Non-classical nanopatterning and self-organization in Pb/Si(111) growth at low temperatures

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Different self-organized nanostructures have been found during the epitaxial growth of Pb on Si(111). Uniform, stable odd height Pb(111) islands (5- 7- 9-, etc layer) of flat tops and steep edges are grown at low temperatures T~180K [1]. The formation of these unusual island structures is related to Quantum Size Effects (QSE) i.e. the dependence of the energy of the confined electrons on island height. These structures have been observed with two complementary techniques Scanning Tunneling Microscopy (STM) and High resolution Low Energy Electron Diffraction.

However the very fast formation time at low temperature T~180K (i.e. within the deposition time of ~minutes) has been puzzling so far. Recently we have focused with controlled experiments to understand the role of QSE in modifying the kinetic barriers. The results show that the island growth is a novel type of nucleation driven by QSE instead of classical Gibbs Thompson growth (i.e. the dependence of island stability on its curvature). Both the terrace diffusion on top of the islands and the step edge barrier controlling the transfer of atoms from the wetting layer to the islands depend on island stability (whether the island height is odd or even). In addition coarsening from an initial mixture of stable and unstable islands (grown at high flux rates) towards stable islands is much faster than what expected from classical Ostwald ripening predictions[3].

The controlled growth of other island dimensions (in addition to height) is possible for growth on the anisotropic Si(111)-In(4x1) substrate. Elongated 1-d Pb ”wires” of preferred 6.5nm width (due to anisotropic substrate strain) and preferred 4-layers height (due to QSE) were observed. Unlike islands grown on other substrates which are stable only up to ~250K the islands grown on In(4x1) for still unknown reasons are stable above room temperature[4].

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