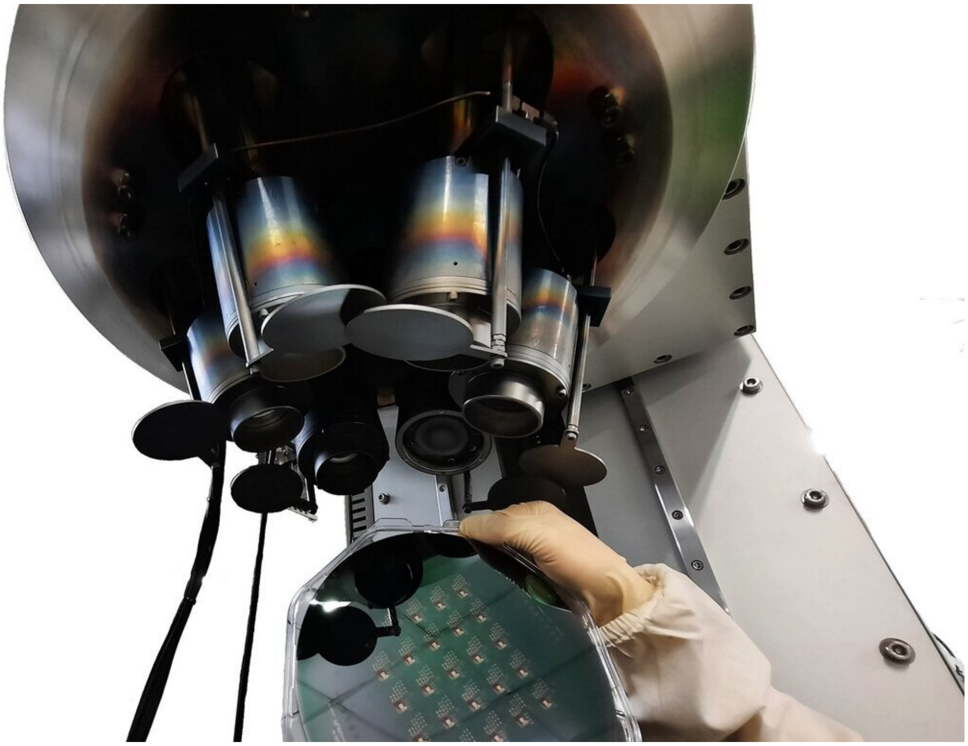


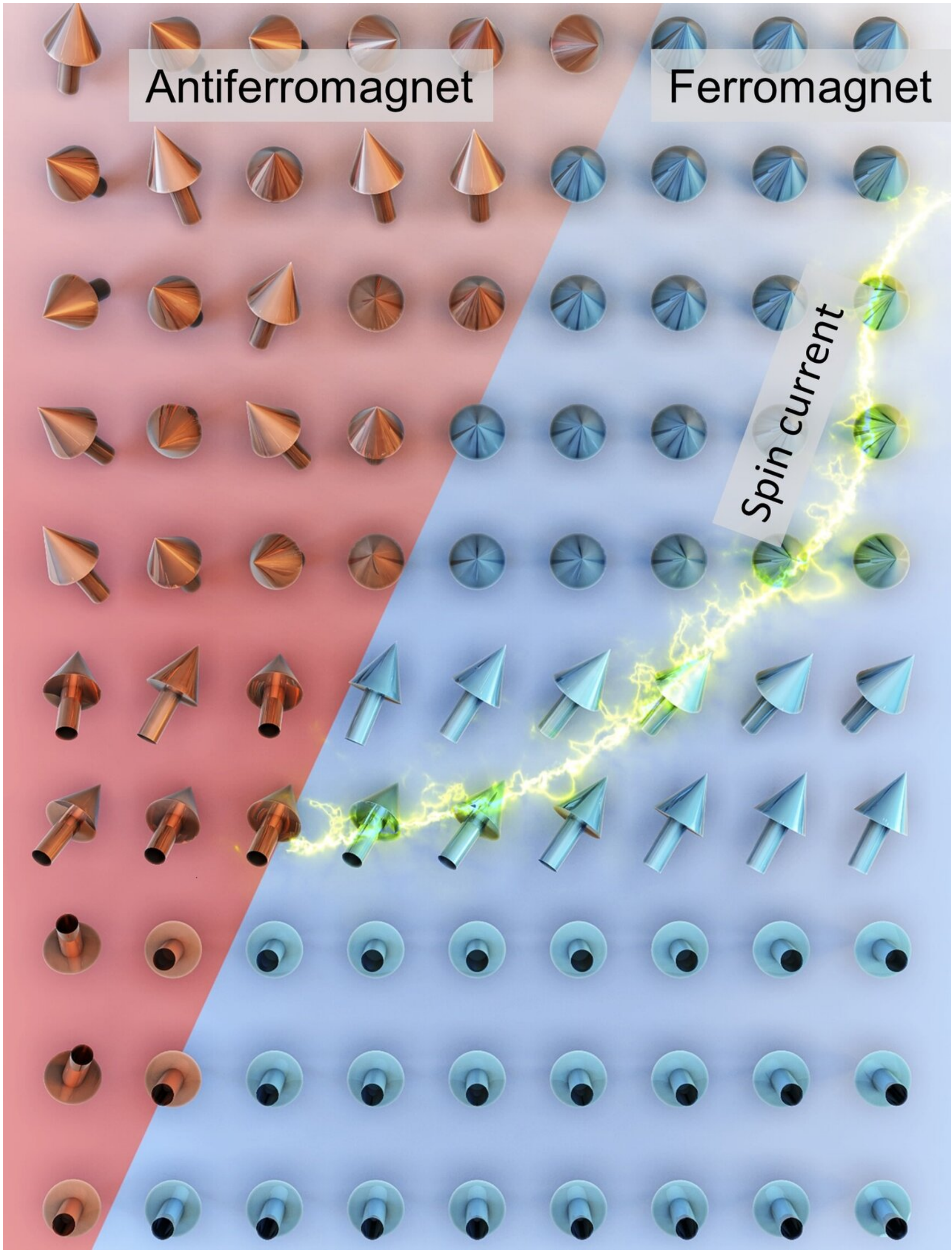
The sputtering technique has been widely used for thin film deposition. Under the sputtering guns, an eight-inch wafer with patterned device fabricated by deposition, photolithography, etching, etc. is shown. Credit: NTHU MSE, Taiwan

