Spatial Architecture Impact in Mediation Open Circuit Voltage Control of Quantum Solar Cell Recovery Systems

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***Abstract*—**These photocurrent generations are influencing ultra-high efficiency solar cells based on self-assembled quantum dot (QD) nanostructures. Nanocrystal quantum dots (QD) provide a great enhancement toward solar cell efficiencies through the use of quantum confinement to tune absorbance across the solar spectrum enabled multi-exciton generation. Based on theoretical predictions, QD solar cells have potential for efficiencies greater than 50%. In solar cell devices, an intermediate band formed by the electron levels in quantum dot systems. Spatial architecture is exploring how can solar cell integrate to produce not only high open circuit voltages (> 1.7 eV) but also large short-circuit currents due to the efficient absorption of sub band gap photons. In the proposed QD system, the structure allows barrier material to absorb wavelengths below 700 nm while multi-photon processes in the used quantum dots to absorb wavelengths up to 2 µm. The structure and material compositions are flexible to tune the energy bandgap of the barrier material and quantum dot to their respective optimum values. This structure is expected to outperform single or multi-junction solar cells in terms of energy virtual conversion efficiency and cost. A key milestone towards achieving the claimed high-efficiency solar cell device is flexibly tuning the energy bandgap between the barrier material and QD according to the designed limits. Despite this remarkable potential for high photocurrent generation, the achievable open-circuit voltage (V_{oc}) is fundamentally limited due to non-radiative recombination processes in QD solar cells. Comparing experimental V_{oc} variation with the theoretical upper-limit obtained from one diode modeling of the cells with different bandgap (Eg), the proposed architecture is clearly demonstrated that there is a tremendous opportunity for improvement of V_{oc} to values greater than 1 V by using smaller QDs through QD solar cells confined states with other nano operation systems. .

***Keywords*—**Nanotechnology, Photovoltaic Solar Cell, Quantum Systems, Renewable Energy, Environmental Modeling,

I. Introduction

SIGNIFICANT documents are focus on diagnoses function of nanocrystal quantum Systems. Quantum Systems are a complete class of semiconductors quantum dots, which are nanocrystals, composed of periodic groups of II-VI, III-V, or IV-VI of the periodic table, such as CdS, CdSe, CdTe, CdS@ZnS, CdSe@ZnS, CdSeTe@ZnS. These QDs provide excellent fluorescence properties that have been applied in biosensing and intracellular or in vivo imaging materials and can confine electrons (quantum confinement) in quantum solar cell systems [1]. When the size of a QD approaches the size of the material's exciton Bohr radius, quantum confinements, the effect becomes prominent and electron energy levels can no longer be treated as continuous band, they must be treated as discrete energy levels [2]. Hence, QD can be considered as an artificial molecule with energy gap and energy levels spacing dependent on its size (radius). The energy band gap increases with a decrease in size of the quantum dot. As the size of a QD increases its absorption peak is red shifted due to shrinkage of its band gap of QDs [3]. The adjustable band gaps of quantum dots allow the construction of nanostructured solar cell that is able to harvest more of the solar spectrum [4]. QDs have large intrinsic dipole moments, which may lead to rapid charge separation. Quantum dots have been found to emit up to three electrons per photon due to multiple exciton generation (MEG), as opposed to only one for standard crystalline silicon solar cell. Theoretically, this could boost solar power efficiency from 20 % to as high as 65 % [5].

Initially, there are main important parameters can be characterized to quantify the performance of a photovoltaic cell. These are the open-circuit voltage (V_{oc}), the short circuit current (I_{sc}), and the fill factor (F F). However, the fill factor is also a function of V_{oc} and I_{sc}. Therefore, these focus on two parameters that are the key factors for determining the cell's power conversion efficiency. In the regular conditions, each photon incident on the cell with energy greater than the band gap will provide energy to produce an electron flowing in the external intermediate circuit. The false or fill factor is determined from the maximum area of the I-V characteristics under illumination voltage meter with other preliminary circuit current and open circuit voltage, or comply with fundamental given equation to[6]:

$$FF = \frac{V_{mp} \times I_{mp}}{V_{oc} \times I_{Sc}} \quad (1)$$

where, V_{mp} and I_{mp} are the majority operating point that will collect and charge the power output. While, the initial energy conversion efficiency is given by [7]:

$$\eta = \frac{V_{oc} \times I_{sc} \times FF}{P_{in}} \quad (2)$$

where P_{in} *is the input power*.

