Synthesis and Size-control of Si Nanocrystals by SiO/SiO_2 Superlattices

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After first investigations on the room temperature photoluminescence (PL) signal of porous Si [1,2], interest in the optical properties of semiconductor nanoparticles, especially porous Si and Si nanoparticles, has grown over the last decade [3,4]. Different processes for the synthesis of nanocrystalline Si (nc-Si) like Si ion implantation into high quality oxides [3], sputtering of Si-rich oxides [5] or reactive evaporation of Si-rich oxides [6] are known. Within these methods the Si crystal size is controlled by the Si content in the SiO_2 matrix. Therefore, crystal size and density cannot be controlled independently.

We have developed a new approach of SiO/SiO_2 superlattices for nc-Si synthesis which allows independent control of these properties, adjusting the crystal size by the SiO layer thickness [7]. Si nanocrystals were prepared by alternating evaporation of SiO powder in vacuum or oxygen atmosphere and subsequent annealing at 1100°C in N_2 atmosphere.

Cross section TEM imaging by Fresnel defocus contrast proves the layered structure of the samples and the phase separation of the SiO layers into nc-Si and SiO_2 after annealing. The strong PL signal shows a blue shift from 950 nm for the sample with an SiO layer thickness of 4 nm to 750 nm for the sample with a layer thickness of less than 1 nm. The evidence of phonon replica of Si in the resonant excited PL spectra proves the quantum confined band to band recombination of electron-hole pairs to be the origin of this luminescence. The size dependent blue shift of the PL signal demonstrates the correlation between crystal size and SiO layer thickness under this assumption. The peak position of the PL signal for different SiO layer thicknesses is in agreement with calculated band gap energies for nc-Si with the corresponding crystal size measured by X-ray diffraction method [8]. Additional optical characterization of the described samples will be included.

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