Researchers generate electron spin vortex state "skyrmion molecules"

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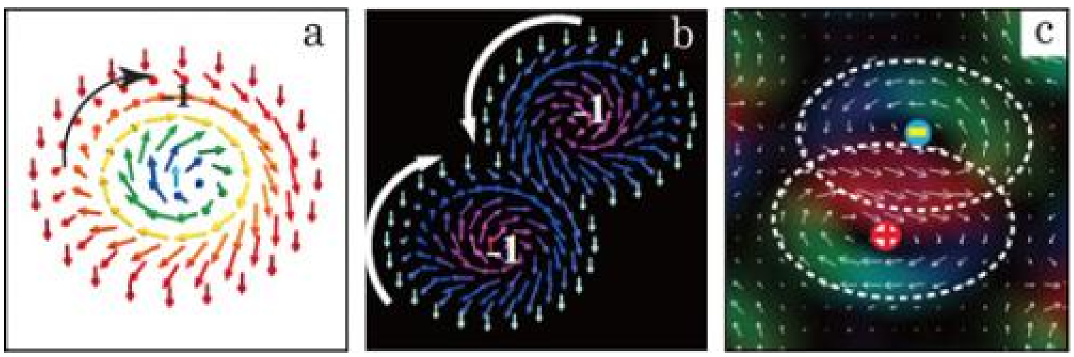

Fig. 1: The arrows indicate the directions of the electron spins. The electron spins in a skyrmion head toward the center, while spinning in a vortex shape. The spin directions at the center and at the outermost periphery are vertically opposite. b: Schematic diagram of a skyrmion molecule c: Skyrmion molecule observed within a ferromagnetic thin film in an experiment The plus and minus signs respectively indicate clockwise and counterclockwise spin direction.

RIKEN, the University of Tokyo, and the National Institute for Materials Science (NIMS; President: Sukekatsu Ushioda) succeeded for the first time in generating and visualizing electron spin vortex state "skyrmion molecules" with topological charge 2 within a thin film of "La1+2xSr2-2xMn2O7," a layered manganese oxide which is a ferromagnetic material with uniaxial anisotropy. While the current density required for driving domain walls within a ferromagnetic system is about 1 billion amperes per square meter, they managed to drive those skyrmion molecules with one-thousandth that density .

This result was achieved by a joint research group led by Dr. Xiuzhen Yu, Senior Research Scientist, and Dr. Yoshinori Tokura, Group Director (Professor at the School of Engineering, the University of Tokyo) of the Strong Correlation Physics Research Group, RIKEN Center for Emergent Matter Science (Center Director: Dr. Yoshinori Tokura), and Dr. Koji Kimoto, Unit Director of the Surface Physics and Structure Unit, Advanced Key Technologies Division (Division Director: Dr. Daisuke Fujita), NIMS.

Magnetic memory devices, which use the direction of electron spins within materials as magnetic information, are considered to be promising next-generation devices with high-speed and non-volatile properties. In recent years, magnetic memory devices that manipulate domain walls within ferromagnetic nanowires by using spin polarized electric current have been intensively studied. However, moving domain walls requires a large current density of at least about 1 billion amperes per square meter, and the large power consumption presented a problem. Therefore, a way to drive them under smaller current density had been sought.

In this respect, attention has been paid to "skyrmions," which are magnetic topological textures in which electron spins are aligned in a vortex shape. Unlike ferromagnetic domain walls, skyrmions have no intrinsic pinning sites and can avoid obstacles in the device. Thus, they can be driven under smaller current density than ferromagnetic domain walls. A single skyrmion has topological charge 1, which is equivalent to 1 bit of information. Skyrmions with higher topological charge had been predicted theoretically, but they had never been actually observed. The joint research group succeeded for the first time in generating skyrmion molecules with topological charge 2 in layered manganese oxide La1+2xSr2-2xMn2O7 while controlling the uniaxial anisotropy and the externally-applied magnetic field, and in driving them with one-thousandth the current density conventionally required for driving ferromagnetic domain walls. Such findings will bring about great development in designing novel magnetic memory devices with high-density and low power consumption with use of skyrmions. The research result has been published in the online edition of the British science journal *Nature Communications* on January 25

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