As-grown state of pinwheel artificial spin ice

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Artificial Spin Ice (ASI) systems made of two-dimensional arrays of nanomagnets in close interaction provide a playground to directly observe magnetic frustration [1, 2]. By the use of shape anisotropy, mesoscopic Ising-like spins could be patterned with various spatial distributions. In this study, we examine the square lattice and modified such that each nanomagnet is tilted around its central point from 5° to 45° every 5°. Both extreme cases, square and 45°-tilted lattice have been studied [1, 2], the latter is called “pinwheel ASI”. They are fabricated using electron beam lithography and liftoff to define 20nm-thick Permalloy nanomagnets with 400 x 100 nm² lateral dimensions. Before any field history, we investigated the as-grown state just after lift-off. Magnetic Force Microscopy (MFM) configurations are shown in Fig. 1 (a) and (b). We find that the ground state (GS) of the regular square lattice is different from the pinwheel ASI: one corresponding to the ice-rule and the other a ferromagnetic state respectively. In this talk, we will give a comprehensive picture of the evolution of the GS and micromagnetic configuration as a function of angle.

[1] Morgan, J. P., Stein, A., Langridge, S., & Marrows, C. H. (2011). Thermal ground-state ordering and elementary excitations in artificial magnetic square ice. Nature Physics, 7(1), 75.
[2] Gliga, S., Hrkac, G., Donnelly, C., Büchi, J., Kleibert, A., Cui, J., et al. (2017). Emergent dynamic chirality in a thermally driven artificial spin ratchet. Nature materials, 16(11), 1106.

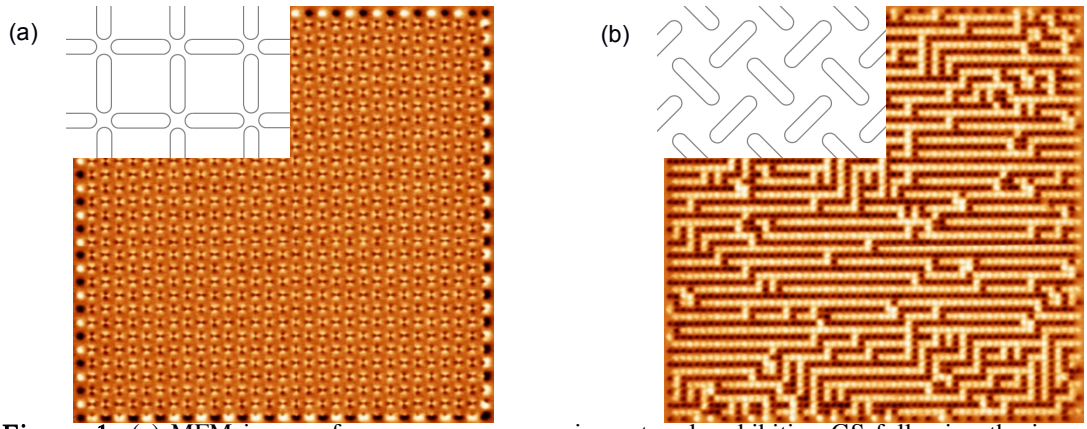

Figure 1: (a) MFM image of an as-grown square ice network exhibiting GS following the ice rule (b) MFM image of a 45° tilted network exhibiting ferromagnetic GS.