Strain Fields of Periodic Dislocation Networks of SME grown Ge on Si(111)

M. Kammler[2], J. Falta[1], P. Kury, B.H. Müller[2], T. Schmidt[1], and M. Horn-von Hoegen

Institut für Festköperphysik, Universität Hannover, Appelstr. 2, 30167 Hannover, Germany
[1] HASYLAB am DESY, Notkestr. 85, 22603 Hamburg, Germany
[2] Institut für Halbleitertechnologie, Universität Hannover, Appelstr. 11a, 30167 Hannover, Germany

Ge heterostructures on Si have an excellent potential for future device applications. Relaxed Ge layers, however, require dislocations for the transition from the Si to the Ge lattice. In an ideal case this happens with a periodic array of dislocations completely confined to the Si/Ge interface, as established only by Sb surfactant mediated epitaxy of Ge on Si(111) [1, 2, 3, 4, 5]. Each of the dislocations is surrounded by a strain field which elastically distorts the lattice: This results in a 2-dim. 104×104 Å periodic modulation of the lattice parameters due to alternate tensile and compressive stress.
The surface of the Ge film also shows a height undulation with an amplitude of less than 1 Å. This periodic height undulation has been observed by spot splitting in high resolution low energy electron diffraction (SPA-LEED) and is well understood [6, 7]. Goal of this project is the determination of the geometric structure of the strain fields and the dislocation network at the buried Si/Ge interface by x-ray diffraction measurements. The strain fields could be described by a 2-dim. discrete Fourier sum which manifests in spot splitting of the fundamental spots also in x-ray diffraction.
Along the surface normal the strain fields originating from the dislocation network show no periodicity and hence weakly modulated intensity rods are expected for these satellite peaks. The in-plane Fourier coefficients of the distribution of dislocations can be measured at vanishing vertical scattering vector, i.e. grazing incidence and exit angle of the x-rays. The intensity of the satellite spots is expected to increase proportional to the square of the order of the fundamental spot. Therefore measurements were performed in the vicinity of the Si(22$\bar{4}$) Bragg peak. For samples 5 nm thick SME grown Ge films on Si(111) were used. The experiments were performed at the beamline BW1 using a Si(111) double crystal monochromator and focussing mirrors at a photon energy of 9.1 keV. Fig. 1 shows a q_x, q_y plot of the reciprocal space around the Si(22$\bar{4}$) Bragg peak at $q_z \simeq 0$. The data have been recorded using a position sensitive detector in a ω - 2ω scan mode. The data set has been corrected for image distortion and is shown in a logarithmic intensity scale. The Si(22$\bar{4}$) Bragg peak is well observed as a slighty elongated bright spot (instrumental resolution function). A broad

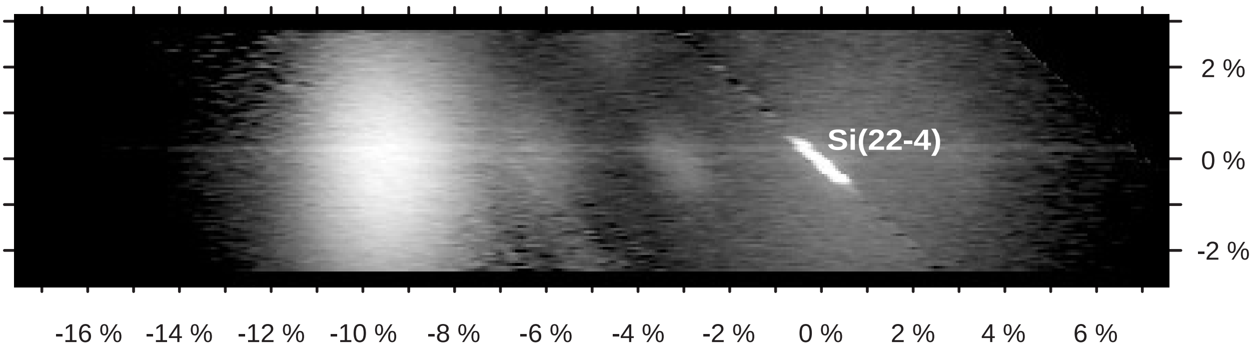

Figure 1: Reciprocal space map for $q_z \simeq 0$ for a 5 nm thicke Ge film. The bright spot is the Si(22$\bar{4}$) Bragg peak, the diffuse broad spot is the Ge(22$\bar{4}$) Bragg peak. Four satellite spots originating from the periodical dislocation network at the Ge/Si interface are found in between the Si Bragg peak and the Ge Bragg peak.

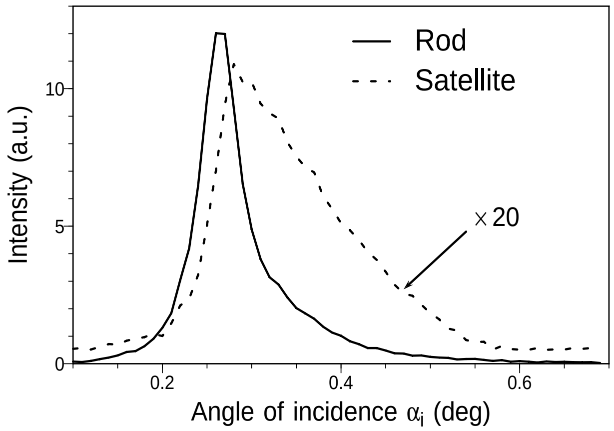

Figure 2: Rodscan of fundamental spot and satellite spot. Due to the finite vertical extension of the strain fields intensity is still observed for larger vertical scattering vectors q_z

Ge(22$\bar{4}$) Bragg peak is seen left of the Si peak at a reciprocal distance of -9.5% Brillouin zone. The broadening of the Ge peak can be attributed to a variation of the Ge lattice constant in the film due to variations of the dislocation - dislocation distance at the Ge/Si interface [7]. Satellite spots are visible in the region between the Si and the Ge Bragg peak. The dependence of the satellite spots intensity on the vertical scattering vector is shown in Fig. 2. Teh intensity of the satallite decreases much more slowly than the intensity of the Si Bragg peak shown for comparison in the same plot (Rod). This reflects the finite vertical extension of the strain fields. Further measurements of rod scans and reciprocal space maps with larger $q_z > 0$ are in progress.

References

[1] M. Horn-von Hoegen, F.K. LeGoues, M. Copel, M.C. Reuter, and R.M. Tromp, Phys. Rev. Lett. **67**, 1130 (1991)

[2] M. Horn-von Hoegen, Appl. Phys. A **59**, 503 (1994)

[3] J. Falta, M. Copel, F.K. LeGoues, and R.M. Tromp, Appl. Phys. Lett. **62**, 2962 (1993)

[4] M. Horn-von Hoegen, F.-J. Meyer zu Heringdorf, M. Kammler, C. Schaeffer, D. Reinking, and K.R. Hofmann, Thin Solid Films **336**, (1998)

[5] T. Schmidt, J. Zeysing, R.L. Johnson, and G. Materlik, Appl. Phys. Lett. (in press)

[6] M. Horn-von Hoegen, A. Al-Falou, H. Pietsch, B.H. Müller, M. Henzler, Surf. Sci. **298**, 29 (1993)

[7] M. Horn-von Hoegen and M. Henzler, Phys. Stat. Solidi (a) **146**, 337 (1994)