3-dim. reciprocal space mapping of a quasi periodic misfit dislocation array

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The geometric interface structure of heteroepitaxial semiconductor systems is of special importance for the properties of modern electronic devices. The presence or absence of misfit dislocations accounts for the strain state in lattice mismatched heterolayer systems and for the modification of the electronic band structure. The arrangement and type of dislocations at the interface and in the film may also affect the electronic properties of the device. An ideal non-destructive tool for the investigation of such a interface structure is x-ray diffraction. Using 3-dim. reciprocal space mapping with a significant vertical scattering vector allows the complete determination of the strain fields of buried misfit dislocations [1].

In this report we demonstrate the first XRD study of a buried periodic interfacial misfit dislocation array adjusting the lattice constants between a Si substrate and a relaxed epitaxial Ge film. Such a periodic array of dislocations can be formed in the case of Sb surfactant mediated epitaxy of Ge on Si(111) [2]. Each dislocation is surrounded by an elastic strain field in the Si substrate and the Ge overlayer. The strain fields are localized at the interface and decline with increasing distance from the interface [1]. As a result, additional satellite peaks surrounding the Ge and Si Bragg spots can be observed in XRD. The separation of the satellites is determined by the mean distance between the dislocations. The vertical expansion in reciprocal space reflects the decay length of the strain fields perpendicular to the interface plane.

The diffraction experiments have been performed ex-situ using the BW1 stage at HASYLAB. The thickness of the SME grown Ge film was chosen to 10 nm on a Si(111) substrate. Reciprocal space maps were recorded with a position sensitive detector, using a focussed beam at 10 keV photon energy. The incident angle was kept at 1° in order to maintain well-defined surface sensitivity.

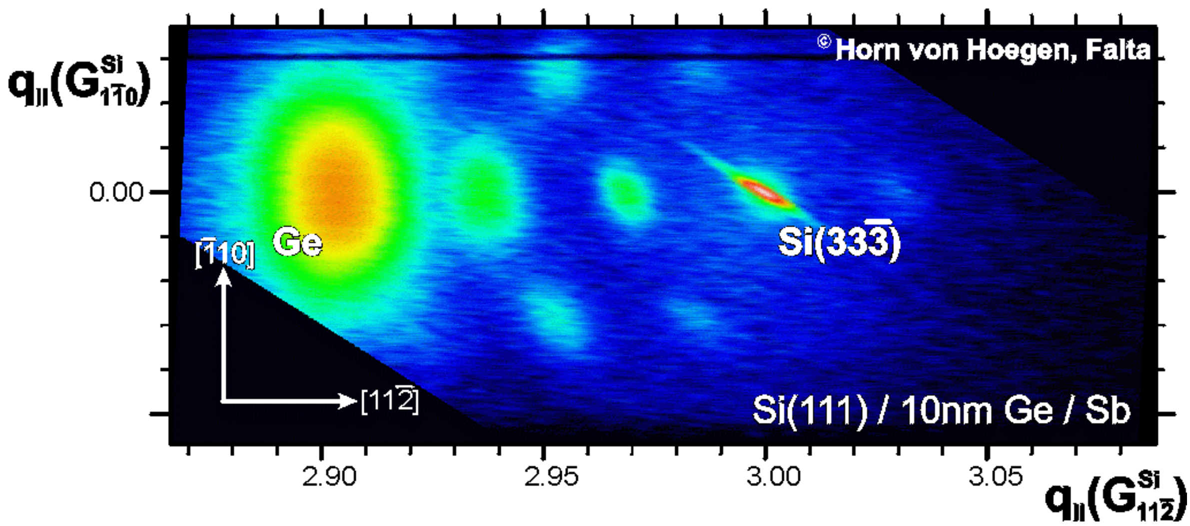

Figure 1: Heterosystem with 10 nm Ge(111) on a Si(111) substrate. In-plane scan of (33-3) Bragg condition. Satellite spots due to interfacial dislocation array are visible

