ROOM TEMPERATURE ELECTROLUMINESCENCE FROM MULTILAYER GE/SI HETEROSTRUCTURES

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The development of an efficient silicon based light emitting device is the challenge task in modern semiconductor physics. One of the promising approach is to utilize a concept of Ge nanostructures embedded in a Si matrix. Our research is devoted to the investigation of structural, optical and electrooptical properties of the multilayer Ge/Si heterostructures selectively doped by Sb. The structures are grown by molecular beam epitaxy (MBE). It is shown [1] that then Sb flux is supplied to the surface during growth and Ge thickness in each layer is slightly higher then critical thickness of 2D-3D growth transition the defect free Ge/Si quantum dot superlattices (QDSL) are formed (Fig.1). The surface density of the QDSL clusters, grown at 600^0C, is 10^{10}cm^{-2}. Room temperature (RT) photoluminescence (PL) investigations of the QDSL samples show that in the range of 1.3-1.8μm a broad band is observed (Fig.2, curve 1). The integral intensity of the band for different samples at RT is 10^1-10^3 times higher then integral intensity of the fundamental Si_{To} line. In the low temperature (10K) spectrum no D1-D4 lines are found and the broad band can be attributed to the electron-hole pair recombination in the Ge quantum dots (QD). Normally, Ge QD related PL band is intensive at low temperatures, but vanishes at room temperature. In the case of Ge/Si multilayer heterostructures Sb doping of Si spacers between Ge QDs leads to higher electron confinement in Si spacer layers. Measured values of exciton activation energies in Ge/Si QDSL reach 85meV. Beside of a strong RT PL, related to the Ge QDs, we have observed some another unusual properties of the grown samples. First, an integral intensity of QD PL at RT is characterized by a N^2 function with increasing of the number of structure periods. Second, time resolved PL taken at 10K at the wavelength of 1.55μm shows fast (to the best of our knowledge, shortest for such a system) time of PL decay $\tau \sim 0.1\mu s$. Third, QD PL maximum shifts to the shorter wavelengths with increasing of excitation power density. In the range of 1-40 W·cm^{-2} this blue shift looks like that one in the I-type heterostructures, while in the range of 50-1000 W·cm^{-2} shows typical for II-type Ge QD behavior. We have proposed following model to explain observed phenomena. We assume that in the QDSL holes are localized in the Ge QDs, whereas for the electrons a miniband is formed. At low excitation densities recombination from miniband states to the QD states demonstrate I-type heterojunction behavior, but at higher excitation densities electron-electron interaction destroys miniband and each QD act as a separate objects.

Finally, Si diode structures with Ge QDSL placed in between of p and n regions was grown by MBE and Al/Au metal contacts are formed at the n and p sides. The electroluminescence (EL) measurements for the edge and in-plane emitting geometry have been done [2]. At RT the EL spectra show a broad band in the range of 1.4-1.7μm which, as in the case of PL, we attribute to the radiative recombination of excitons in the Ge QDSL. Typical EL spectrum is shown on the fig.2 (curve 2). Note that The QDSL band is detected in the EL spectra when applied voltage >0.7V. The QDSL band is dominated in EL spectrum and the external QDSL EL efficiency of our devices, measured using sphere Ulbriht method, is higher than 0.04%.

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References:

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Figures:

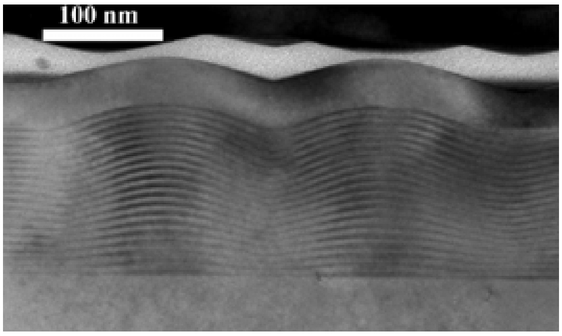

Fig.1 Cross section transmission electron microscopy image of 20-layer Ge/Si heterostructure doped by Sb.

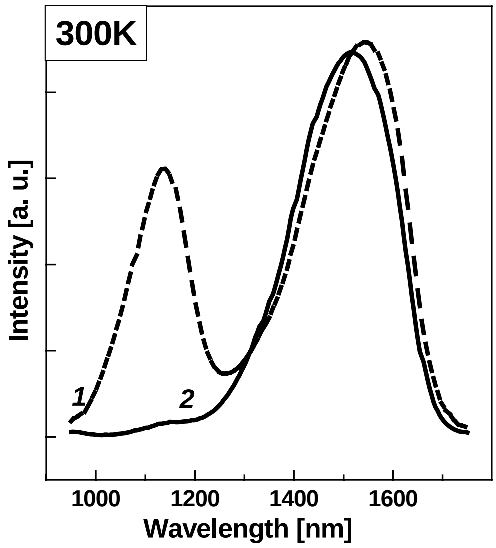

Fig.2 Photoluminescence (1) and electroluminescence (2) spectra of the Si-diode with 20-layer Ge(Sb)/Si heterostructure incorporated in the space charge region of a p-n junction. Excitation power density for PL spectrum is $12 W \cdot cm^2$. EL spectrum is recorded at current of 0.7A and voltage of 1.7V.