MBE growth of Ag nanocrystals on self-organized striped Si(111) surfaces. Morphology and Magnetism of Co films formed on this Ag-Si template.

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The self-organization approach, often used in combination with lithography-based control techniques, is considered as one of the most attractive routes for surface patterning in micro- and nano- technologies. Vicinal surfaces naturally provide arrays of steps which, together with step rearrangement processes spontaneously occurring during annealing or epitaxy, have proved to be very useful in order to create self-assembled regular patterns on the surfaces of many materials [1,2]. For the particular case of Si surfaces, this subject is very interesting and has been widely investigated, due to the importance and high development degree of the Si technology. In fact, we have already reported the formation of a 3D checkboard-like Si pattern on vicinal surfaces [3], whose building-blocks are triangular-like 7x7-(111) terraces, with lateral dimensions of hundreds of nanometers, bound by step bunches about 30 nm high. If used in combination with thermally activated growth (at Tsu= 400ºC), such a template permits to achieve i.e. regular distributions of metallic (Ag) nanocrystals, thanks to a selective positioning of Ag dots at the arrow-head corners of the Si pattern [3].

We present now a different type of *self organized* Si surface nanopattern (see Fig. 1) that is also created by step rearrangement *during homoepitaxy* on vicinal Si(111)-7x7 surfaces misoriented 4º toward the $[11\bar{2}]$ direction. It provides a 1D-like template and consists of a periodic array of alternating 7x7-(111) reconstructed flat terraces and step-bunched facets (total stripe wdth: 75 nm). A relevant feature of this pattern is that can be obtained as well without homoepitaxy, using instead a high temperature treatment of the vicinal surface [2]. We focus here on discussing the potential ability of these Si striped surfaces to template the growth of regular distributions of metallic nanocrystals.

Silicon and metal films were grown in a multichamber MBE (Molecular Beam Epitaxy) apparatus equipped with electron diffraction (RHEED, LEED) and spectroscopic (AES) techniques. Si deposition was performed at substrate temperatures (600ºC -850 ºC) high enough to ensure step-flow growth and good epitaxy, on clean Si(111)7x7 surfaces that have been prepared by exposure to the vapour of an HF solution and subsequent annealing in UHV. The surface topography and magnetic properties of the "as prepared" samples (i.e., without capping layers) were studied by "ex situ" Scanning Force Microscopy (SFM) and Vibrating Sample Magnetometry (VSM) measurements, respectively.

By using the Si stripe-like patterning and a thermally activated Ag growth (at moderate temperatures, Tsu = 250ºC), we have succeeded to obtain fairly regular distributions of nanoscale Ag(111) crystallites exhibiting extremely flat tops (Fig. 1). Note that most of the Ag islands have the same base width, which corresponds to three times the total width of the Si stripe. Thus, the rather similar shapes and sizes of the Ag islands achieved in this way (Fig. 1) seem to be a consequence of the template geometry.

Finally, we discuss preliminary results of Co deposition and post-growth annealing experiments performed on the combined Ag-Si template of Fig.1, in order to create regular arrays of magnetic nanostructures. In particular, RHEED, AES, SFM and VSM measurements indicated, that if Co deposition at RT is followed by annealing at progressively higher substrate temperatures (in the range: 150ºC – 450ºC), we managed to convert the initial Si surface in a Co-silicide surface, leaving isolated Co clusters/nanocrystals on top of the Ag islands. Figure 2 displays SFM and VSM results for a 10 nm Co film deposited at RT on a Si-Ag template surface like that of Fig. 1, and annealed at Tsu = 250ºC or Tsu = 350ºC. Note that for the Tsu=350ºC case, the field-cooled (ZFC-FC) results confirm the formation of isolated superparamagnetic Co clusters with a blocking temperature of 110 K.