Magnetoresistive random access memory (MRAM) is the top candidate for next-generation digital technology. However, manipulating MRAM efficiently and effectively is challenging. An interdisciplinary research team based at National Tsing Hua University (NTHU) in Taiwan, led by Prof. Chih-Huang Lai, Department of Materials Science and Engineering, and Prof. Hsiu-Hau Lin, Department of Physics has now achieved a breakthrough. By adding a layer of platinum only a few nanometers thick, their device generates spin current to switch the pinned magnetic moments at will—a task that has never been accomplished before. For faster reading and writing, reduced power consumption and retaining data through a power outage, MRAM is particularly promising.

At present, information processing in digital devices is mainly carried out using dynamic random access memory (DRAM), but it consumes significant power and faces serious hurdles when reduced in size. DRAM uses the charge of electrons. "But electrons have both charge and spin," Lai said. "Why can't one work with electron spin to manipulate MRAM?" To put the idea into practice, Lai and Lin formed an interdisciplinary research team with doctoral students Bohong Lin and Boyuan Yang.

Lin explained that the structure of MRAM is like a sandwich. The upper layer consists of a freely flipping magnet, used for data computation, while the bottom layer consists of a fixed magnet, responsible for data storage. These two layers are separated by an oxide layer.

The challenge is to switch these layers by electrical means. After a long series of experiments, they found success with a nanometer-thin layer of platinum. Due to spin-orbit interactions, the electric current drives the collective motion of electron spins first. The spin current then switches the pinned magnetic moment effectively and precisely.



A spin current (the yellow electric-like path) passes through the ferromagnetic

(FM, blue region)/antiferromagnetic (AFM, red region) bilayer structure (the arrows mean the magnetic moment direction). The ferromagnetic moment and antiferromagnetic moment (the exchange bias) can both be switched (middle part: switching; upper part: already switched; lower part: to be switched). Credit: NTHU MSE, Taiwan

In recent years, NTHU has been promoting cross-disciplinary cooperation, such as the MRAM research conducted by the materials expert Lai and the physicist Lin.

Major international companies are pursuing MRAM technology, including TSMC, Intel, and Samsung. It's likely that mass production of high-density MRAM will begin sometime this year, a development where the research team led by Lai and Lin has played a key role.

The research team is currently extending their groundbreaking discovery to other structures, and their findings are expected to have major impacts on the development of memory technology. In Lai's view, the development of MRAM technology is going to have a decisive influence on the future growth and evolution of the world's semiconductor industry.

More information: Po-Hung Lin et al. Manipulating exchange bias by spin–orbit torque, *Nature Materials* (2019). DOI: 10.1038/s41563-019-0289-4

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