Magnetic force microscopy versus scanning vortex microscopy: Probing pinning landscape in granular niobium films

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In our recent papers [1,2], we presented new experimental technique known as scanning quantum-vortex microscopy (SQVM). The purpose of this presentation is to provide a comprehensive explanation of its methodology and underlying principles. We studied the magnetic properties of magnetron-sputtered 50-240 nm thick Nb films by low-temperature magnetic force microscopy (MFM) within the temperature interval from 4 to 9 K. The sensitivity of our system is high enough to identify individual single-quantum vortices (Fig. 1a) generated either by external magnetic field or by stray field of a magnetized MFM tip. At low temperatures, the magnetostatic coupling between the tip and a vortex is rather weak, therefore, the tip cannot move the vortices. As a result, all vortices remain well pinned due to their strong interactions with intrinsic structural defects. At higher temperatures, pinning potential becomes weaker; the MFM tip can drag a vortex during scanning process (SQVM regime). Since the dragging vortex still interacts with the defects, it can be considered as effective nano-probe exploring pinning potential and visualize grain boundaries in granular Nb films (Fig. 1b) with a resolution comparable to the coherence length (15-20 nm).

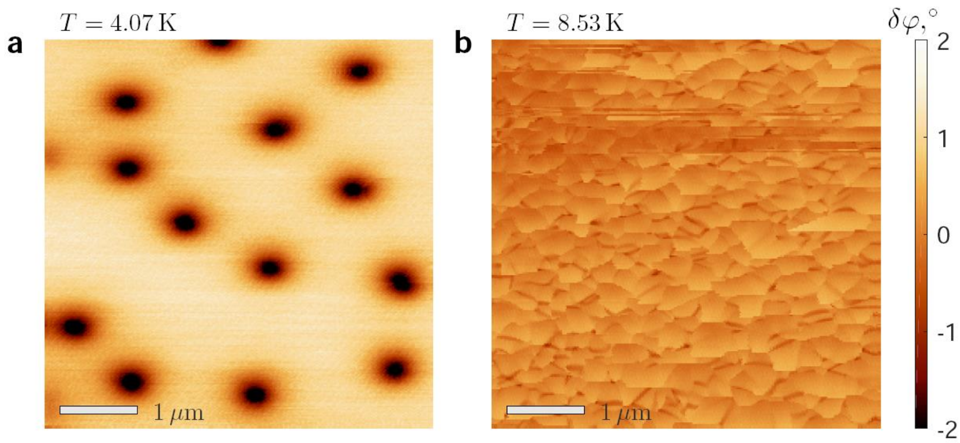

Fig.1. a – Map of the phase shift $\delta\varphi(x,y)$ acquired for 240-nm thick Nb film in the MFM regime (low-T limit, 5×5 μm^2, cooled at 10 Oe, lift 80 nm). b – Map of the phase shift acquired for the same film in the SQVM regime (high-T limit, 5×5 μm^2, zero magnetic field, lift 80 nm).

Bibliography

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