Self-nanostructuration of the chemical termination of $SrTiO_3$(001) substrates: templates for fabrication of functional oxide nanostructures

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Low-dimensional structures of complex oxides with a wide range of functional properties, from ferroic to catalytic properties, hold the promise to lead to a new generation of materials with unrivalled properties compared to their bulk counterparts. However, nanostructure fabrication of complex oxides is not as well-established as these of metals or semiconductors, which is partly due to the complexity of lattices and the numerous chemical elements. Moreover, the long-range order in self-assembling methods is very challenging. Therefore, new strategies are required for cost-effective fabrication of ordered oxide nanostructures. Here we report a method to fabricate functional oxide nanostructures ordered over the centimeter scale. The method is based in tailoring the chemical termination of $SrTiO_3$(001) substrates and exploiting the selective nucleation of functional oxides on SrO(001) and TiO_2(001) surfaces.

We have studied in detail the morphological and chemical evolution of the topmost surface of STO substrates with annealing. We recently reported that annealing of STO substrates at 1100-1200 ºC causes surface diffusion of the two existing chemical terminations. As a result, TiO_2-terminated terraces separated by SrO-terminated quasi one-dimensional regions are formed [1]. Now we will show that proper annealing at higher temperature (1300 ºC) under oxidizing conditions causes Sr diffusion from the bulk, resulting in atomically flat surfaces, perovskite-layered SrO terminated. Moreover, we will show that the progressive surface enrichment of SrO allows to obtain surfaces with chemical-termination separated at the nanoscale (Figure 1). Such large-area nanopatterned surfaces, stable at relatively high temperature, can be used as template to grow functional ordered nanostructures, exploiting the termination-dependent nucleation.

We will show how the intermediate chemically-organized surfaces occurring during the progressive SrO enrichment can be used as template for nanostructure fabrication of ferromagnetic oxides by chemically-driven selective nucleation. First we prove it with $SrRuO_3$, which is known to nucleate distinctly and preferentially on TiO_2 rather than on SrO termination of $SrTiO_3$(001) surfaces [1,2]. The topographic atomic force microscopy images of a treated substrate and a deposited film in Figure 2 show that $SrRuO_3$ nucleates exclusively on the TiO_2-termination, and thus it replicates any nanostructuration of a treated substrate.

We have also investigated the selective growth of the ferromagnetic oxides $La_{2/3}Sr_{1/3}MnO_3$ and $CoFe_2O_4$ on nanostructured substrates. The results confirm the selective growth and indicate that the method here presented offer new opportunities for the fabrication of functional low-dimension structures of complex oxides.

References:

[1] R. Bachelet, F. Sánchez, J. Santiso, C. Munuera, C. Ocal, J. Fontcuberta, *Self-organization of the $SrTiO_3$(001) chemical terminations: a route for oxide nanostructure fabrication by selective growth*, Chemistry of Materials, in press (published online)

[2] R. Bachelet, F. Sánchez, J. Santiso, J. Fontcuberta, *Reversible growth mode transition in $SrRuO_3$ epitaxy*, Applied Physics Letters **93**, 151916 (2008)

Figures:

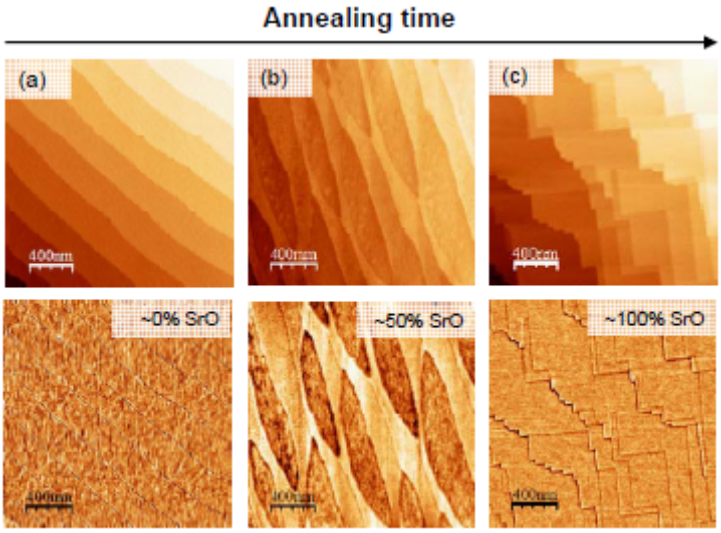

Figure 1: AFM topographic (top panels) and phase-lag (bottom panels) images of a chemically-treated $SrTiO_3$(001) substrate after annealing at 1300 ºC for (a) 2h, (b) 12h, and (c) 72h.

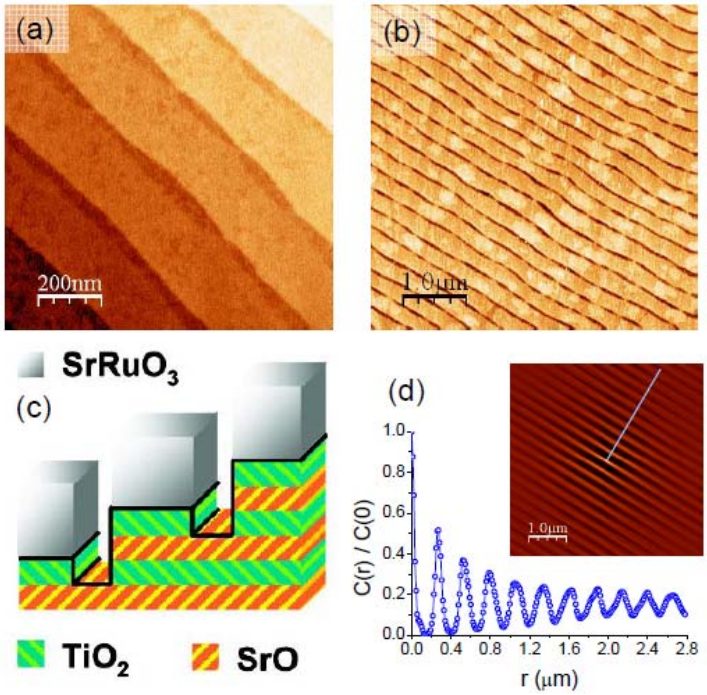

Figure 2 : AFM topographic images: (a) 1 x 1 μm^2 area of bare $SrTiO_3$(001) substrate after annealing at 1200 ºC for 2h, and (b) 5 x 5 μm^2 area of a $SrRuO_3$ film, 7 monolayer thick, deposited on (a). (c) Sketch of the substrate nanostructuration and the selective growth. (c) Self-correlation of (b) and the corresponding profile taken perpendicular to the steps signalling the long-range spatial order.