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Strain Relaxation in InAs Quantum Dots and its Suppression by Indium Flushing

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InAs quantum dot (QD) system has been explored for intermediate band solar cells (IBSCs) to overcome the Shockley-Queisser limit of one-bandgap solar cells. The intermediate bandgaps introduced by the QDs provide additional transition paths for light absorption which ideally increases the current in IBSCs while preserving the output voltage [1]. AlGaAs is used as matrices to approach the optimum bandgaps for high photovoltaic efficiency [2]. Lattice mismatch, which is necessary for QDs formation by Stranski-Krastanov growth mode [3], can result in plastic relaxation and degrade the photocurrent by the presence of dislocations. The plastic relaxation can be prevented by increasing the temperature for a brief period after the InAs QDs are partly covered by a capping layer. The effect of this so called *indium flushing* [4] technique on removal of plastic strain relaxation is studied here.

The InAs/AlGaAs QD structures were grown by metalorganic chemical vapor deposition (MOCVD). InAs dots formed as a result of Stranski-Krastanov growth. We capped the QDs by a 10 nm GaAs capping layer in sample *A* and a 5 nm GaAs capping layer in sample *B*. The temperature was raised after deposition of the capping layer. The structure consisted of ten layers of InAs dots separated by 70-nm-thick $Al_{0.3}Ga_{0.7}As$ barriers. Two-beam diffraction contrast images and high resolution transmission electron microscopy (HRTEM) images of the QDs in each sample were recorded in a Philips CM200-FEG electron microscope. The morphology of the InAs dots was studied from high-angle annular dark field (HAADF) images which were taken in a JEOL 2010 F electron microscope.

Two-beam diffraction contrast images of sample *A* and sample *B* under $\boldsymbol{g}$ = 220 are shown in Figure 1a and 1b. Moiré fringes in the QDs of sample *A* (Fig. 1a) show that the lattice parameters of the dots and the matrix are different suggesting strain relaxation. In sample *B* (Fig. 1b), bend-contour contrast is observed suggesting the dot is strained. HREM of a QD in sample *A* (Fig. 1c) shows a 60 degree dislocation (left) and a Lomer dislocation (right) at the hetero-interface confirming strain relaxation in sample *A*. The HAADF images (Fig. 2) show that the QDs in sample *A* can be as thick as the 10 nm GaAs capping layer while the QDs in sample *B* are limited to 5 nm in height. The critical height of QDs to form dislocation loops is calculated based on the balance of the lattice misfit force and the dislocation line tension. Strain relaxation is suppressed by limiting the height of QDs below the critical height using thin capping layers in indium flushing [5].

References:
[1] A. Luque and A. Martí, Phys. Rev. Lett. **78** (1997) p. 5014.
[2] R. Jakomin *et al*, J. Appl. Phys. **116** (2014) p. 093511.
[3] D. Leonard *et al*, Phys. Rev. B **50** (1994) p. 11687.
[4] Z. Wasilewski *et al*, Cryst. Growth **202** (1999) p. 1131.

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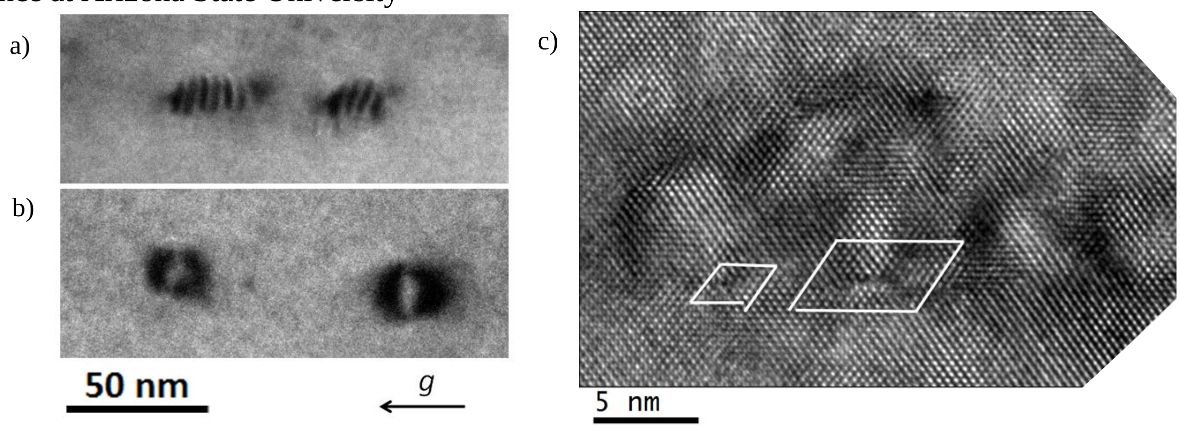

