Growth of $Si_xGe_{1-x-y}Sn_y$ Structures with High Sn Content for Bandgap Investigation

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In recent years, there has been a lot of research on the integration of electronic and photonic functionality on one single chip. However, Si as most common semiconductor is not suitable for photonic device applications due to its indirect bandgap. Therefore, one of the greatest challenges of current Group-IV research is to find a concept to integrate optoelectronic device functionality on chip. In this context, the ternary alloy $Si_xGe_{1-x-y}Sn_y$ is a particularly interesting material to investigate. On one side it allows the decoupling of bandgap and lattice constant. This fact allows the lattice matched growth of $Si_xGe_{1-x-y}Sn_y$ on Ge at a certain ratio of Si to Sn. Furthermore, the ternary alloy is predicted to become a direct bandgap semiconductor at specific compositions and strain [1].

A key issue for further research is the knowledge of the compositional bandgap dependency of $Si_xGe_{1-x-y}Sn_y$. A common parameterization of the bandgap includes terms up to quadratic order in compositional parameters [2]. Here, the prefactors of the quadratic terms are the so-called bowing parameters. However, while the bowing parameters for $Si_{1-x}Ge_x$ and $Ge_{1-x}Sn_x$ are well known, the previous results for the bowing parameter of $Si_{1-x}Sn_x$ show a huge discrepancy [2].

In our presentation, we will highlight the opportunities and challenges of growing lattice matched $Si_xGe_{1-x-y}Sn_y$ structures with high Sn content. For this purpose, we grew two series of $Si_xGe_{1-x-y}Sn_y$ layers with different composition. The layer growth on 4” substrates started with a 50 nm Si buffer, which was then overgrown with a 100 nm thick Ge virtual substrate. In order to fulfill the condition of lattice matching of the $Si_xGe_{1-x-y}Sn_y$ layers to the Ge VS, we kept the ratio of Si to Sn fixed.

The first series ended with a 100 nm intrinsic $Si_xGe_{1-x-y}Sn_y$ layer on top. The MBE-grown layers were analyzed by x-ray diffraction (XRD), see Fig. 1, photoluminescence spectroscopy (PL) and Rutherford back scattering (RBS) to get detailed information about the compositional dependency of the bandgap and the crystal quality.

For the second series, the intrinsic $Si_xGe_{1-x-y}Sn_y$ layer was overgrown with 100 nm highly n-doped $Si_xGe_{1-x-y}Sn_y$. Afterwards, single mesa diodes were fabricated out of these layers to investigate the electro-optical performance of the diodes containing the $Si_xGe_{1-x-y}Sn_y$ layers.

We present results of the material characterization as well as electrooptical device characterization results and discuss the impact of layer composition on bandgap parameters.

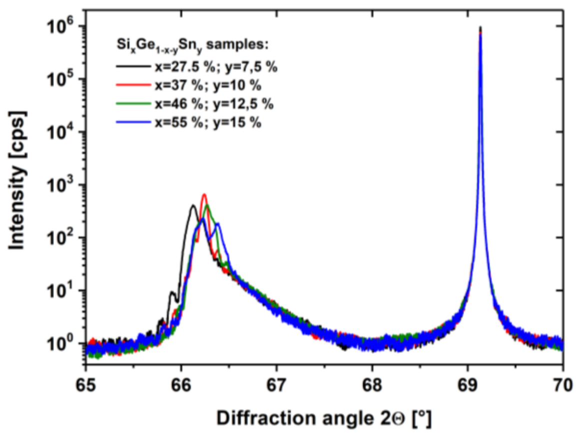

Fig. 1: XRD pattern of $Si_xGe_{1-x-y}Sn_y$ layers with different compostion

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[2] T. Wendav et. al., Appl. Phys. Lett. **108**, 242104 (2016);

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