NT-MDT Spectrum Instruments

NT-MDT

Magnetic measurements

Application Notes

INVESTIGATIONS OF THE DOMAIN STRUCTURES OF THE MAGNETS

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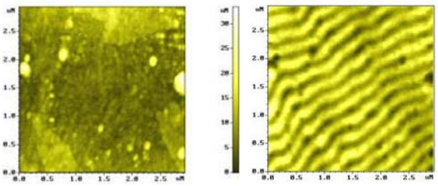
Magnetic force microscopy (MFM) measurements enable to investigate in detail the magnetic structure of various magnets [1-5]. Here we demonstrate several examples of using of the NT-MDT SPMs for investigation of the domain structure. Fig.1 shows topography (a) and MFM image (b) of thin iron film deposited on lavsan by ion-beam deposition. The period of the stripe domain structure, which is clearly seen on MFM image, is less than 250nm.

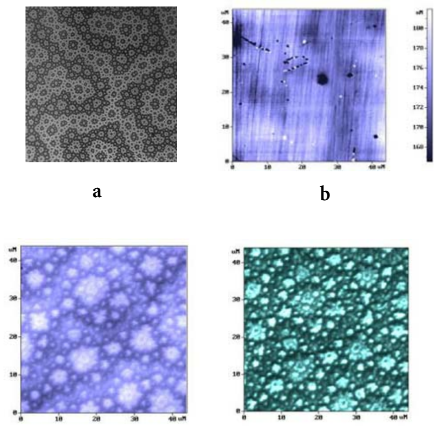


a b

Fig.1.

Fig.1b demonstrates the high resolution of MFM, which is impossible with the magnetooptic visualization. The irregularities of domains caused by film defects are clearly seen on the magnetic image. The contrast on Fig.1b corresponds to the phase shift of oscillating cantilever caused by magnetic tip-sample interaction (AC MFM). In fact this contrast is proportional to the distribution of the second derivative of the sample magnetic stray field. The two-pass technique was used for MFM image, both topography and magnetic image were obtained simultaneously; the second pass was executed with the displacement DZ=60nm from the first pass level. The cantilever with cobalt coating was used in this experiment. Owing to non-ideal feedback loop the topography influence on the magnetic image (dark spots on Fig.1b). Such situation is typical for rough surface. Both the increasing of DZ and the decreasing of the amplitude as well as more precision first pass (higher value of feedback gain, smaller scanning velocity) can reduce this influence. Also the nonmagnetic contamination affects the MFM image owing to essential different distance between magnetic sample and tip in clean and dirty areas.

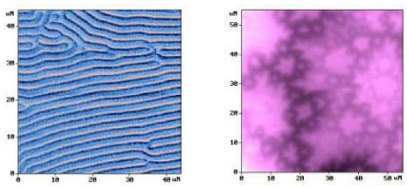
Fig.2a shows the domain structure of high anisotropic tetragonal ferromagnet $Nd_2Fe_{14}B$, which was obtained by both magnetooptic visualization and following computer processing [6].



a b c d

Fig.2.

The smallest detail on the Fig.2a is about 1mkm. Investigated thick single crystal with perpendicular anisotropy has domains of closure in the form of flower. These domains exist due to splitting of domain walls near the crystal surface. Their existence makes the analysis of the configuration of the main domains difficult. Fig.2b and Fig.2c show the topography and the distribution of the cantilever normal deflection (DC MFM), i.e. magnetic force distribution in arbitrary units. Light areas correspond to repulsive forces, and dark areas correspond to attractive forces. If we know exact value of cantilever force constant k then we can calibrate the normal component of



a b

Fig.3.

the magnetic force F=k*DFL. Fig.2d demonstrates phase changes (AC MFM) for same area, i.e. the map of the magnetic force derivative. The force image (Fig.2c) is more interpretable than the force derivative image (Fig.2d). It is desirable to obtain both magnetic force and magnetic force derivative images if it is possible, because the first is more interpretable than the second and the second is more sensitive.

Often only sensitive AC MFM mode is possible. For example the domain structure of garnet film can be clearly revealed only with resonant technique. Fig.3 demonstrate stripe domains in thin garnet film (3mm thick). The period of the domain structure is about 2mm. This is phase image, which was obtained by two-pass method. Garnets relate to soft magnetic materials and its domain structure can be easily perturbed by hard cobalt tip. The using of the tip with reduced stray fields (covered by more thin magnetic film or containing the domains) enable to qualitatively image magnetically soft materials.

The NT-MDT SPMs enable to observe of the domain structures transformation under heating and cooling. The bulk single crystal of cobalt has domain structure like NdFeB at the room temperature (Fig.4, magnetic force distribution). The changes of the domains shape of such sample under heating were investigated with SMENA head for high temperatures measurements.

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