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The main objective is to give an introductory coverage of a sophisticated quantum system. Construction model depends on the physics, designs, structures, and some growth/synthesis techniques of quantum solar cell systems. The comprehensive description of spatial architectures of QD solar cells systems (e.g., Schottky cell, layer of p-i-n configuration, depleted heterojunction, and quantum dots sensitized solar cell) provide an innovation nanotechnology to sustainable production of clean energy and reduce greenhouse gases (GHG) [8], [9].

II. Quantum Solar Cell Systems

Current solar cells systems cannot convert all the incoming light into usable energy because of the light back out escape of the cell into the air reflection. Additionally, sunlight has spectrum within a variety of colors and the cell might be more efficient at converting bluish light while being less efficient at converting reddish light. While the light lower energy passes through the cell unused, a higher energy light does excite electrons to the conduction band, and a partial of energy beyond the band gap energy is converted as heat. The solar cell systems are organized to capture these excited electrons aren't captured and redirected its charge to the electrode, they will spontaneously recombine to create differential voltage current that produce energy from heat or light [10].

Solar cell is also known as the photovoltaic cell which converts the solar energy from the sun into electrical energy based on the principle of photovoltaic effect. Solar cell is the building blocks of photovoltaic effect. The operation of photovoltaic cell requires two functions-one is photo generation of charge carrier in a light absorbing material and the second is the separation of charge carrier to a conductive contact that will transmit the electricity [11].This is called as the photovoltaic effect. The photovoltaic cell system was first experimentally said by Edmond Becquerel in 1839. The first practical photovoltaic cell system was demonstrated in the year 1954. Later the model of the quantum solar cell systems was developed and it is used mostly in the solar cell silicon as the light absorbing material to convert solar energy into clean electrical energy [12].

A. Conventional Work of a Solar Cell

Solar cell converts the solar energy into electrical energy. The sun rays contain certain energy level and some of the photons in the sun rays are absorbed by the light absorbing material which is present in the solar cell. Silicon is present in the classical solar systems as the light absorbing material. Silicon consist of two types namely n-type and p-type. N-type silicon consists of n-type material which consists of electron and the p-type consists of holes [13]. These two types are placed side by side. When the light is absorbed by the light absorbing material the photons are absorbed and the electron present in the n-type material jumps to the holes present in the p-type material. The electrons are filled by the holes present in the p-type region. Due to the conduction of electron from n-type to the p-type there is a flow of current in the cell. Thus the solar energy is converted into electrical energy [14], [15].

B. QD Nanotechnology in Solar Cell

The rays from the sun consist of different energy levels. Solar spectrum has the photons with the energy level from 0.5ev to 3.5ev. So, by the use of the silicon in the solar cell most of the photons with the energy level of above 1.14ev will be wasted as the heat. The practice solution is used to overcome this problem with Quantum dot as a nano material used in the solar cell to increase the efficiency of the solar cell [16]. Quantum dot is a zero dimensional system where electron motion is confined in three dimensions. Therefore, a quantum dot possess atomic like density of states that is described mathematically by a delta function $\delta (E-E_{c/v})$.

Unlike conventional materials, one photon generates just one electron; quantum dots have the potential to convert high-energy pho-tons into multiple electrons. Quantum dots behave as the same way, but produce three electrons for every photon of sunlight that hits the dots. Electron is displaced from the valance band into the conduction band. These dots have more sunlight wave spectrums for improving conversion efficiency as high as 65% percent. Another area in which quantum dots could be used to improve efficiency is, so – called a hot carrier cells. Typically the extra energy is transferred by a photon as heat, but with a hot carrier cells the extra energy from the photons result in higher-energy electrons in turn captured to lead to higher voltage efficiency [17], [18].

C. Improving Solar Cell Efficiency with QD

One of the starting points for the increase of the con-version efficiency of solar cells is the use of semiconductor quantum dots (QD). By means of quantum dots, the band gaps can be adjusted specifically to convert also longer- wave light and thus increase the efficiency of the solar cells. These so called quantum dot solar cells are, at present still subject, to basic research. As material systems, QD solar cells, III/V semiconductors and other material compositions such as Si/Ge or Si/Be Te/Se are considered as potential advantages of these Si/Ge QD solar cells for:

1) Higher light energy absorption in particular to the infra-red spectral region,
2) Compatibility with standard conventional silicon solar cell production (in contrast to III/V semiconductors),
3) Increasing of photo current at higher temperatures,
4) Improving radiation hardness in comparing to conventional silicon solar cells.

