Phonon Bottleneck Effect and Photon Absorption in Self-ordered Quantum Dot Intermediate Band Solar Cells

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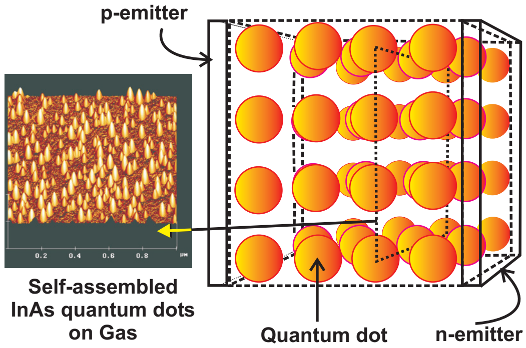
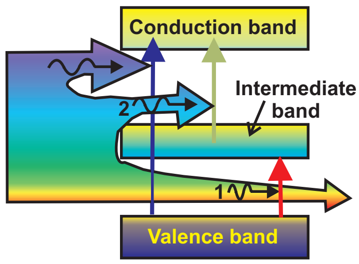
Purpose

A feasible implementation for the intermediate band solar cell (IBC) consists of using self-assembled and self-ordered quantum dots (QDs). Since a QD is able to create an electron level within the host semiconductor, a QD superlattice is expected to produce an intermediate band (IB).

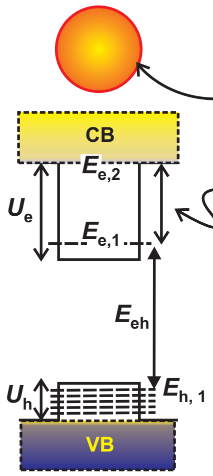


An intermediate band solar cell aims to exploit the two-step absorption of sub-bandgap photons via a half filled IB located within the semiconductor gap: The absorption of sub-bandgap photon "1" excites an electron from the valence band (VB) to the IB, while the absorption of sub-bandgap photon "2" pumps an electron from the IB to the conduction band (CB). The concept behind this operation is that there must be three quasi-Fermi levels for describing the electron concentration in the three bands involved. The recombination between these bands must be predominately of radiative nature.

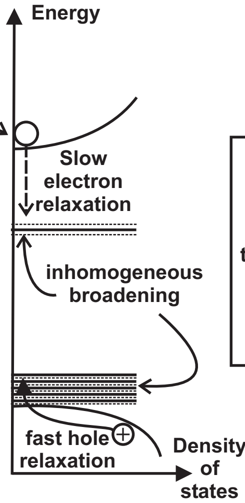


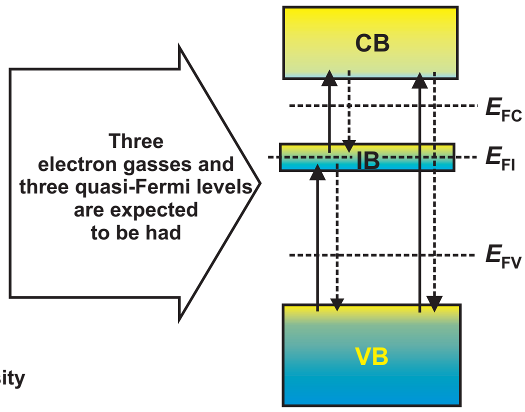
The purpose of this work is to explore the phonon bottleneck effect and the photon absorption in the quantum dot intermediate band solar cell.

Approach and results

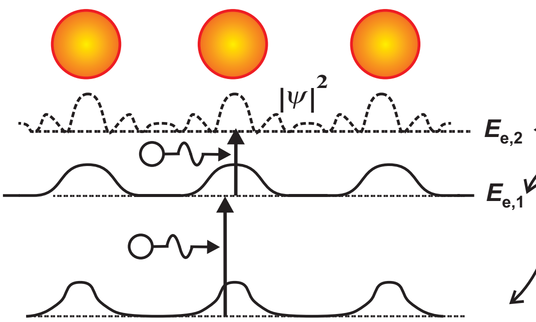


In a quantum dot, the electron inter-sub-level separation may not match the phonon spectrum. This could reduce severely (or even suppress) the electron relaxation via the emission of phonon(s) from the CB to the IB. This is the "phonon bottleneck" effect. It could keep the electron gasses in the conduction and intermediate bands well separated.

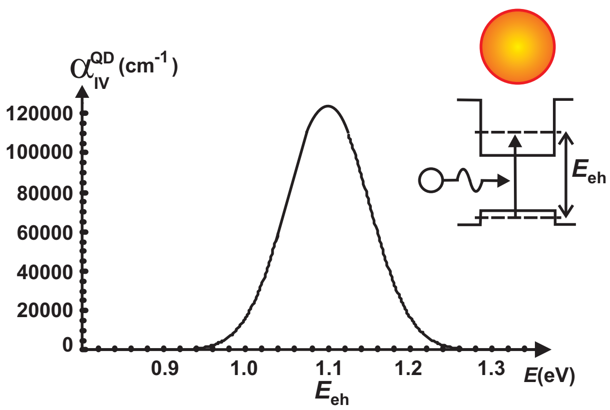




The radiative recombination has therefore the chance to exceed the non-radiative one.



Since the wave functions in these states have great overlap integrals, sub-bandgap photons can be absorbed (once selection rules allow it). The figure on the right illustrates this for electrons and holes in the ground states.



Conclusions

The phonon bottleneck effect could reduce the electron relaxation and keep the electron gasses in the conduction and intermediate bands well separated. Hence, three quasi-Fermi levels are expected to be had.

The phonon bottleneck effect makes also the radiative recombination between the conduction and the intermediate these bands become potentially dominant. The recombination between electrons and holes confined within the dots is predominantly radiative because of their high wave function overlap integrals. In the same way, photon absorption is also strong because of the great value of the overlap integrals involved.

Acknowledgements

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