# Morphology evolution during oxide nanoclusters heteroepitaxy: $Cu_2O$ on $SrTiO_3$(100)

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The lattice mismatched heteroepitaxial growth, driven by interfacial elastic strain, offers a possibility of producing self-assembled coherent (defect-free) quantum dots, as it has been demonstrated for semiconductor materials of groups IV, III-V, and II-VI. Although there has been success in the formation and analysis of semiconductor quantum dots, much less attention has been devoted to the oxide quantum dots.
Non-contact atomic force microscopy (NC AFM) *in-situ* analysis during the oxygen plasma assisted molecular beam epitaxy has been used to evaluate the morphology and mechanism of the $Cu_2O$ nanocluster formation on the $SrTiO_3$(100) surface. NC AFM data have been supplemented with results of the x-ray photoelectron spectroscopy, scanning Auger microscopy, theoretical simulations and *ex-situ* taping mode AFM analysis. Selective self-assembled formation of the single phase nanoclusters of $Cu_2O$ on $SrTiO_3$(100) substrates is found to occur only in a very narrow growth parameter window, outside which a coexistence of the multiple phases ($CuO/Cu_2O$ and $Cu_2O/Cu$) has been detected. Observed changes in the nanocluster composition are found to correlate with differences in cluster morphologies. Formation of $Cu_2O$ nanoclusters may be described as progressing through several stages. Unlike lattice-mismatched heteroepitaxy in the typical semiconductor systems, initial stages of the growth of oxide nanodots proceed without formation of the wetting layer. Already at sub-monolayer coverages small, epitaxial, truncated square $Cu_2O$ nanodots, with widths and heights in the range of ~ 8-15 nm and 0.8-2.0 nm, respectively, start to form. At the initial stages of growth, the nanodot size is only weakly changes with coverage and exponentially scales with temperature. Continued deposition leads to increase of the dot density, eventually reaching a critical dot density (~ $10^{13}$ $cm^{-2}$ for 760 K growth temperature), upon which larger mid-sized (30-80 nm) nanoclusters start to grow. At significantly higher thickness (~ 20 nm), large (150-300 nm) dome-shaped clusters form. Resulting morphology consists of mid-sized and large islands on top of the closed-packed layer of the small nanodots. The coexistence of the different types of the clusters at high coverages results in a multi-modal distribution of sizes and shapes. Using a kinetic model of film morphology development, we show that the larger island formation can be caused by small nanodots coalescence, driven by fluctuation of island-island separation at increased dot density.

This work was jointly supported by the Department of Energy (DOE), Basic Energy Sciences Division and the Laboratory Directed Research and Development at Pacific Northwest National Laboratory, which is operated by Battelle for the DOE.