The transport of electrons across the particle net-work is the major problem in achieving higher photo conversion efficiency in nanostructured electrode. Utilization of CNT network support to anchor light harvesting semiconductor particles is assisting the electron transport to the collected electrode surface in DSSC and charge injection from excited CdS into SWCNT excitation of CdS nanoparticle. When CNTS attached in Cdse & CdTe, charge current can induce transfer process under visible light irradiation. The enhanced interconnectivity between the titanium dioxide particles and the MWCNTs in the porous titanium dioxide film is concluded to be the cause of the improvement in short circuit current density [19], [20].

III. Quantum Structure Design of Solar Cell

The quantum structure design is reflecting the impact of QD media between layer states and doping on the open circuit voltage of QSDSCs through device–level simulations complemented by quantum mechanical calculations to correlate the QD morphology and electronic structure. Based on the numerical simulation, the design introduce a simple analytical model that highlights the competition that highlights the competition between barrier and QD recombination mechanisms and correlates the effective QD capture rate to the achievable open circuit voltage. The fatigue distribution is determined using continuum elastic theory and minimizing the free energy within the crystal, and energy bands are calculated taking into account the potential induced by the strain deformation. QD energy levels are calculated by solving the 3D Schrödinger equation with the 8-band ($k - p$) method.

Then, the QD electronic structure is correlated to solar cell performance through device-level simulations using the QD-aware modeling approach described in [21]. The model exploits a drift–diffusion–Poisson formulation coupled with a set of rate equations (RE) describing the QD carrier dynamics. At each QD layer, the barrier continuity equation for electrons charge transfer within QD states is modeled by a three – levels rate equation (RE) system, involving thin layer (TL), excited state (ES), and ground state (GS), and accounting for band-to-band recombination and photo generation through QD states. The operation of these three key transformative paradigms holds great promise for construction of robust and efficient electrolyte free solid-state photovoltaic devices.

In the conventional systems, current dye-sensitized solar cell (DSSC) designs[22] have achieved efficiencies of over 10% but make use of expensive, toxic compounds (e.g., Ru–based dyes) and comprise a reactive liquid electrolyte, leading to potential sealing and aging/degradation problems of the solar panels. Recently, a new biosensitized solar cell (BSSC) [23], [24] has an advantage of the use of low-cost and environmental friendly biomaterials able to enhance the energy transfer mechanism [25].

A. Assembly QD/bR Absorption Layer with Controlled Fluorescence Resonance Energy Transfer Efficiency

In recent year, systems ecology is pronounced to integrate environmental issues in emerging frontier in the development of green energy sources. Thavasi et al., [26] reported several advances mechanisms for the feasibility of bacteriorhodopsin (bR) as bio photosensitizer in excitonic solar cells. The goal of efficient energy transfer is designing a hybrid layer composed of QDs and bR levels [27], [28]. Therefore the hypothesis does not affect the amount of photo voltage recovery. In a hybrid material engineered from protein bio-Reassembling (bR) and quantum dots (QDs) to absorb and trap the photon energy [29−32] in a thin film to produce the ballistic electrons and recovery the retinol fragment in bR. The mechanism for this transfer in the QD/bR layer relies on the near-field resonance of simple electric dipoles that is hypothesis known as FRET. Fluorescence resonance energy transfer (FRET) or electronic energy transfer (EET) [33] and further, from bR-QD to thin film via a nonradiative "Auger-mediated de-excitation" (AMD) to ensure maximal spectral absorption with bR [34], [35]. This material is important because it might provide an efficient active absorption media for a new reassemble type of biosolar cell. In its simplest formulation, FRET is the quantum version of a classical resonance phenomenon, whereby oscillating electric dipoles exchange energy through their mutual electric fields. While bR acts as a light-driven proton pump during charge separation on photon absorption, free electron charge ejection occurs concurrently. Because of the later property of bR, it is logical to leverage its bio–reassembling application in excitonic solar cells [36].

