Compositional Mapping of Individual Semiconductor Nanostructures

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There is a lot of interest in the study of quantum dots (QDs) due to the three-dimensional confinement of carriers leading to an atom-like density of states. QD lasers and photodetectors with improved characteristics have already been demonstrated. However, there are at least two critical issues to be addressed in the growth of self-assembled semiconductor QDs, namely: (i) the control of the composition of individual QDs, which ultimately determines their physical properties; and (ii) the controlled positioning of QDs on a suitable substrate.

A few years ago we have started to use laterally resolved x-ray photoelectron spectroscopy for the compositional analysis of individual semiconductor nanostructures [1]. More recently we have refined the analytical tools for this spectroscopic microscopy, which now provides a minimally intrusive elemental (and chemical state-sensitive) mapping of surfaces at the nanoscale and holds the promise of remarkable versatility. We have applied our procedure to the characterization of two quantum dot model systems, namely InAs/GaAs [2] and Ge/Si [3], with the aim of investigating surface stoichiometry gradients and gaining insight into intermixing dynamics. By analysis of detailed surface compositional maps from individual nano-islands we associate alloying in these islands to surface diffusion processes.

More recently we have also addressed the issue of controlled positioning of QDs [4]. In the Ge/Si system, a square array of submicron Au dots on the Si (001) surface induces the assembly of deposited Ge adatoms into an extensive island lattice. By using in situ spectromicroscopy we could show that patterning of a hydrogen-terminated Si surface with a square array of Au dots followed by brief exposure to air leads to the spontaneous, local oxidation of Si. The resulting oxide nanopattern limits the surface migration of Au during annealing up to 600°C, resulting in complete preservation of the Au pattern. Subsequent deposition of Ge induces a redistribution of Au across the surface even as the oxide nanopattern persists. As a result, the oxide pattern drives the growth of Ge islands into an ordered assembly.

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