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ENHANCEMENT OF POWER CONVERSION EFFICIENCY IN SPHERICAL CENTERED DEFECT QUANTUM DOT (SCDQD) SOLAR-CELLS

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ABSTRACT
In this paper a $n^+ - i - p^+$ solar cell with enhanced power conversion efficiency based on Spherical Centered Defect Quantum Dot (SCDQD) is proposed. The proposed idea contains a quantum dot with a spherical defect inside it. Complete analysis of the proposed QD based on the effective mass equation is done. Optical interband absorption of the introduced SCDQD and maximum power conversion efficiency of the proposed SCDQD-solar-cell are also investigated. The effects of defect and dot sizes on interband absorption and maximum power conversion efficiency of the proposed solar cell are examined. We report that inserting the defect inside the QD strengthens carrier confinement and so increases the absorption coefficient ($4.6\times10^5\ \mathrm{cm}^{-1} \sim 6.41\times10^5\ \mathrm{cm}^{-1}$). Also a blue-shift in absorption peak is observed. Considering the operation wavelength of the GaAs-QD ($0.81\mu\mathrm{m}$) and the sun radiation spectra, it will be shown that the defect-induced blue-shift in absorption peak (~30 nm) pushes the absorption spectra to higher intensity region of sun radiation spectra. This fact and either the increase of absorption coefficient enhances the solar cell maximum power conversion ($\sim 8.5\%$).

KEY WORDS
Quantum Dot, Spherical Defect, Interband absorption, Solar cell, Maximum power conversion efficiency.

1. Introduction

Solar cell element in electronic domain was introduced to convert solar energy to clean electrical energy which is interesting between energy resources. For this purpose, in this paper a novel idea for realization of high-efficiency solar cell based on a new quantum dot structure (which was introduced by the authors in previous works [1-4]) is proposed.

There are some interesting published papers that discussed this subject from different points of view. We review some of them for illustration of the theoretical and experimental background of subject.

Since, the solar radiation is a plentiful and clean source of power, providing carbon-free, reliable and affordable solar electricity is the main goal in the technology development of solar cells. Recent studies indicate that from 10 to 30 TW-Year of annual carbon-free energy ($1\,TW = 10^{12}W$; $1\,TW - yr = 31.5\times10^{18}\ jouls = 31.5EJ$) will be required globally by the year 2050 to accommodate the world expected population of 10-11 billion people, combined with modest annual global economic growth rate of 2%. If CO_2 is to be stabilized at 400ppm in the atmosphere then about 30TW-Year of annual carbon free energy will be required by 2050 [5]. The total amount of energy incident upon the earth's surface is enough to provide the annual global energy consumption over 10,000 times. However, due to high cost of electrical conversion on per watt basis, conventional solar cells have not been exploited to their full potential. The cost per watt can be reduced by increasing the conversion efficiency in solar cells. Semiconductor nanocrystals are potentially ideal for greatly increasing efficiency of solar cells. Single junction semiconductor solar cells only convert effectively photons with energy close to the semiconductor band gap E_g as a result of mismatch between the incident solar spectrum and spectral absorption properties of the material [6]. The maximum thermodynamic for the conversion of unconcentrated solar irradiance into electrical free energy is the radiative limit assuming detailed balance and a single threshold absorber was calculated by Shockley and Queissar in 1961 [7] to be about 31%. Recently several design schemes have been proposed to increase Shockley-Queissar (S-Q) limit. By using two or more p-n solar cell junctions, tandem cells made of different semiconductors, a multi-heterojunction design yields a better match to the solar spectrum than a single junction cell can be provided. Also hot carrier solar cells [8-10], producing multiple electron-hole pairs per photon through impact ionization [11, 12], multiband and impurity band solar cells [13, 14], and thermo photovoltaic/thermo photonic cells [13] can be used for exceeding efficiency. Here, we will only discuss quantum dot (QD) solar cells for enhancing the conversion efficiency. Due to the strong dependence of energy levels on the geometry and size, the QDs are