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TEM Characterization of InAs Quantum Dots with GaAsSb Spacer Layers

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Intermediate band solar cells (IBSCs) are expected to increase photocurrent by absorbing sub-bandgap photons, while maintaining voltage that would otherwise be decreased if the longer-wavelength photons were captured in multijunction cells [1]. Using a detailed balance calculation, the maximum theoretical efficiency of IBSCs has been reported as 63% under full concentration [2], compared to the famous 30% of Schockley and Queisser for a silicon *pn*-junction [3], and greater even than the efficiencies of tandem cells [2]. The intermediate band is grown between the materials forming the traditional *pn*-junction [1], and is usually formed by growing arrays of self-assembled quantum dots [4]. Incorporating Sb into the spacer layers between InAs quantum dots offers several advantages over traditional GaAs layers, including increased carrier lifetime, increased areal density of quantum dots, and decreased lattice mismatch [5]. In the current work, ten stacks of InAs quantum dots were grown embedded in $GaAs_{0.83}Sb_{0.17}$ spacer layers of thicknesses 2, 5, 10, and 15nm, on *n*-type GaAs (001) substrates with 400-nm-thick GaAs buffer layers and capped with 50-nm-thick GaAs. Samples were prepared using polishing, dimpling, and argon-ion-milling at liquid-nitrogen temperatures. Images were recorded using an FEI-Phillips CM200 FEG operated at 200kV and a JEOL JEM-4000EX operated at 400kV.

Plan-view and cross-sectional TEM images were compared to x-ray diffraction (XRD) triple-crystal (TC) ω rocking curves (RCs) taken around the (004) symmetrical reflections of the GaAs capping layers and the GaAsSb layers, as shown in Figs. 1, 2, and 3 [5]. The crystal quality of the capping layer, as implied by the narrow full-width-at-half-maximum (FWHM) of the rocking curves in Fig. 1a, is greatest for the thinnest spacer layer (2nm) and decreases dramatically for thicknesses going from 10nm to 15nm. This observation is verified by plan-view TEM images, as shown in Fig. 2, where individual threading dislocations terminated at the surface can be seen in the sample with 2nm spacer layers, whereas a cross-hatched pattern corresponding to an array of in-plane misfit dislocations oriented along orthogonal <110> directions, is observed for the 15nm spacers. For the spacer layers themselves, however, the 10nm layer produces the narrowest FWHM of the rocking curves in Fig. 1b. In the corresponding XTEM images, as shown in Fig. 3, the 10nm layers are seen to grow with less undulation, due to the optimal strain balance condition, whereas the QD layers are poorly defined for the samples with 2-nm and 5-nm GaAsSb layers.

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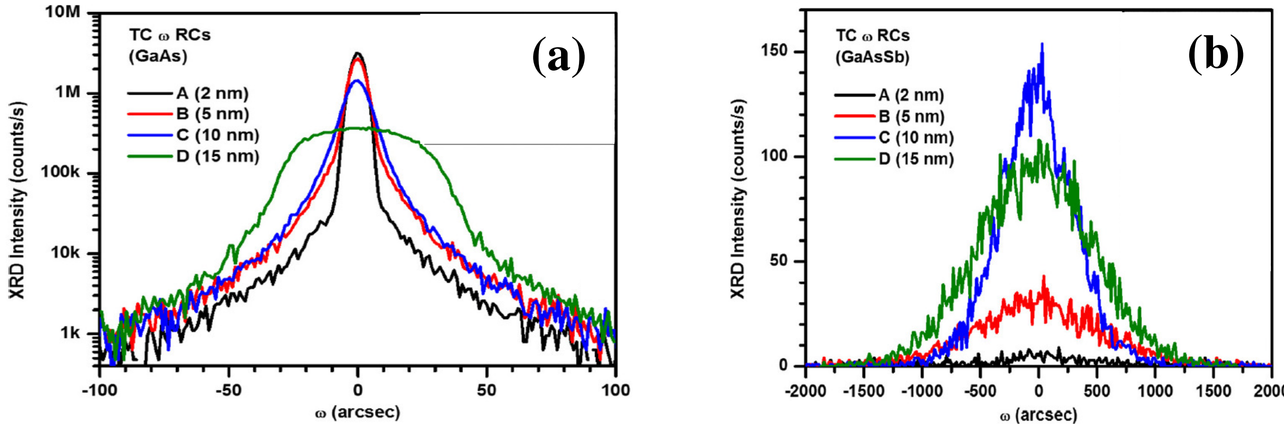

Figure 1. XRD TC ω RCs for: (a) GaAs; and (b) GaAsSb layers [5].