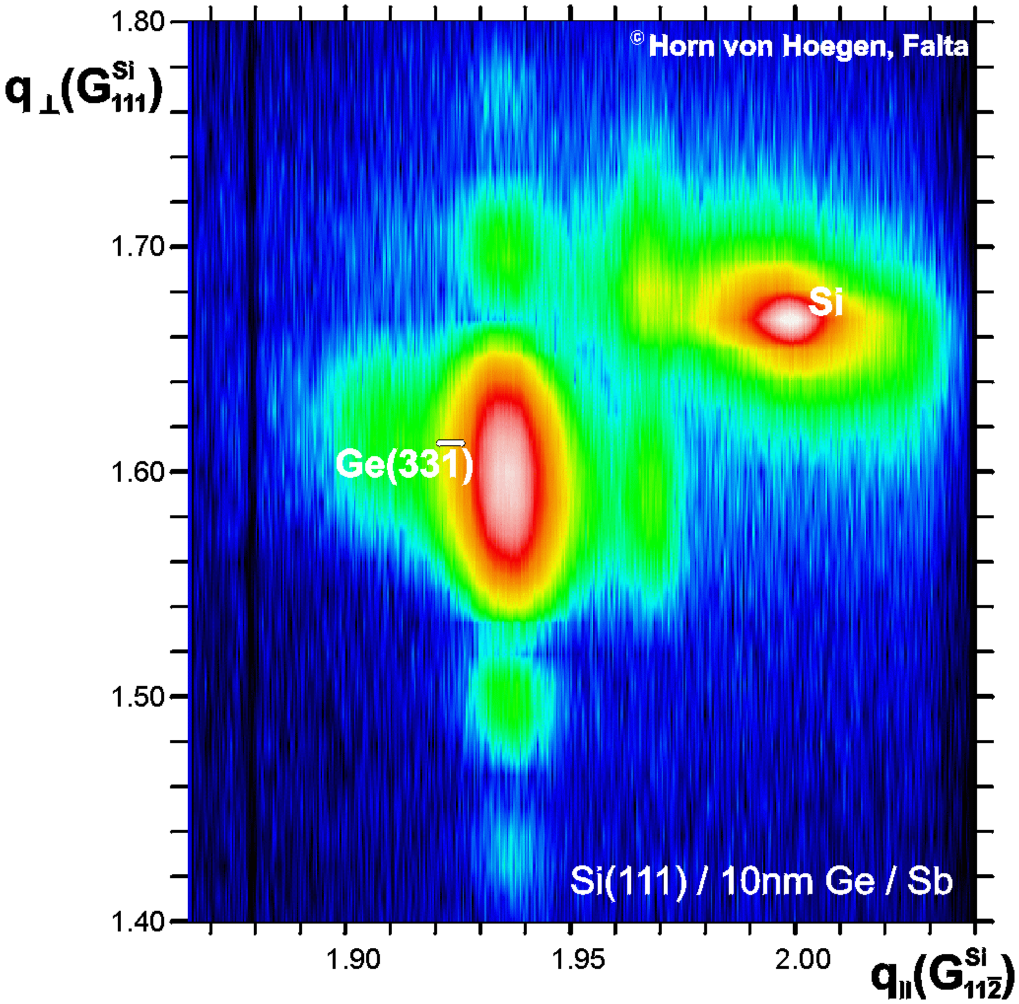

Figure 2: Vertical cut of reciprocal space at the Ge(331) Bragg condition. Both Si and Ge spots are visible. Satellite spots surround the Ge and Si spots.

Figure 1 shows an in-plane scan of the diffuse intensity surrounding the Si crystal truncation rod for the (33-3) Bragg condition. The periodic hexagonal arrangement of diffuse satellites is clearly visible. The intense broad spot at the left part of the image corresponds to the (33-3) Bragg spot of the Ge film. From the width of the spot we can conclude that the lateral lattice constant of the Ge film is not well defined for this film thickness [3].

Figure 2 shows a vertical cut of reciprocal space for the Ge(33-1) Bragg condition roughly along the [11-2] direction Again the Ge (33-1) spot is strongly broadened laterally and vertically. The vertical peak width is determined by the finite film thickness of 10 nm. Thickness oscillations are also vsible above and below the Bragg spot. On the left and right side of the Ge spot two additional spots show up. Those are the satellites arising from the dislocation array at the interface. The absence of finite thickness oscillations is a direct hint for the localization of the strain fields at the interface. From the vertical width of the satellite spots we conclude a decay length of the dislocations in the order of the film thickness.

References

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