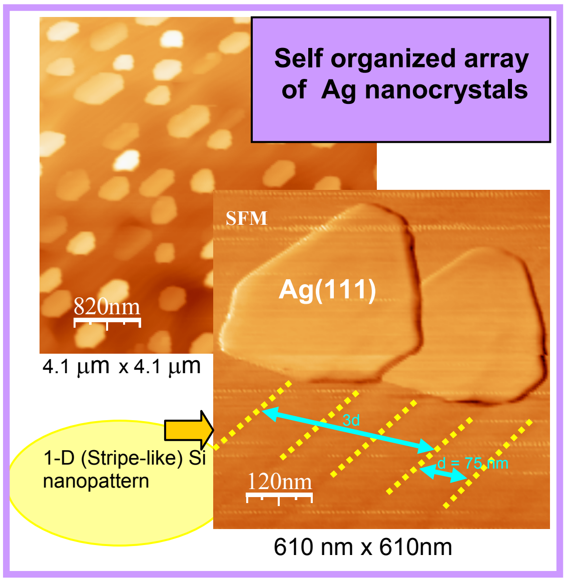
References:

[1] T. Ogino et al., Critical Reviews in Solid State and Materials Sciences **24** (1999) 227; T. Ogino et al. Surf. Sci. 514 (2002) 1; F. Lin et al. Appl. Surf. Sci. 237 (2004) 68.

[2] F.K. Men, Feng Liu, P.J. Wang, C.H. Chen, D. L. Cheng, J.L. Lin, and F.J. Himpsel, Phys. Rev. Lett. 88 (2002) 096105; F.J. Himpsel, J.L. McChesney, J.N. Crain, A. Kirakosian, V. Pérez-Dieste, Nicholas L. Abbott, Yan-Yeung Luk, Paul F. Nealey, and Dimitri Y. Petrovykh, J. Phys. Chem. B 108 (2004) 14484.

[3] Natalia Galiana, Pedro-Pablo Martin , Carmen Munuera, María Varela, Federico Soria, Carmen Ocal , Ana Ruiz, and María Alonso, Surf. Sci. 600 (2006) 3956.

Figures:



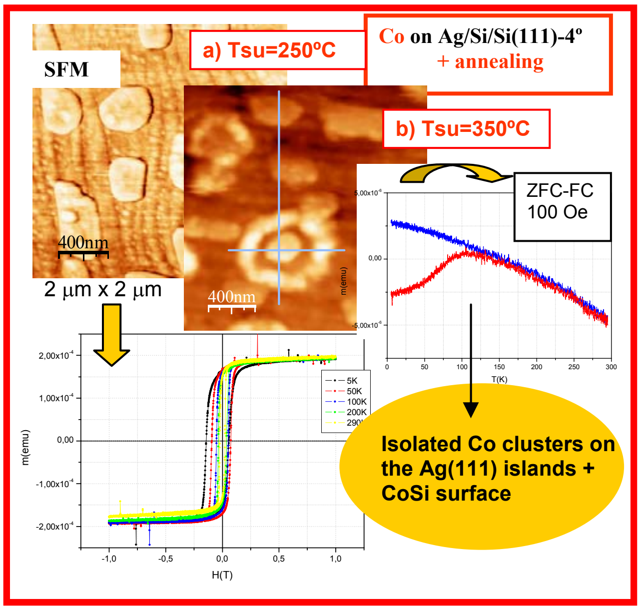


FIG. 1. SFM data showing the surface morphologies of Ag films (2 nm thick) deposited at a substrate temperature of 250ºC on the Si(111)-7x7 surface with the stripe-like pattern. Two of the Ag islands and the Si stripes (75 nm wide) are shown in more detail on the right panel.

Fig. 2. SFM and VSM results for a 10 nm Co film deposited at RT on the Si-Ag template of Fig. 1, and annealed at (a) Tsu = 250ºC and (b) Tsu = 350ºC. Hysteresis loops at T between RT and 5 K are shown for case (a), and ZFC-FC results for case (b).