Subsurface Epitaxial Growth of Hidden Co Nanoclusters

O. Kurnosikov, T. Siahaan, H.J.M. Swagten, B. Koopmans

Eindhoven University of Technology, Den Dolech 2, 5600MB Eindhoven, The Netherlands
o.kurnosikov@tue.nl

Abstract A new subsurface growth mode in the Co-Cu system is reported [1]. A direct subsurface growth of Co nanoclusters by depositing Co atoms on the Cu(001) surface in a single stage at elevated temperature is achieved. At the temperature range close to 650K Co is able to diffuse easily a few atomic layers below the Cu surface whereas a remarkable diffusion in the bulk is still not activated (Fig.1). Co accumulates near the surface and forms the subsurface clusters while Co on the surface or embedded in the surface is presented insignificantly. The resulting subsurface Co nanoclusters are located 2 monolayers (ML) deep below the atomically flat surface of Cu(001). Although the formed nanoclusters are hidden below the copper surface they can still be detected using STM/STS. The detection of hidden subsurface Co clusters is achieved by the analysis of the sub-atomic deformation of the Cu(001) surface, which is in the range of 20 pm, as well as via local variations of surface electron density of copper above the clusters (Fig.2). Monitoring the evolution of the surface depressions and STS spectra versus the deposition dose the shape of subsurface Co nanoclusters is deduced: they are typically 5-10 nm in lateral size but only 2 to 3 ML in thickness. The thickness of the nanoclusters does not evolve significantly under a heat treatment. The kinetics of growth indicates a nucleation dead-time. A simple model is implemented to describe the growth kinetics. The results in this study reveal that intense processes of diffusion, nucleation, and growth take place down to 1 nm below the surface, thus defining the near-surface region.

References

[1] T. Siahaan, O. Kurnosikov, H. J. M. Swagten, and B. Koopmans, Phys. Rev. B, **90** (2014) 165419.

Figures

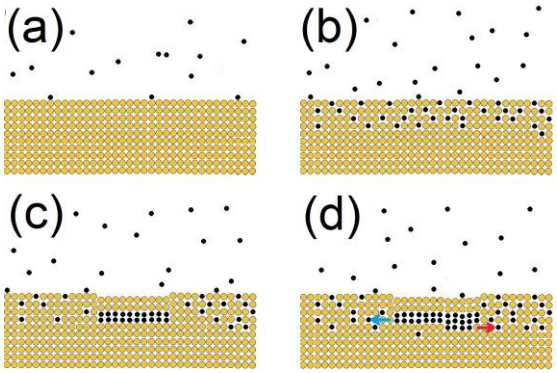

Fig.1 Process of subsurface nanoclusters formation. (a) Beginning of Co deposition on a hot Cu(001) substrate. (b) Incorporation and accumulation of Co in the near-surface region. (c) formation of an initial Co cluster. (d) Further growth of the next layer of the clusters, accompanied by Co segregation (blue and red arrows).

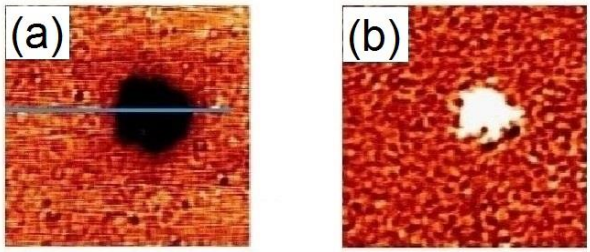

Fig.2 (a) A typical STM image (18 × 18 nm^2) of the atomically flat Cu(001) surface with a local depression induced by a subsurface Co cluster. The depression depth across the blue cross-section line is of about 20 pm. The tunnelling set point is (0.2 V, 1 nA). (b) The surface differential conductance map (STS mapping) corresponding to the area shown in (a) at the same tunnelling set point shows the enhanced conductance above the hidden Co nanocluster. The ripple observed in both types of images originates from single Co atoms dissolved near-surface.