**Magnetic-field-free atomic resolution scanning transmission electron microscopy: Or how I learned to stop worrying and love magnetic materials**

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Scanning transmission electron microscopy (STEM) is a powerful technique to directly visualize atomic-scale structures inside materials and devices. In the state-of-the-art STEM, a probe size of less than 0.5Å in diameter has been experimentally realized. Now, the following interesting question arises: beyond just atoms, what might become observable by using such fine electron probes? One answer to this question may be exploring new possibilities in phase contrast imaging in STEM [1]. By using segmented or pixelated detectors, we can not only image single atoms, but can also image electric field distribution inside single atoms [2]. It then becomes tempting to directly observe magnetic fields of atoms. However, atomic-resolution observation of magnetic materials is essentially very difficult because high magnetic fields (>2T) are always exerted on samples inside the magnetic objective lens. In recent years, we have developed a new magnetic objective lens system that realizes a magnetic field free environment at the sample position [3]. Using this new objective lens system in combination with differential phase contrast imaging technique, real-space visualization of intrinsic magnetic fields of an antiferromagnet has been achieved [4]. This novel electron microscope (Magnetic-field-free Atomic Resolution STEM: MARS) is expected to be used for research and development of many magnetic materials and devices. In this talk, I will show some recent application results of MARS.

[1] N. Shibata *et al.*, *Nature Phys.* **8**, 611-615 (2012).

[2] N. Shibata *et al.*, *Nature Comm.***8**, 15631 (2017).

[3] N. Shibata *et al.*, *Nature Comm.***10**, 2380 (2019).

[4] Y. Kohno *et al.*, *Nature***602**, 234 (2022).