SURFACE NANO-STRING MORPHOLOGY OF OBLIQUE PULSED LASER DEPOSITED COBALT THIN FILMS

Vicente Madurga, José Vergara, Cristina Favieres.
Departmentof Physics, Universidad Pública de Navarra, Campus de Arrosadía,
31006 Pamplona, Spain
vmadurga@unavarra.es

We prepared pulsed laser deposited, PLD, Co films whose thickness varied from 1.5 nm to 150 nm. Their surface morphology corresponded to nano-strings whose size was a function of deposition parameters: off-normal angle and deposition time. We studied different physical properties of these films, and their anisotropic behaviour, as a function of nano-string morphology of the films.

The beam from a pulsed Nd-YAG laser (λ=1064 nm, 20 Hz repetition rate, and pulses of 5 ns) incised on a rotating Co target (99.99% pure). The power per unit area on the target was 0.2 GW/cm^2. The base pressure in the chamber (Neocera) was 10^{-6} mbar. Circular pieces of common glass 7 mm in diameter were used as the substrates. We placed the substrates on the lateral surface of a cone which vertices pointed towards the target. The off-normal angle was controlled for each deposition process by using cones with different angle each time. These cones were rotated at 200 rpm during the deposition process in order to produce homogeneous Co films. The substrates were at room temperature. The maximum deposition rate of Co (0.13 nm/s) was measured for the samples which remained perpendicular to the direction of the ejected plasma during the deposition process. In a first set of samples, the deposition time changed as a function of the off-normal angle in order to keep the magnetic moment of the different Co films constant for every sample. In a second set of samples, the off-normal deposition angle remained fixed at 55 degrees and the deposition time varied between 30 s and 45 minutes. The surface of the samples was observed with a Scanning Tunnelling Microscope, STM (METRIS-1000, Burleigh). The magnetic moment of the samples was measured with a Vibrating Sample Magnetometer, VSM (EG&G). The anisotropy field, H_u, was determined by measuring the magnetization along the in-plane hard magnetization directions in our VSM. The electrical resistivity of the Co thin films was measured by a conventional four probes AC ASL Resistance Bridge (75 Hz). The optical coefficient transmission was measured using a homemade optical system, using a conventional low power red laser, two polarizers and a conventional photo-diode detector.

The *X* ray diffraction studies corresponding to these films shown an amorphous structure. The transmission electron microscopy results revealed a nano-structure with a grain size of 1-2 nm.

Our STM studies of the surface morphology of the films, Fig. 1, showed like nano-string structures transverse to the incidence plane, whose geometry depends on the off-normal deposition angle and deposition time. Nano-strings 300 nm long and medium width between 8 and 24 nm as a function of deposition time were observed for samples deposited at 55 degrees.

The easy direction for the magnetization was always parallel to the nano-strings direction. A maximum anisotropic magnetic field of 770 Oe was measured for the films deposited at 55 degrees. Anisotropic magnetic fields between 12 and 770 Oe were measured for different deposition angles and different deposition times.

The resistance of the films reached relative values, $R_{\text{parallel to the nano-strings}} - R_{\text{perpendicular to the nano-}}$

strings / R parallel to the nano-strings ≈ 14% for off-normal angles of 75 degrees.

The optical anisotropy of these samples achieved a value of 19% of the relative intensity of the transmitted light through the sample, ($I_{\text{parallel to the nano-strings}} - I_{\text{perpendicular to the nano-strings}}$) / $I_{\text{parallel to the nano-strings}}$. $I_{\text{parallel to the nano-strings}}$ was the intensity of the transmitted light which polarized plane was parallel to the nano-strings direction. This maximum 19% corresponds to the samples obtained with a deposition off-normal angle of 55 degrees and 40 nm thick.

A model that combined erosion [1] and growing [2] processes during PLD allowed to find the scaling parameters of the nano-string morphology, rippel morphology with nanometer dimensions, of these films.

References:

[1] R. Cuerno and A. L. Barabási. Phys. Rev. Lett., **74** (1995) 4746

[2] S. Rusponi, G.Constantini, C. Boragno, and U. Balbusa. Phys. Rev. Lett., **81** (1998) 2735.

Figures:

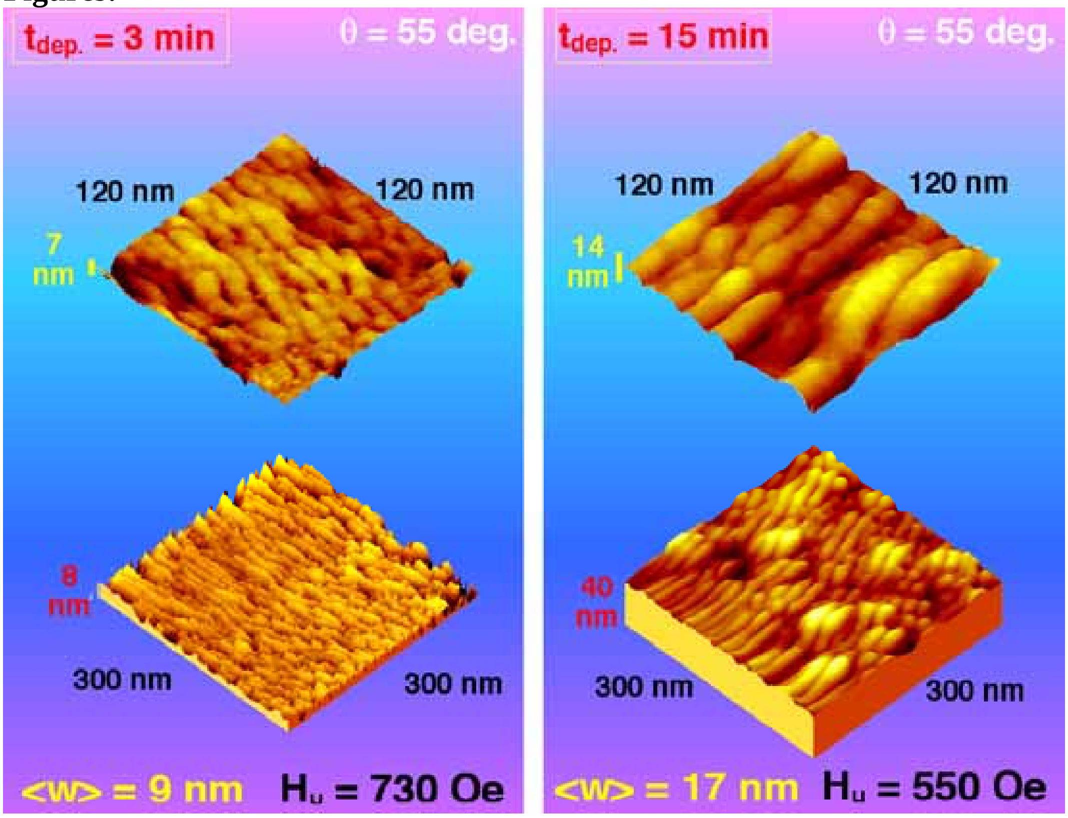

Fig. 1. STM results corresponding to two different films obtained at the same deposition angle but with different deposition time: 3 and 15 minutes respectively. The thickness of the samples is indicated in the two STM pictures at the bottom using a 300 nm scale. The two STM pictures at the top correspond to the surface roughness of these two films using a 120 nm scale. The difference between the size of the surface nano-string corresponding to the two samples can be observed: the medium string width, <*w*>, was 9 and 17 nm for the PLD samples during 3 and 15 minutes respectively. The values of the magnetic anisotropy field, H_u, for these two samples are also indicated.