Characterization and comparison of InAs quantum dashes uncapped and capped by InGaAsP layer

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In current research the material system InGaAsP is one of the most promising systems for optical applications in the telecommunication sector. Optical fibers exhibit a low damping and dispersion at light wavelength of 1.3 μm and 1.55 μm. On InP substrates, InGaAsP can be grown without lattice mismatch, the band gap adapted to these required wavelengths at the same time.

In this study, we characterize InAs quantum dashes embedded in InGaAsP by means of TEM. Quantum dashes are quantum dots strongly elongated in one direction while in the short direction providing widths about 20-30nm. The InAs dashes under investigation were grown on [001]-InGaAsP by means of MOVPE with the long axis in [$\underline{1}$10]-direction. Uncapped InAs quantum dashes are compared with dashes capped by another InGaAsP layer. Various methods have been applied to investigate the strain in the dashes itself as well as the strain induced by the dashes into the nearby layers: By employing single reflection analysis (Geometric Phase Analysis), the displacement field can be obtained from high resolution micrographs [1]. This allows measuring the strain in the dashes and their close vicinity. The strain in larger regions of the sample can also be observed qualitatively by means of dark field imaging.

The samples in figure 1 and 2 were prepared by conventional cross section preparation, which includes dimpling on both sides (<20 μm) and Argon ion milling. To minimize preparation artifacts, the milling was done with LN_2 cooling and with milling voltage below 2.5 kV.

Figure 1 shows a dark field image using the (002)-reflection (growth direction) of an uncapped sample. This sample is viewed along the long direction of the dashes. In the center of the image, crescent-shaped contrasts can be observed. These contrasts range into the InGaAsP layer below the dashes while reaching the surface in the area between them. We attribute these contrasts to strain induced by quantum dashes.

In Figure 2 (a), a HRTEM image of a capped InAs quantum dash elongated in the direction perpendicular to the electron beam is shown. Figure 2 (b) indicates the displacement in growth direction, i.e. [001], with respect to the InGaAsP lattice in the lower right area of the image. The displacement field is estimated from geometric phases of the {111}-reflections. The observable slope in the area of the quantum dash results from the larger lattice constant of the InAs as well as strain in the dash. In Figure 2 (c), the resulting lattice mismatch of InAs quantum dash is shown, where a_S is the lattice constant of the InGaAsP and the dashed line displays the smoothed displacement which was used for determination of the mismatch. A lattice mismatch of about 4.1% with respect to the reference area is observed. When tetragonal distortion is considered, a lattice mismatch of 4.9% for a thin

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sample in [110] beam direction is expected, which lies within the error of the accomplished measurement [2].

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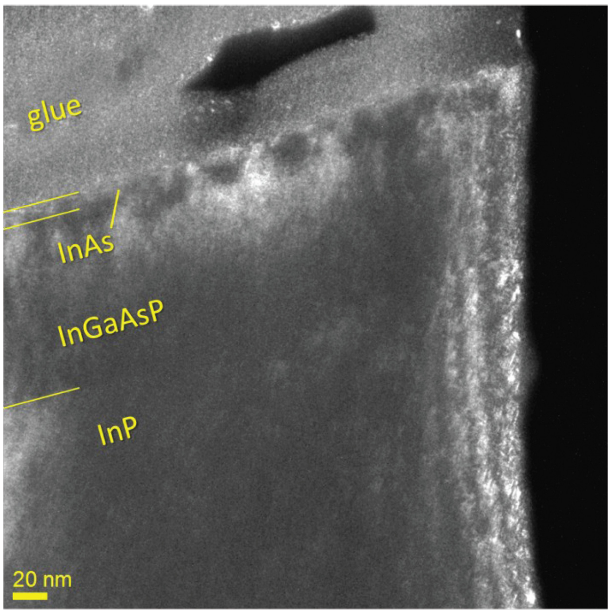

Figure 1. TEM dark field image of (002)-reflection of uncapped InAs quantum dashes

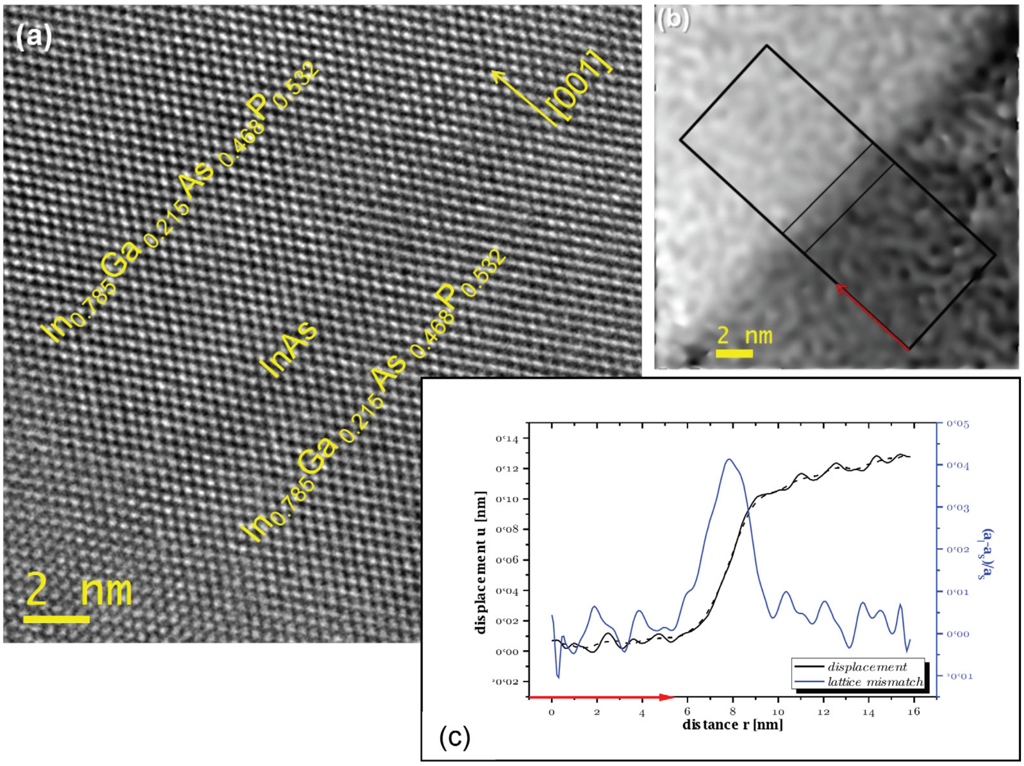

Figure 2. (a) HRTEM image, (b) displacement field of the same region in [001]-direction, (c) the resulting lattice mismatch of InAs quantum dash capped by InGaAsP-layer

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