Figure 1. Two-beam diffraction contrast images of QDs in sample *A* (a) and sample *B* (b) and HREM images of a QD in sample *A* (c).

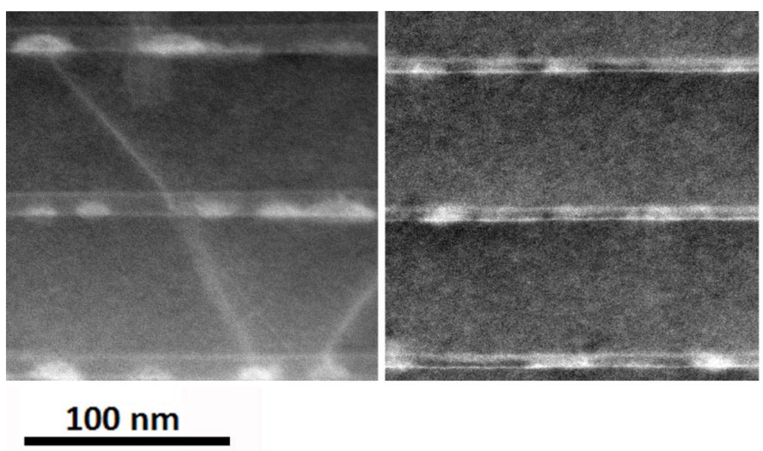

Figure 2. HAADF images of QDs in sample *A* (left) and sample B (right).

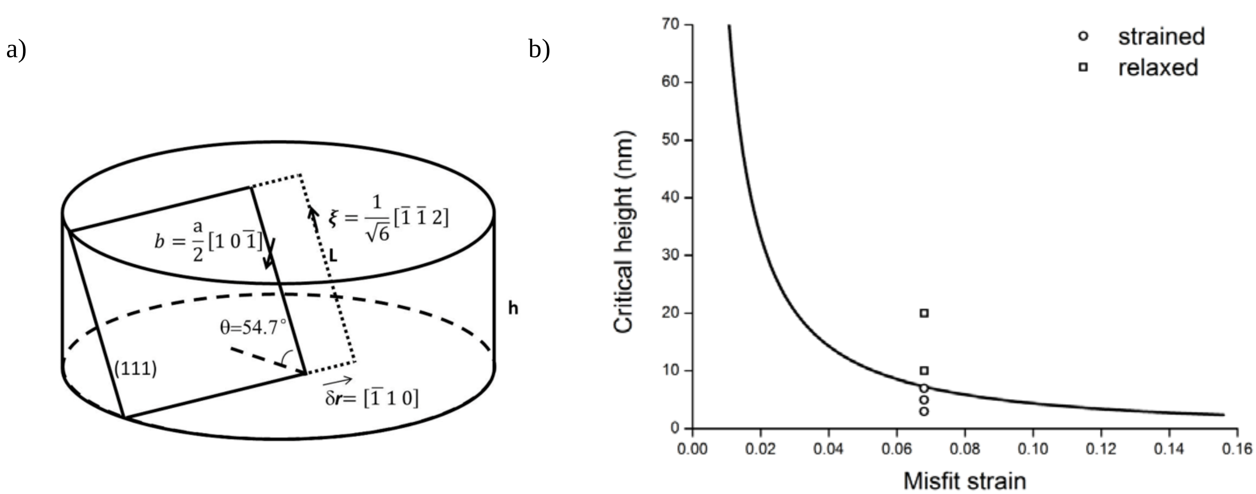

Figure 3. (a) The simplified model of a QDs with a dislocation loop expending across the QD. (b) The critical height of QDs to form dislocation loops vs the misfit strain between dots and matrices. Experimental data are also shown in the graph.

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