Abstract for the 17th International Conference on Composites/Nano Engineering
Oxide Nanocomposites Symposium, Hawaii, July 16-August 1, 2009

NANOSCALE RIPPLE FORMATION IN COBALT FILMS WITH 1 keV Ar^+ BEAM SPUTTERING

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Introduction

In recent years, surface structuring using ion beams has attracted great interest [1]. Nanoscale ripple and dot pattern formation are thus created in a variety of materials including epitaxial magnetic metal films [2] and polycrystalline iron or nickel films [3]. Because of possible recording applications of such surface treatment, our interest is focused on polycrystalline cobalt based films.

Experimental

Film deposition is made in a vacuum chamber with a base pressure of $4{\cdot}10^{-8}$ mbar [4]. Polycrystalline cobalt thin films were deposited by dc magnetron sputtering onto unheated Si(100) wafers The films were sputter grown in the $8{\cdot}10^{-3}$ mbar pressure range with a discharge power of 30W, corresponding to a growth rate of 0.25 nm/sec. The as-deposited film thickness was 60nm and larger (obtained with ex situ x-ray reflectometry). After deposition, the samples were transferred in situ to a process chamber equipped with a 3 cm Kauffman ion gun. The samples are then irradiated with 1.2 keV Ar+ ions at an incidence angle of 80º with respect to the substrate normal for the production of ripple structures. At these conditions, the ion current density is ~0.1 mA/cm2 and the estimated etch rate is 0.04 nm/sec. Exposure time varied from a few minutes to an hour. Topography and dimensions of the nanoscale patterns were characterized ex situ by means of atomic force microscopy at room temperature.

Results and Discussion

A series of 60 nm cobalt films were made under identical growth conditions. Ar+ beam irradiation proceeded at constant ion flux and only the exposure time determines the final thickness and ripple morphology. With short irradiation times the surface shows ripples (see figure 1) but their length and spacing is characteristic of initial stages of sculpting.

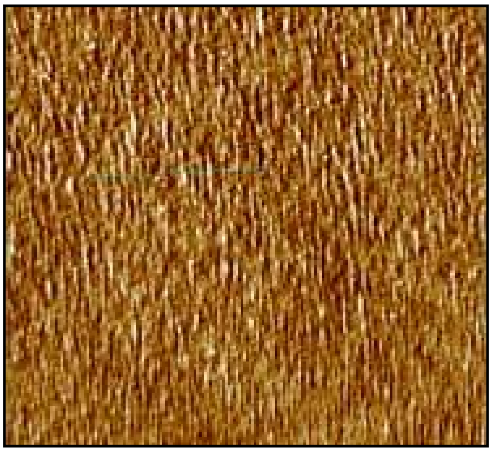

Fig. 1: Atomic Force Microscopy 2µm x 2µm scan of a Co film after 5 minutes argon ion etching in oblique incidence. Average ripple spacing in this case is around 40 nm.

Longer exposure times lead to a well defined ripple structure with a larger average spacing up to 70-80 nm (see figure 2). These thinned cobalt layers have an rms roughness of about 1-2 nm that is nearly the same value as the as-grown film. SQUID magnetometry of a 41nm thick etched film with such ripples does not indicate any in-plane uniaxial anisotropy. Accordingly, Magnetic force microscopy images of these films indicate uniform magnetization that does not change upon application of in-plane fields up to 2 kG.

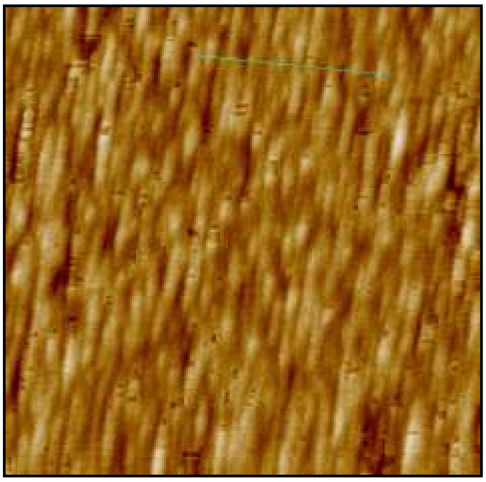

Fig. 2: Atomic Force Microscopy 2μm x 2μm scan of a Co film after 23 minutes argon ion etching in oblique incidence. Average ripple spacing is 70 nm.

Other cobalt films were made at the same rate for longer deposition times to obtain thicker as-grown layers (60-380 nm). The surface roughness is again studied and found rms values that increase with as-grown film thickness. Typically, the rms surface roughness is 1.1nm for a film thickness of 60 nm and 7.6 nm for a film thickness of 380 nm. All roughness analysis has been performed in scans of size 2μm x 2μm. X-ray diffraction scans with Cu Kα radiation revealed the three lines corresponding to polycrystalline hcp cobalt.

The ion irradiation of these samples took place in the same conditions as described above for long exposure times, over 20-30 minutes. The resulting ripple morphology shows similar lateral average spacing and a much larger final rms roughness. Measurements are underway to study magnetic properties of the latter series and possible uniaxial anisotropy in the thinnest – almost completely etched – films.

Conclusion

We have investigated the formation of nanoscale ripples on polycrystalline cobalt films etched with Ar+ beam in grazing incidence. Cobalt films of an initial 60 nm thickness then develop ripple morphology progressively to an average lateral spacing up to 70-80 nm. The final ripple rms roughness is strongly dependent on the surface roughness of the as-grown film, this being larger with increasing as-grown layer thickness. The latter result opens a pathway to tailor the in-plane magnetic anisotropies.

We would like to acknowledge the spanish Junta de Comunidades de Castilla-La Mancha for grant PAI08-0067-2673 and the Ministerio de Educación y Ciencia for grant MAT2006-06242.

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