ESRF	**Experiment title:** Plane Wave Topography of curved heterostructures: Evaluation of strains, compositional gradients and early stages of relaxation in SiGe/Si	**Experiment number:** HS-397
Beamline: ID19	**Date of experiment:** From: 25.9.97 to: 28.9.97	
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Report:

The experiment was a continuation of HS-108. Some remarks on our experimental requirements:
In view of an increased sensitivity to the sample surface we use small glancing incidence angles (about 3”) and in order to get a undistorted topographic image (i.e. nearly normal exit from the sample) diffraction angles close to 45”. During our experiment HS-108 wavelengths below about 0.7 Å were available only. Therefore we had to use a 448-reflection at 0.69 Å. As compared to the 224-reflection at 1.38 Å this gives a peak halfwidth smaller by a factor of about 15 and correspondingly longer exposure times. Lateral resolution is related with the extinction length: 30 µm at 0.69 Å and 5 µm at 1.38 A. As a consequence neither exposure times nor resolution were as good as intended!
Therefore working at about 1.4 Å was one of our requirements for experiment HS-397. This capability was confirmed by the beamline responsible, as it was planned to replace the last remaining Al window in the beam path by a polished Be window long before our experiment. Unfortunately, the Al window had to be inserted again because of a necessary overhaul of this Be window. This happened too close to our experiment as to allow for a change of the beam time schedule. Therefore at the time of our experiment only radiation below about 0.7 Å was accessible, with all the negative consequences mentioned above.

Besides: last time (HS-108) we had reported on a torsion effect that limited the ability to compensate for the curvature of the sample. This problem could be overcome by an additional degree of freedom for the detector in the horizontal plane, which allows to compensate for torsion effects. This significantly enhances the performance of the double crystal camera which we have installed on ID19.

Despite the problems mentioned above our experiment was very successful. Especially we were able to solve the two following problems (published in [1]).

- **Measurement of the effect of carbon impurities**

We have made in-situ annealing experiments with nominally undoped SiGe/Si layers and SiGe/Si-layers with a carbon content of $4.5 \cdot 10^{19}$ at/cm^3. The thicknesses of the samples were 95 nm and 91 nm and the Ge contents 23 % and 24 %, respectively. It is already known that at higher carbon contents SiC precipitates are formed, which effectively prevent relaxation [2]. However, it was an open question, whether a lower carbon content may influence dislocation velocities significantly. Our results show that the misfit propagation velocities (glide velocities of the leading threading dislocation segments in the SiGe-layer) are rather close to the theoretical values (compare fig. 1). Above mentioned carbon content reduces the dislocation velocities significantly, but only to 70% of the value for undoped samples. As compared to that, it was shown that a oxygen content of $2 \cdot 10^{20}$ at/cm^3 reduces the dislocation velocity by a factor of 6 to 10 [3].

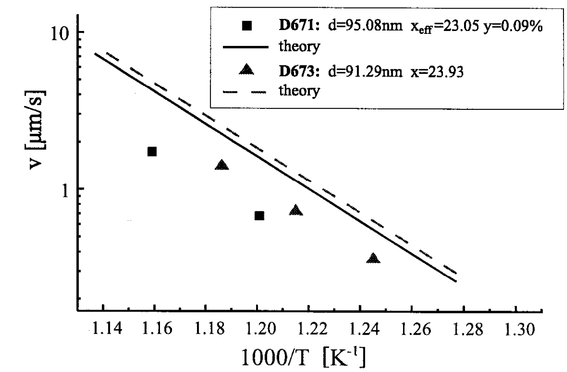
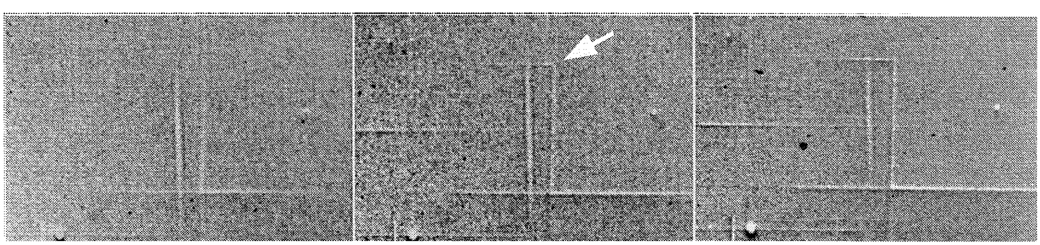


Fig.1:
Misfit dislocation propagation velocities in undoped samples and in samples with a carbon content of $4.5 \cdot 10^{19}$ at/cm^3.

- **Direct evidence of dislocation cross slip**

We had found evidence of cross slip before [4]. Now we could demonstrate the process of cross slip by sequences of images (fig.2). Due to the comparatively poor resolution, the crossing misfit dislocation is not visible, which causes the dislocation bundle in fig. 2 to cross slip. Topographs in our laboratory have, however, clearly shown this dislocation.

Fig.2: Cross slip of a propagating misfit dislocation into another { 111) slip plane due to a crossing misfit dislocation



References:

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[2] G. FISCHER, Thesis, Univ. Potsdam 1997

[3] D.B. NOBLE, J.L. HOYT, P. KUO, W.D. NIX, J.F. GIBBONS, S.S. LADERMAN, J.E. TURNER, S.J. ROSNER, M.P. SCOTT; Mat. Res. Soc. Symp. Proc. **220** (1991) 247-252

[4] R. KÖHLER, J.-U. PFEIFFER, H. RAIDT, P. ZAUMSEIL; presentation at the U.S. X-TOP'97 (46th Annual Denver X-ray Conference), Denver, August 1998 - based on results of HS-108 and lab. topographs