Carbon-mediated epitaxy of SiGe virtual substrates on Si(001)

J.Schmidt [1*], **D.Tetzlaff** [1], **and H.J. Osten** [1,2]

[1] *Institute of Electronic Materials and Devices, Leibniz Universität Hannover, Schneiderberg 32, 30167 Hannover, Germany*
[2] *Laboratory of Nano and Quantum Engineering, Leibniz Universität Hannover, Schneiderberg 39, 30167 Hannover, Germany*

We report on the effect of carbon submonolayer deposition on the growth of thin $Si_{1-x}Ge_x$ (SiGe) layers on Si(001) substrates for ultra-thin virtual substrate (VS) applications.

SiGe VS are of interest for various applications in semiconductor technology. However, conventional methods like graded buffer layers [1] have limitations regarding layer thickness. Alternative methods, as low temperature growth [2] or the use of surfactants [3], can greatly reduce the VS layer thickness but come with other difficulties concerning defect densities.

It was shown for Ge epitaxy on Si(001) that the low-temperature deposition of Ge in combination with a submonolayer of Carbon and subsequent annealing can successfully suppress island formation and lead to a smooth, relaxed layer at arbitrary thicknesses.[4] We adapted this process flow to evaluate the usability for SiGe layer growth. The process we used consists of several growth steps: During an initial deposition step at a low temperature, a thin SiGe layer is deposited onto the substrate. This is followed by deposition of a sub-monolayer of C and subsequent annealing to enable further crystallization and relaxation of the SiGe layer. A subsequent SiGe growth step at elevated temperature yields a carbon-free surface and the desired layer thickness.

We investigated several growth parameters, such as the initial growth temperature, the Ge fraction of the layer, the annealing ramp and the carbon amount. The growth took place in a DCA S1000 MBE cluster system. Si and Ge were evaporated from electron gun evaporators, a sublimation cell was used for C deposition. The growth was *in situ* monitored with RHEED and *ex situ* characterized with XRD, XRR, SEM and TEM.

From in situ RHEED measurements during all stages of the growth process, we observe that the layer shows crystalline and amorphous parts throughout the first SiGe deposition step. The streaky RHEED pattern during annealing and throughout the second growth step indicates a smooth layer. Transmission electron microscopy investigations in cross-section confirm the layer thickness of 30 - 70 nm and the low surface roughness of the layers. The defect structure analysis is subject of ongoing investigations.

The SiGe layers show a Ge fraction between 0.44 - 0.81, which was obtained from reciprocal space maps around the 113+ reflection, as can be seen in Fig. 1.

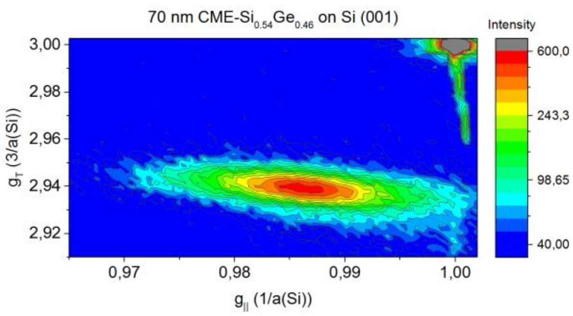

Fig. 1: reciprocal space map around the 113+ reflection for a CME-SiGe sample with a layer thickness of 70 nm.

The samples with Ge fractions at x = 0.75 – 0.80 are almost fully relaxed (R = 93%), whereas the the layers with x = 0.44 – 0.5 show a degree of relaxation around R =75%

In summary, we propose that carbon-mediated epitaxy is a promising candidate for the growth of ultra-thin, smooth SiGe layers with high degrees of relaxation.

References

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[*] Contact: schmidt@mbe.uni-hannover.de