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Controlled self-assembly of Ge Si nanostructures and its perspective in Si micro cavities

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Monolithic integration of Si based microelectronics and optoelectronics is expected to be the viable solution to overcome the performance of bottleneck for semiconductor microchips in terms of power consumption, speed and band width. Ge Si quantum nanostructures (QNs) have been of great interest for their potential in both microelectronic and optoelectronic device applications, considering their unique properties and the compatibility with the sophisticated Si technology. However, the poor quantum efficiency of the Ge/Si system associated with the indirect band structure hampers their applications in the optoelectronic devices. It is found that the quantum confinement effect and the partial relaxation of the law of momentum conservation can considerably increase the quantum efficiency of the Ge Si nanostructures. Further improvement can be realized by embedding Ge Si QNs into some micro cavities since the light-matter interaction in the cavity can be dramatically enhanced. It is a critical issue to realize the spatial matching, as well as the spectra matching, between the Ge Si QNs and the cavity. In this talk, controlled Ge Si QNs in Si microcavities (micropillars and microdisks) are systematically studied. The periodic Si micropillars and microdisks are fabricated by nano sphere lithography. Controlled Ge Si coaxial quantum wells (CQWs) on periodic Si (001) micropillars in a large area is realized. By tailoring the growth conditions and the diameters of the pillars (or the microdisks), different configurations of Ge Si QNs, including quantum dots (QDs) 'necklace', quantum rings (QRs), quantum dot molecules (QDMs) and single QD are realized on the top edge of the micropillars, as shown in Fig. 1. By reducing the Si pillar into small dot, four self-assembled Ge Si QDs can be induced at the base edges of the Si dot, resulting in the Ge-Si compound QD molecules. Particularly, the Ge Si QNs can be readily modulated by a two-step growth procedure. Such an engineering of Ge Si QNs is explained in terms of the surface chemical potential and the anisotropic surface diffusion of adatoms around the patterned Si microstructures during growth. Our results disclose the critical effect of the surface curvature on the diffusion and the aggregation of Ge adatoms, which further clarify the unique features and the inherent mechanism of self-assembled QDs on patterned substrates. More interestingly, by designing the diameter and the period of the Si microcavities (pillars or disks), the strong coupling between the spontaneous emission of Ge Si QNs and the cavity modes, as well as the effect of the photonic crystal bandgap, will remarkably improve the optoelectronic properties of the Ge Si QNs. Accordingly, the Ge Si QNs embedded in the Si microcavities will have promising futures in the applications of innovative optoelectronic devices.

Biography

Dr. Zhenyang Zhong is a Professor in the Physics Department at Fudan University, China. He has completed his BS at Peking University in 1995 and PhD degree in the Institute of Physics at Chinese Academy of Science, Beijing, China in 2001. He has worked in Institute for Semiconductor Physics at University Linz, Austria from April 2001 to December 2003 and from May 2005 to December 2005 and worked in Max Planck Institute for Solid State Research, Stuttgart, Germany, as a Postdoctoral Research Fellow from April 2004 to April 2005. Since 2006, he is working in the Physics Department at Fudan University. His research interest focuses on the controlled formation of varieties of nanostructures on Si substrates, and the exploration of the unique properties and the applications of those nanostructures. He has authored or coauthored 71 journal articles and 2 book chapters.

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