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Controlling the antiferromagnetic domain state of ultrathin $La_{0.45}Sr_{0.55}MnO_3$ films through oxygen vacancies

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Antiferromagnetic (AFM) materials are drawing significant interest as building blocks for spintronics on account of their faster spin dynamics compared to conventional ferromagnets (in the THz instead of GHz range), the absence of stray fields and their immunity to external magnetic field perturbations [1]. However, for such applications, control of the equilibrium antiferromagnetic domain state down to the nanometer or atomic scale and a good understanding of the domain formation process remain challenging. Here, we report the evolution of the antiferromagnetic domain structure of epitaxial $La_{0.45}Sr_{0.55}MnO_3$ (LSMO) ultrathin films with thickness, using x-ray photoemission electron microscopy (XPEEM). We find that, while the 5 uc thick LSMO shows no magnetic contrast down to 50 K, thicker films display a multidomain antiferromagnetic configuration with a nonmonotonic variation in the characteristic domain size, from 0.3 μm at 10 uc, to 3-5 μm at 15-16 uc and 1 μm for 50 uc. Post-growth annealing impacts strongly the magnetic domain state, leading to much larger domain sizes, 15-30 μm wide, and to the presence of well-organized stripes in the ferromagnetic contrast images. The latter arise from alternating spin terminations of the A-type antiferromagnetic configuration due to atomic steps in the substrate [2]. We attribute the impact of the post-growth annealing on the domain structure to a reduction in the density of point defects, in particular oxygen vacancies, that pin the antiferromagnetic domain walls and which determine the equilibrium domain configuration. Our results demonstrate control of the domain size by tuning the film thickness and the density of oxygen vacancies, constituting a steppingstone in controlling the antiferromagnetic domain state required for oxide antiferromagnetic device applications.

References:

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