Correlated Structural and Magnetization Reversal Studies on Epitaxial Ni Films Grown with MBE and with Sputtering

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Introduction

Metal-ceramic interfaces are important in applications as diverse as catalysis, magnetic storage media, and electrodes in spin-dependent tunneling junctions [1]. It is important to understand how the crystallography and microstructure of metallic films deposited onto ceramic substrates depend on growth and/or annealing conditions so that their physical properties (magnetic, electronic, etc.) can be tailored for specific applications. To this end, we have studied the epitaxial growth and annealing of (001) and (111) Ni and FeN films grown on MgO substrates by using different deposition techniques, such as molecular beam epitaxy (MBE) and magnetron sputtering.

Methods and Materials

The evolution of the surface has been studied by using correlated *in situ* reflection high-energy electron diffraction (RHEED), scanning tunneling microscopy (STM), transmission electron microscopy (TEM), and high-resolution x-ray diffraction measurements.

We have completed studies on the magnetic properties of these films, particularly the azimuthal dependence of the magnetization reversal as determined by the longitudinal magneto-optic Kerr effect (MOKE), and, in part, this research project is to correlate these findings with the structural characterization obtained with *ex situ* STM, TEM, and x-ray diffraction studies performed at the MHATT-CAT sector 7 beamline at the APS.

Results

From the azimuthal dependence of the coercive field and the reciprocal space maps obtained with high-resolution x-ray diffraction, we found that Ni films deposited on MgO under identical conditions with MBE and with sputtering are epitaxial films and have the same average coercivity as a result of the film's structure. Only the film grown with MBE shows additional uniaxial anisotropy, which we believe may be due to a particular surface morphology characteristic of MBE growth.

From reciprocal space maps similar to those shown in Fig. 1, we are able to determine the absence of lattice mismatch between the film and substrate and the consequent absence of strain in thin film samples, as well as the mosaicity. We find excellent correlation with the magnetoelastic contribution to the in-plane magnetic anisotropy shown in Fig. 2 for the MBE and sputtered samples. However, we have not yet been able to resolve the structural origin of the uniaxial contribution evident in Fig. 2(a). High-resolution TEM measurements have recently revealed the existence of a new phase that forms at this interface. We believe that this new interface structure, which has lower symmetry than cubic bulk Ni, may also be responsible for the uniaxial anisotropy in the magnetic properties. Further experiments using glancing

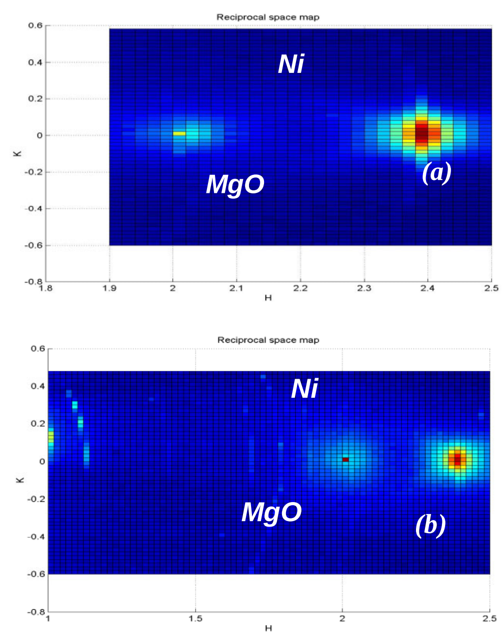

FIG. 1. Reciprocal space maps obtained with high-resolution x-ray diffraction, showing epitaxial cube-on-cube growth for (a) 30-nm (001)Ni film MBE and (b) 30-nm (001)Ni films sputtered on MgO.

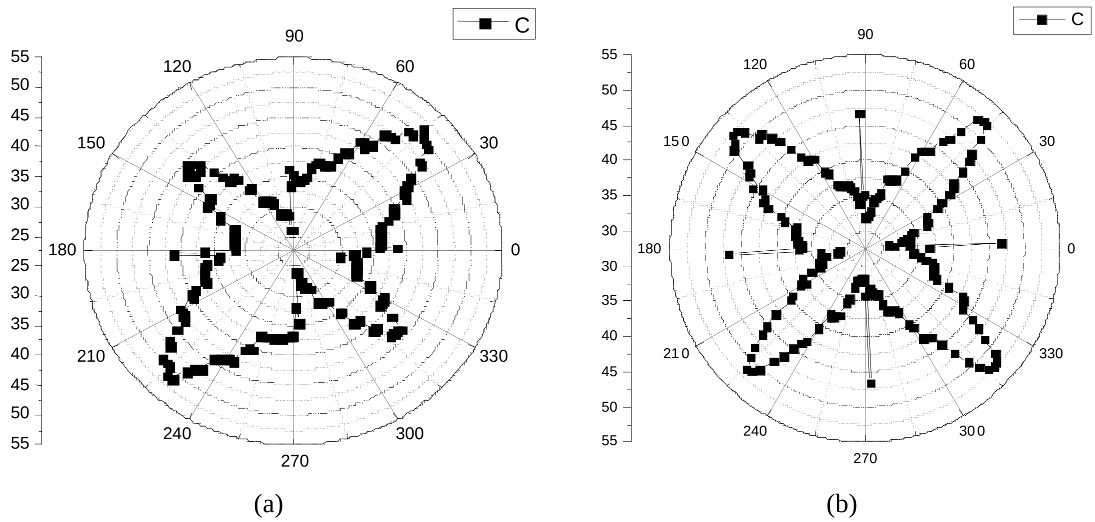

FIG. 2. Polar plot of coercive field determined with longitudinal MOKE for (a) 30-nm (001) Ni film MBE grown on MgO and (b) 30-nm (001) Ni films sputtered on MgO. Note that only the fourfold symmetry is evident in this sample.

angle diffraction geometry and the COBRA technique are in progress to probe the interface region in more detail.

Acknowledgments

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Reference

[1]. R.A. Lukaszew, Y. Sheng, C. Uher, and R. Clarke, “Use of magnetocrystalline anisotropy in spin-dependent tunneling,” Appl. Phys. Lett. **75**, 1941-1943 (1999).