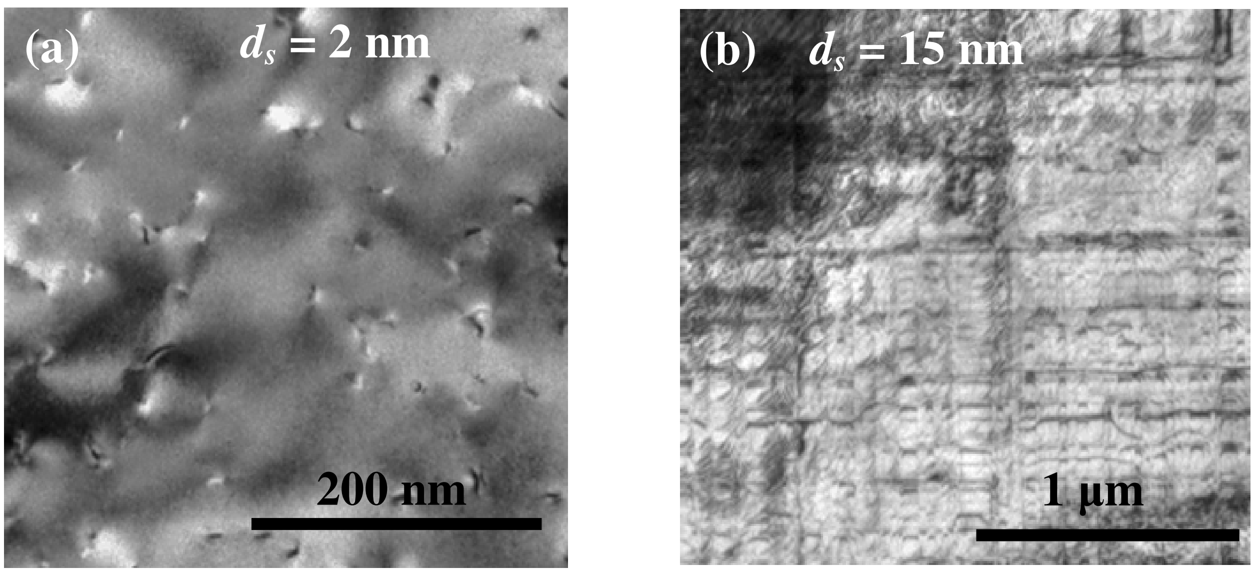

Figure 2. Plan-view TEM images for spacer layer thicknesses d_s= 2nm (a), 15nm (b) [5].

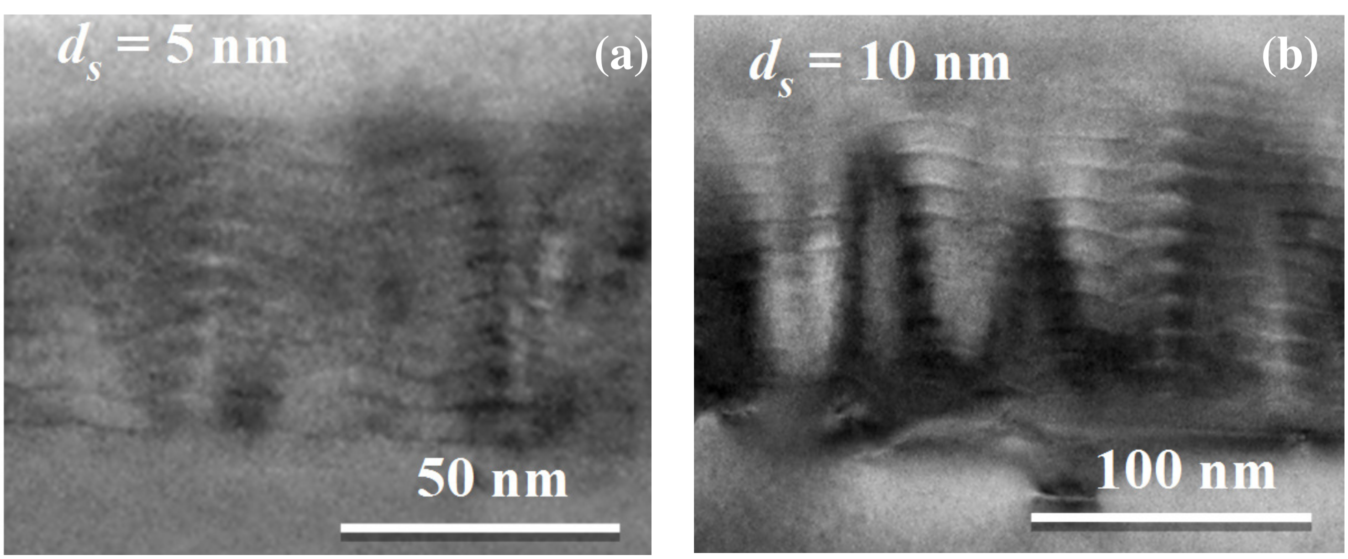

Figure 3. XTEM images for spacer layer thicknesses d_s= 5nm (a), 10nm (b) [5].

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