"Advances in Magnetic Imaging: From 2D to 3D nanostructures"

In recent decades, magnetic imaging techniques have advanced significantly, offering unprecedented insights into magnetic configurations at the nanoscale. These developments have mainly focused on enhancing lateral resolution and sensitivity, including achievements as the single-spin detection [1]. Beyond these milestones, crucial objectives are quantification of the magnetic moment and the 3D description of domain wall configurations [2,3] and its dynamics, being this last frequently reduced to the scope of micromagnetic simulations. Magnetic microscopies have driven advances in magnetism by verifying models and revealing new phenomena.

For the 2D characterization, Magnetic force microscopy (MFM) is widely utilized in both research and industry due to its key advantages [4]: high spatial resolution (down to 10nm), adaptability to diverse environments, compatibility with applied magnetic fields and recent advancements in quantitative imaging and probe engineering [5]. Complementing MFM, scanning nitrogen-vacancy (NV) center techniques offer the added benefit of eliminating the influence of stray fields from the probe, enhancing measurement accuracy in sensitive magnetic systems [6].

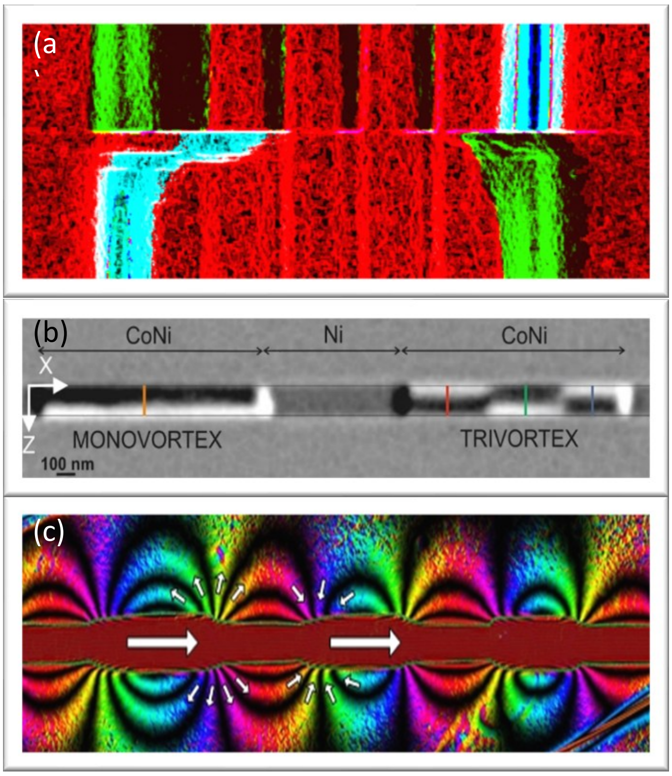

Figure: (a) Non-standard MFM image of a FeCo/Cu NW, (b) TXM contrast of a selected part of CoNi/Ni NW (c) magnetic flux image reconstructed from the magnetic phase shift images corresponding to a FeCoCu modulated NW.

However, as nanotechnology evolves, the demand for 3D imaging of complex magnetic architectures has grown. Recent innovations in techniques like X-ray magnetic circular dichroism (XMCD) tomography and electron holography now allow for volumetric reconstruction of magnetic textures at the nanoscale [2,7]. These developments are critical for understanding emergent phenomena as the curvature-based effects. In the current landscape, characterizing devices based on magnetic materials demands the ability to operate under real-world conditions. Remarkable progress has been made through "in situ" characterization, enabling a deeper understanding of the complex magnetization processes in nanostructures [8].

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