Micro-Raman spectroscopy and imaging of group IV semiconductor epitaxial nanolayers for photonic and opto-electronic applications

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Raman spectroscopy demonstrates an excellent ability for analysis of stress, composition and defects in groups III-V and II-IV semiconductors, including SiGe, SiC and GeSn alloys. SiGe alloys, for example, were intensively studied for the last quarter of the century and the relationship for different Raman modes depending on Ge content and stress were well established [1]. However, there are only few Raman investigations of GeSn alloys and very thin SiC epitaxial layers published up to date. Furthermore, there are discrepancies of the reported results, related in particular, to the frequency dependence of the main Raman modes versus Sn content for strained and relaxed GeSn layers [2]. In this presentation the results of our recent investigations on ultra-thin SiC layers using micro-Raman mapping (or imaging) technique and on polarized micro-Raman spectroscopy of homogeneous and non-homogeneous GeSn alloys are discussed.

For GeSn alloys it was demonstrated from the comparison of the Raman spectra in two different polarizations, that Ge-Ge and Ge-Sn peaks are more easy to analyze in $z(x,x)\underline{z}$ configuration, while Sn-Sn peak is more pronounced and isolated in $z(x,y)\underline{z}$ configuration. Based on analysis of the aforementioned Raman bands, the dependences of various peaks position vs Sn content (obtained from XRD measurements) were established. It was also shown that the segregates, obtained at higher Sn content as a result of phase separation and Sn diffusion to the surface, are of metallic tin origin.

The thin SiC layers grown by a new method of solid-gas phase epitaxy were also investigated. It is shown that the ultra-thin SiC layers on Si (111) are composed of a cubic polytype of SiC with a small amount of 6H-SiC [3]. The presence of the voids formed in Si under SiC film has been experimentally confirmed by micro-Raman spectroscopy and SEM. Line and area Raman mapping was performed at the voids area. The strong enhancement in the peak intensity of the TO and LO modes is observed for the Raman signal measured in the void area. The intensity of TO Si-C peak increases with void depth. The enhancement of the electromagnetic field at the voids was also confirmed by theoretical calculation based on Fresnel's equation. The Raman line mapping experiments presented in this work confirm that the voids formed in the Si substrate under the SiC layer cause relaxation of the elastic stress caused by lattice mismatch between the SiC and Si. This enhancement of the Raman signal allows micro-Raman measurements to be used for the detection of different polytypes in ultra-thin SiC layers. It was demonstrated that the quality of GaN layers grown on SiC layers consisting of a mixture of the cubic and hexagonal polytypes is better than that of GaN layers grown on a single SiC polytypes [4].

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