DIGITAL STRESS COMPENSATION FOR STACKED INAS/GAAS QUANTUM DOTS SOLAR CELLS

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III-V semiconductor quantum dots (QD) receive great interest at present due to their advantages and unique properties as zero dimensional systems. Most of their applications require stacking multiple QDs layers to increase the gain of the devices. However, this strategy also increases the accumulated stress in the material during growth generating dislocations and nonradiative recombination centers [1]. The introduction of stress compensation (SC) layers to reduce the accumulated stress is a promising way to improve material quality and efficiency of devices based on QDs.

In this work we report the stacking of 50 InAs QDs layers using 2 GaP monolayers (ML) for SC and a stack period of only 18 nm on GaAs (001) substrates. We chose a “digital” stress compensation method by the introduction of single monolayers of GaP instead of a GaAsP alloy due to the difficulty to control the phosphorus to arsenic incorporation ratio during MBE growth of the stacked QDs structure.

The stacking of this large number of QDs layers have already been achieved in other systems with limited lattice mismatch, with and without SC. However, the lattice mismatch between the QDs and the substrate is 6.7 % for the InAs/GaAs QDs system. Since the accumulated strain energy density depends on the square of this mismatch, the stacking of closely spaced InAs/GaAs QDs layers with good crystalline and optical quality becomes a very challenging task.

We fabricated a GaAs based solar cell with fifty such QDs layers in its active region using the described scheme. The goal of this study is to demonstrate the quantum dot intermediate band solar cell (IBSC) principles as proposed by Marti et al [2]. The structure of the sample can be seen in figure 1 and includes an AlGaAs top layer and a back surface field layer to prevent minority carrier recombination in the top and bottom interfaces respectively. A field damping layer has been inserted between the emitter and the intrinsic region, which contains the dots, to screen the electric field generated by the former and to keep all the QDs layers partly filled with electrons.

The structural quality of the sample has been tested by means of cross-section transmission electron microscopy (XTEM) (figure 2). As it can be seen, the structure is almost defect-free with only some planar defects in the very last few layers. These defects seem to be produced by the interaction of very close or especially large QDs. The image also reveals columnar growth of the QDs along the structure. The direction of the column is not vertical, but forms an angle of 7° with the growth direction. The stacking behavior suggests the existence of residual stress around the nanostructures that propagates to the following layer creating sites of preferential nucleation. This behavior has already been observed and predicted by *ad-hoc* simulations in other nanostructures [3,4]

In conclusion, we have studied the effect of "digital" stress compensation with GaP monolayers of stacked InAs/GaAs layers. Very good structural quality has been found by XRD and AFM, and PL measurements have shown thermal activation energy of 431 meV. A solar cell including 50 QDs layers with SC has been fabricated with exceptional structural quality, as revealed by the TEM images. The nanostructures have extended the absorption range of the sample up to 1.2 μm although an excessive trapping in the QD region has also being found, to the detriment of the short wavelength response of the device

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Figures:

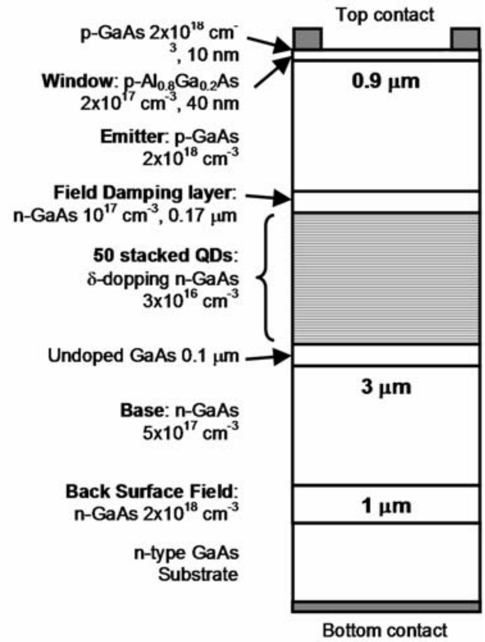

Figure 1: Scheme of the MBE fabricated QDs solar cell

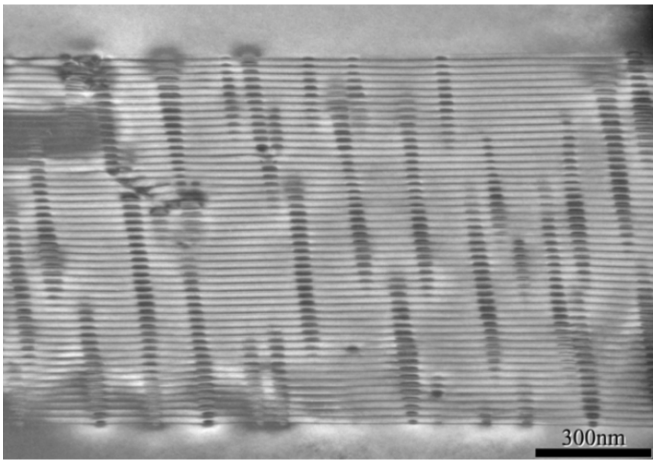

Figure 2: Cross-section TEM image of the stress compensated 50 stacked QDs.