

# Imaging of Multifunctional Domains/Walls by *In Situ* Scanning Probe Microscopy

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Coexistence of multiple order parameters is a general phenomenon in condensed matter physics [1]. Recently, coupled ferroic orders in magnetoelectric multiferroics have generated new excitement in materials research because of potential multifunctional applications [2]. It is also of fundamental interest to study coupled order parameters in condensed matter systems where new concepts (e.g., toroidal moment, multiferroic vortices, etc.) or new phases may emerge. Because the presence of domains is a hallmark of any ferroic orders, it is imperative to visualize the cross-coupled domains or walls and their response to cross-coupled fields. Yet little has been done on nanoscale imaging of multiferroic domains because of many technical challenges (low temperature, *in situ* high magnetic and/or electric fields). To address these vital issues, we utilize state-of-the-art scanning force microscopy with *in situ* high magnetic/electric fields or multimodal capabilities to image multifunctional domains or walls in complex materials such as multiferroics.

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[1] P. M. Chaikin and T. C. Lubensky, *Principles of Condensed Matter Physics*, Cambridge, UK: Cambridge University Press (2000).

[2] N. A. Spaldin, S.-W. Cheong, and R. Ramesh, "Multiferroics: Past, present, and future," in *Physics Today*, (2010).