Generating and measuring anisotropic elastic behavior of Co thin films with oriented surface nano-strings on micro-cantilevers

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Si micro-cantilevers, MCL, ≈ 450 x 50 x ≈2 μm^3 were coated with Co by the pulsed laser deposition, PLD, technique, using an off-normal incidence plasma procedure. A Nd:YAG laser beam –λ = 1054 nm, 20 Hz repetition rate, 240 mJ per pulse of 4.5 ns (≈ 12 Gw)– was driven to a pure Co target located inside a chamber with a base pressure of 10^{-6} mbar. The laser beam made an angle of 45º with the normal to the target, which rotated at 32 rpm. The generated Co plasma reached two MCL at an off-normal angle θ = 55º when they were situated at the lateral surface of a cone with angle 2θ, which also rotated around its axis at 120 rpm. We used the advantage of micro-cantilevers [1, 2] measuring their mechanical and magneto-mechanical properties determining the elastic and magnetic properties of the Co thin films deposited on them.

The same two MCL were coated in consecutive processes. After determination of the resonant frequency of each MLC, ν_0, they were positioned parallel and perpendicular to the generatrix of the cone respectively. So, the incidence plane of the plasma was parallel or perpendicular to the longitudinal direction of each MCL respectively. Then the generated nano-strings in the deposited film were perpendicular, (transverse) or parallel, (longitudinal) to the longitudinal direction of each MCL [2]. By scanning tunneling microscopy, STM, Fig. 1a, they were imaged these two different kind of nano-strings, Fig. 1b and 1c. After each deposition time, *t*, the resonant frequency of each coated micro-cantilever, $\nu_{(c\ MCL)}$, was measured again and so successively for the consecutive coating processes. So the change of this resonant frequency was measured, as shown in Fig. 2a. For a MCL the initial resonant frequency satisfies the expression $\nu_0^2 \sim k_0/m_0$, being k_0 the spring constant of the MCL and m_0 its mass. For the coated MCL the ratio $\nu_{(c\ MCL)}^2/\nu_0^2 = (k_{(c\ MCL)}/m_{(c\ MCL)})/\ (k_0/m_0)$, R2-FRQ, will vary when *k* or *m* change: an increase in the mass will produce a decrease in this ratio R2-FRQ and an increase of the spring constant will produce an increase in this ratio. Fig. 2b and 2c show the changes of R2-FRQ when coating processes with deposition time *t* = 15 s and 1 min. where performed respectively. The percolation phenomenon in the deposited Co over the MCL, was deduced for a total deposition time ≈1.6 min., Fig. 2b, when the decrease of R2-FRQ changed its slope. The initial decrease of R2-FRQ produced by the increase of *m* was balanced by the increase in *k* produced then by the percolated film. Fig. 2c shows the evolution of R2-FRQ for deposition time *t* = 1 min. Because the mass deposited over the two MCL was equal, the split of the value of R2-FRQ (starting approximately at 2.2 min.) must be due to the generation of the nano-strings, which produced different values of *k*. In fact, the coated MCL with longitudinal nano-strings exhibited a value of *k* higher than the corresponding to the coated MCL with the transverse ones. Taking into account that the resonant frequencies ν_0 of the two MCL was in the interval (8665 ± 5) Hz, and the values of the density of the Si: $2.33\cdot10^3$ kg/m^3, its Young modulus: $1.69\cdot10^{11}$ Pa, the MCL length: 450 μm, and its width: 50 μm, it was deduced the mass of the MCL, $m_0 = 6.66\cdot10^{-11}$ kg and k_0 = 0.200 N/m. The increment in m_0 for each min. of deposition time was $4.16\cdot10^{-13}$ kg. The relative change in the spring constant after 4 min. of deposition for the MCL coated with longitudinal nano-strings was at least 40% higher than the produced for the MCL coated with transverse nano-strings. This 40% was a measurement of the anisotropic elastic property consequence of the surface nano-strings morphology of these thin films.

References

[1] P. S. Waggoner and H. G. Craighead, *Lab Chip.* **7 (**2007) 1238
[2] V. Madurga, C.Favieres, J. Vergara, Nanotechnology, **21** (2010) 095702

Figures

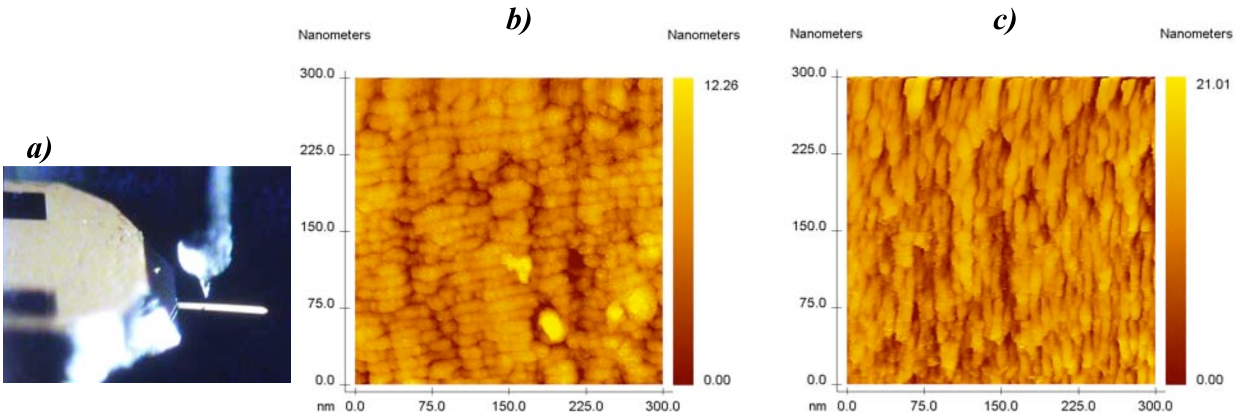

Fig. 1

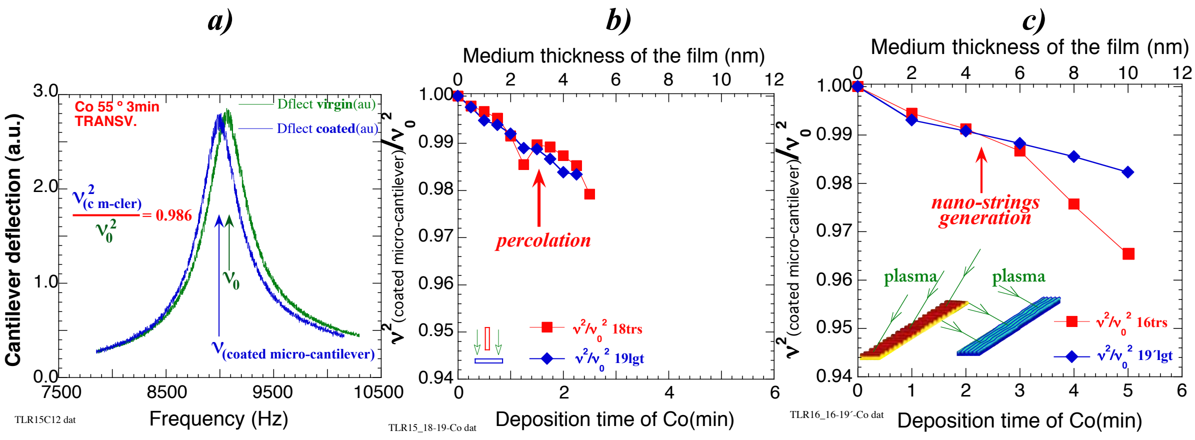

Fig. 2