On the compliant behavior of Ge nanocrystals on free-standing Si(001) nanopillars

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Due to its superior optoelectronic properties, Ge is attracting increasing interest to build up future photonic modules within Si chip baseline technology. The major stumble block is given by the 4.2% lattice mismatch. The theory of 3D nanoheteroepitaxy (NHE) offers the vision to shift the critical thickness for defect nucleation in the epilayer to infinity by the so-called strain partitioning phenomenon (compliance) between Ge and Si.

We report on the structural characterization of Ge clusters selectively grown by chemical vapor deposition on free-standing Si(001) nanopillars. Synchrotron based x-ray diffraction, Raman spectroscopy and transmission electron microscopy were performed to experimentally verify the compliant substrate effects in the Ge/Si (001) system. In contradiction to the present NHE theory, no compliant substrate effects were observed in ~50 nm wide nanostructures monolithically prepared from a Si(001) wafer. The absence of the strain partitioning between Ge and Si is caused by the stress field exerted by the SiO_2 growth mask on the Si nanopillar. This is not the case for the pattern fabricated on Silicon-on-insulator substrate. Here, the compliant substrate effects were observed for pillar widths even bigger than those expected from theoretical calculations.

Our work demonstrates, that although NHE theory does not yet include all the aspects of the thin film growth on the nanoscale, it offers a Si-CMOS compatible approach of integrating Ge and other lattice mismatched materials (e.g. III-V compounds) for future Si microelectronics technologies.