Imaging various vortex-like magnetic textures by using atomic-resolution TEM

Xiuzhen Yu

[1] *RIKEN Center for Emergent Matter Science*

The nanometer-scale vortex-like spin textures, such as vortex-anrivortex pairs in ferromagnetic (FM) domain walls [1], votices in superconductors [2], skyrmion (lattice) [3] and antiskyrmions [4] in magnets with inversion symmetry, have recently attracted enormous attention owing to their emergent phenomena [5]. To confirm such minute complex spin textures and their dynamics with external stimuli, ultrafast real-space high-resolution imaging technique, such as time-resoved X-ray microscopy or Lorentz transmission electron microscopy (TEM) is useful.

In this talk, I will present several vortex-like spin textures realized by Lorentz TEM with atomic resolution in several systems, such as chiral magnets, ferromagnets with uniaxial anisotropy and the fluctrated magnets with Ruderman–Kittel–Kasuya–Yosida (RKKY) interaction. In addition to the hexagonal skyrmion lattice (hex-SkL), a square lattice of merons and antimerons (sq-ML)—topologically distinguish with skyrmions—have been observed [6]. By finely varying the external magnetic fields, the transformation between the sq-ML and a hex-SkL have been induced. We found that the skyrmions were very robust, lasting even as we lowered the temperature of the thin plate, but the merons and antimerons were much more sensitive, and relaxed into spin helices as the temperature fell.

Fithermore, the transition between skyrmions (topological “particals”) and antiskyrmions (“antiparticles”) via non-topological magnetic bubbles have been also demonstrated by means of the *in-situ* Lorentz TEM observations in a chiral system with D_{2d}-symmetry. The control of topological nature among various magnetic vortices with external stimuli will be shown.

These works have been done in collaboration with Profs. Yoshinori Tokura, Naoto Nagaosa, Taka-hisa Arima, Yusuke Tokunaga, Shinichiro Seki and Fumitaka Kagawa, and with Drs. Wataru Koshibae, Yasujiro Taguchi, Khanh Nguyen, Daisuke Morikawa, Naoya Kanazawa, Tomoyuki Yokouchi, Kiyou Shibata, Licong Peng and Yoshio Kaneko.

References

[1] X.Z. Yu, *et al.*, *Adv. Mater.* **29**, 1603958 (2017).
[2] A. Tonomura, *et al.*, *Nature* **397**, 308 (1999).
[3] X.Z. Yu, *et al.*, *Nature* **465**, 901 (2010).
[4] Ajaya K. Nayak, *et al.*, *Nature* **548**, 561 (2017).
[5] N. Nagaosa and Y. Tokura, *Nat. Nanotechnol.* **8**, 899 (2013).
[6] X.Z. Yu, *et al.*, *Nature* **564**, 95 (2018).

E-mail: yu_x@riken.jp