Application of MEG in Increasing External Quantum Efficiency Over 100%

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Abstract

This review paper focuses on increasing the efficiency of Solar cell using Quantum Dot. The principle idea is using MEG (Multiple exciton Generation). MEG is more efficient in quantum confined nanostructures than in bulk semiconductors because the momentum preservation prerequisite is relaxed. Even the carrier-carrier interactions are huge due to strong confinement. The carrier multiplication decoupling from the effective band gap allows amplified photo-voltage for corresponding carrier multiplication. Along with this, it was also found that external quantum efficiency (EQE) would reach almost 100%, sometimes even exceeding it, for energy which is greater than twice the band gap energy. This is due to the fact that high energy photons have the ability to produce more than one photo carrier pair. MEG is definitely a promising route to increasing solar cell efficiency. If a threshold of twice the band gap energy could be realized for impact ionization in a colloid Quantum Dot cell, the theoretical maximum possible conversion efficiency would shift to above 60%. The goal is to capture maximum energy incident on a given plane and targeting high-yield transportation of the resultant photo generated charge.

1. Introduction

Quantum dots are nanostructures comprised of semiconductors that limit the motion of conduction band electrons, excitons or valence band holes in all three spatial directions. The captivity can be due to electrostatic potentials (generated by external electrodes, doping, strain, impurities), the presence of an interface between different semiconductor materials, the presence of the semiconductor surface, or a combination of these. A quantum dot has a distinct quantized energy spectrum. The consistent wave functions are spatially contained within the quantum dot, but extend over many periods of the crystal lattice. A quantum dot contains a minor finite number (of the order of 1-100) of conduction band electrons, valence band holes, or excitons, i.e., a finite number of elementary electric charges. Small quantum dots, such as colloidal semiconductor nanocrystals, are almost as small as 2 to 10 nanometers. Self-assembled quantum dots are usually between 10 and 50 nm in size. A quantum dot solar cell (QDSC) is a type of solar cell that uses quantum dots as the absorbing photovoltaic material. It tries to replace bulk materials such as silicon, copper indium gallium selenide (CIGS) or cadmium telluride (CdTe). Quantum dots have bandgaps that are tunable across a wide range of energy levels by changing their size. In bulk materials, the bandgap is secured by the choice of material(s). This property makes quantum dots attractive for multi-junction solar cells, where a variety of materials are used to improve

efficiency by harvesting multiple portions of the solar spectrum. Quantum dots defined by lithographically patterned gate electrodes. Engraving on two-dimensional electron gases in semiconductor heterostructures can have lateral dimensions exceeding 100 nm also defines quantum dots. At 10 nm in diameter, nearly 3 million quantum dots could be put end to end.

2. Application of MEG

In solar cells, when a material absorbs photons containing energies greater than its bandgap, heat is produced. Hence, photogenerated charge carriers should be collected via special contacts which are designed to be energy selective. Carriers with greater kinetic energies are called 'hot carriers' and they reach these special contacts before energy is lost in the form of heat. Thus, minimizing hot carrier loss can make a system up to 85% efficient [1]. In colloidal quantum dots, the relative insufficiency of available states has the capability to slow down the course.[2] This might provide a new way to capture the energy in excess of the excitonic transition. This excess energy could theoretically be harvested using multiple-exciton generation.[6] In an ideal MEG solar cell, external quantum energy would exceed 100% for energies greater than twice the band gap energy. If a threshold of twice the band gap energy could be realized for impact ionization in a colloidal quantum dots solar cell, the theoretical maximum power conversion efficiency would shift to above 60%.[7]

MEG is expected to be more efficient in quantum-confined nanostructures compared to bulk semiconductors because the momentum conservation requirement is relaxed and carrier− carrier interactions are larger due to strong confinement in the nanostructure.[6] Another potential effect in quantum-confined materials is the decoupling of the carrier multiplication profile from the effective band gap, allowing increased photo voltages for equivalent carrier multiplication yields in monocrystalline compared to bulk materials.[8] In lead selenide nanorod solar cells, MEG has been shown to occur with almost 100% efficiency, in some cases even exceeding that limit. Practically, tests have shown quantum dots to reach a maximum value of 114% at 380 nm. On examining the PbSe QD layer, it was shown to produce as many as 1.3 electrons per photon in that spectral region.

3. Conclusion

In this review, particular aspects of the structure, properties, application and performance of Quantum dots have been discussed. These zero-dimension nanostructures have been the pioneers for numerous advances in fundamental and applied sciences. This is mainly because the Quantum dot exhibit significantly different optical, electronic and physical properties as compared to bulk materials. With respect to synthesis of Quantum dots, significant progress has been made in studies of the growth kinetics through both theoretical models and experimental data. Procedures ranging from simple wet chemical methods to very sophisticated and equipment- intensive atomic layer deposition techniques are being used to synthesize Quantum dots. Despite the large amount of research, there is still a lot to understand about the use of Quantum dots in large scale biological and solid-state optical applications, as we discussed throughout the article. Better device fabrication will extend the emission into the near IR region.

The concept of QD solar cell has been described. It has been observed from the computed data that the conversion efficiency of p–i–n structure can be significantly increased by inserting self-organized QD multilayers into the intrinsic section. Thus, solar cells using Quantum Dots have a huge array of possible applications in the upcoming future, from extracting maximum energy from renewable sources to usage

in organic dyes, nanoscopic light bulbs and biochemical sensors. Quantum dots are undoubtedly the front-line technology currently and will remain so for decades to come.

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