Three-dimensional Ge quantum dot crystals prepared by templated selforganization

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Quantum dots provide possible routes towards the realisation of beyond-CMOS device processing,[1] as well as for driving CMOS technology to its limits.[2] The capability of addressing individual quantum dots might be crucial to open new paths for the fabrication of high speed Si compatible electronics. Self-assembled Ge dots, which nucleate randomly on the surface, have been studied intensively, but the addressing of individual dots will require the positioning of dots on predefined spots. To achieve lateral ordering, most approaches employed self-assembled deposition on substrates pre-patterned by either e-beam or optical lithography.[3-8] Here we present the lateral and 3D ordering of small Ge clusters on surfaces pre-patterned by x-ray interference lithography (XIL). The XIL approach provides precise control of the periodity even for periods smaller than 50 nm[9] over areas as big as 2x2 mm with a single exposure. By choosing appropriate growth conditions, 2D dot arrays, quantum dot molecule arrays, as well as 3D quantum dot crystals have been realized.

The structural properties of the samples were subject to careful analysis using AFM, TEM and grazing incidence X-ray diffraction. We obtain a narrow size distribution of the dots, shown in Fig. 1. No degradation of the ordering was obtained by the stacking of the dots into ordered 3D dot crystals with up to 10 dot layers. Cross-sectional TEM reveals accurate stacking of the dots in vertical direction, whereas TEM using Z-contrast imaging suggests a high Ge fraction in the Ge dots.

The samples have been investigated by absorption spectroscopy and photoluminescence in the near to mid-IR spectral range at low temperatures. Narrow, phonon-resolved photo-luminescence was observed from ordered Ge islands in 3D dot crystals. These first experiments of the optical properties are promising for future analysis to study effects of correlated Ge quantum dots in 3D quantum dot crystals.

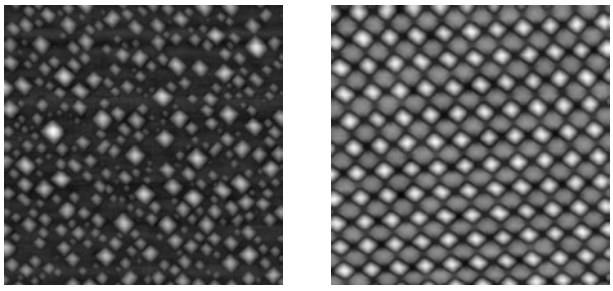

FIG. 1: AFM images of a 1x1 μm area showing Ge dots (light colour) on (a) bare Si and on (b) Si pre-patterned by x-ray interference lithography.

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