Diffraction and Reflectivity from Ge Quantum Dots embeddded into CaF$_2$ Films on Si(111)

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Semiconductor quantum dots received increasing attention during the last time since their electronic structure can be tailored if their size is small. Often quantum dots are fabricated using different semiconductors. This combination of materials, however, leads to small band offset. Therefore, combining semiconductors with an insulating matrix seem to be very advantageous.

Here, we report on Ge quantum dots embedded in CaF$_2$ films. Combining Si, Ge and CaF$_2$ we used lattice matched materials with very different properties. The band gap of Si and Ge is 0.67eV and 1.10eV, respectively, while the band gap of CaF$_2$ is 12.1eV. The lattice mismatch of CaF$_2$ and Si is 0.58% while the lattice mismatch between Ge and CaF$_2$ is 3.58%, respectively.

Here, we present $\Theta - 2\Theta$ x-ray diffraction and reflectivity studies on CaF$_2$/Ge/CaF$_2$/Si(111) performed at beamline W1 at HASYLAB (DESY) on the six-circle diffractometer. Datas were recorded using TASCOM.

Fig. 1 shows the reciprocal space mapping of Ge quantum dots deposited on 5TL CaF$_2$/Si(111) and covered by 10TL CaF$_2$. Here TL denotes a triple layer of CaF$_2$ which is a Ca layer embedded into two F layers. The Crystal Truncation Rod running from left to right is clearly seen. Strong diffraction intensities are also observed close to the Bragg condition ($l = 1$). However, a splitting of the Ge Bragg peak from the Si Bragg peak cannot clearly be observed.

Therefore, we recorded the CTR, too, which is presented in Fig.2(a). There are some oscillations of the intensity. These oscillations, however, have to be attributed to the well ordered CaF$_2$ films. A clear Ge peak at $l \approx 0.96$, however, cannot be observed. Probably the distribution of the Ge quantum dots is too broad. The reflectivity, we measured too, does not show a clear signal of the Ge quantum dots as well (cf. Fig.2). Therefore further studies have to be performed to obtain deeper insight into the structure and morphology embedded Ge quantum dots.

![Figure 1: Reciprocal space map close of Ge quantum dots embedded into CaF$_2$ film. The Crystal Truncation Rod (CTR) runs from left to right (vertical scattering vector $l = 0.8 - 1.10$). The range of the lateral scattering vector is $\pm 0.0095 \text{Å}^{-1}$.](image-url)
Figure 2: (a) Crystal Truncation Rods (CTR, $\Theta - 2\Theta$ scan) and (b) reflectivity of the CaF$_2$/Ge/CaF$_2$/Si(111)

References

