Enhancing intermediate band solar cells performances through quantum engineering of dot states by Droplet Epitaxy

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We investigate the effect of the quantum dot aspect ratio on the sub-gap absorption properties of GaAs/AlGaAs quantum dot intermediate band solar cells. We have grown by MBE PIN AlGaAs solar cells containing GaAs quantum dots made by droplet epitaxy. This technique allows the realization of strain-free nanostructures with lattice matched materials without the presence of a wetting layer, enabling the possibility to tune the size, shape, and aspect ratio of the QDs to engineer the optical and electrical properties of devices [1]. The intermediate band solar cells have been grown with different dot aspect ratio, thus tuning the energy levels of the intermediate band. Numerical simulations using envelope function with an eight-bands k.p approach were performed to correlate the confined energies of the QDs with their measured shape [2]. Photoluminescence measurements were performed to validate the theoretical results. The characterization of the solar cell was obtained by measuring EQE and two-photon photocurrent. A clear increase in sub-gap absorption was observed compared to the reference solar cell without QDs. We show that it is possible to tune the sub-gap absorption spectrum and the extraction of charge carriers from the intermediate band states by simply changing the aspect ratio of the dots. The tradeoff between thermal and optical extraction is in fact fundamental for the correct functioning of the intermediate band solar cells. By tuning the aspect ratio of the QDs, we were able to obtain a large energy separation between the ground and first excited state of ≈50 meV that allows for a detuning from LO phonons. The combination of the two effects makes the photonic extraction mechanism from the quantum dots increasingly dominant at room temperature, resulting in a reduction of the open circuit voltage of only 14 mV compared to the reference cell without the QDs.

References

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