As case study we consider conventional InAs/GaAs QDs and QDs embedded in AlGaAs layers. Alternatively gallium indium arsenide, GaInAs is modeled as cellular–shaped InAs QDs with circular base with radius 14 nm and height of 6 nm. Correlation between QD media and solar cell performance is studied considering a simple surface of GaAs-only solar cell (i.e. without widegap window and back surface field layers), whose intrinsic region is made by a stack of 20 QD layers separated by GaAs spacer layers of about 50 nm thickness. The detailed description of the cell structure is summarized in Table (1), Based on the simulations in Sec. III-A, the influence of Al_xGa_{1-x} as barriers embedding the QDs is studied in terms of shift of the TL energy state in the conduction band with respect to the reference QD media.

TABLE (1)
CELL STRUCTURE AND REFERENCE QD PARAMETERS

Cell Structure

Layer	Thickness [nm]
– p+ (5×10^{18} cm^{-3}) GaAs	50
– p (1×10^{18} cm^{-3}) GaAs	100
– QD region, intrinsic GaAs	1000
– intrinsic GaAs	50
– n (1×10^{18} cm^{-3}) GaAs	300

QD Parameter

– QD density, N_{QD}	[cm^{-2}]	6×10^{10}
– WL Density of States, $N_{TL}^{e,h}$	[cm^{-2}]	2.4×10^{12}
– Peak Opt. Absorption, α_{TL}, α_{ES}, α_{GS}	[cm^{-1}]	10^4, 900, 400
– QD thickness, t_{QD}	[nm]	4

Source: (Green et al., 2014) [37].

The applied model functions in situation where the donor molecule (QD) is rigid, with free thin coupling between its electronic and vibronic states, while the acceptor (bR) has strong electronic-vibronic coupling in its excited state. In this situation, the model is exactly solvable and thus allows a comparison with the incoherent limit derived by Formal and others approaches [38] [39].

B. *Spatial Architecture Control Model*

Photosynthesis involves the simplest nature advanced and efficient system that has crafted to convert solar energy into an electrical potential and into chemical compounds for energy storage. In this section, the developed model provides spatial architecture control of absorbing layer to funnel the energy flow by a combination of electronic, optical, and excitonic means is achieved to predict component cellular mechanisms. The architecture Figure (1) [40], is categorized spatial layer into three main segments for efficient separation electron, and storage inversions functions. *The first segment*: is directly related thin films of electron capture from QDs solar cells systems to open circuit voltage recovery systems. The cellular function is controlled with stable regularly voltage charge current of circuit. This segment has optical coupling between the QD and bR that converts re-emission of light from the QD within its energy nonradiative transfer to bR, and thereby increases the amount of trapped incident energy available for conversion to photocurrent [41], [42].

In moderate segment; the rapid charge of electron is formed to load backup storage panels. The quantum separation move electrons from one side of a compound to other positive side in ideally mechanism to become spatially remote depending on technology and material compositions of battery systems. The quantum structure design ensures minimal spatial distance between donor (QD) and acceptor (bR) and maximal spectral overlap between donor fluorescence and acceptor absorption: as these two conditions are guaranteeing maximal efficiency of resonance energy transfer in bR/QD hybrid material [43]. Thus moderate segment contains current invertors from DC to AC to improve feedback efficiency and acceleration storage capacity. In the luminous application, intensity is integrated with auxiliary generation to guarantee the regular distribution of AC [44]. *The application segment*; present a practical luminous intensity systems. These segments are categorized to tune with DC output and AC input with controller circuit as so, both are connected with three segments for I/O DC and AC voltage controller with disconnect meters system. The regulated luminous is electron intensity recovery controller (EIRC) provided to improve light security integration with other peripherals for performance. Each controller connected directly with temporary recovery systems QDs film for efficient strengthens displacement false signals. In regular function, system is assembled virtual switch to fixable control AC input and DC output devices. These devices in particular function are conveying electrons in wiring nanotube for hybrid system connections [45], [46].

In particular, the model consists of two key components, which implement the energy– transfer in three segments layer. The first segment, for electrons capture is using a hybrid material engineered from bR and (QDs) to absorb and trap the photon energy in a thin layer of GaAs to produce the ballistic electrons and recovery the retinol fragment as in bR. In this architecture, the complexes are engineered in such a way that each QD is coupled to one bR trimer, thus providing both spatial and optical bR/QD coupling. In fact, our recent experimental work shown that the QD/bR system can provide FRET efficiencies substantially exceeding the values predicted by the classical FRET theory formulated by Förster [47][48].

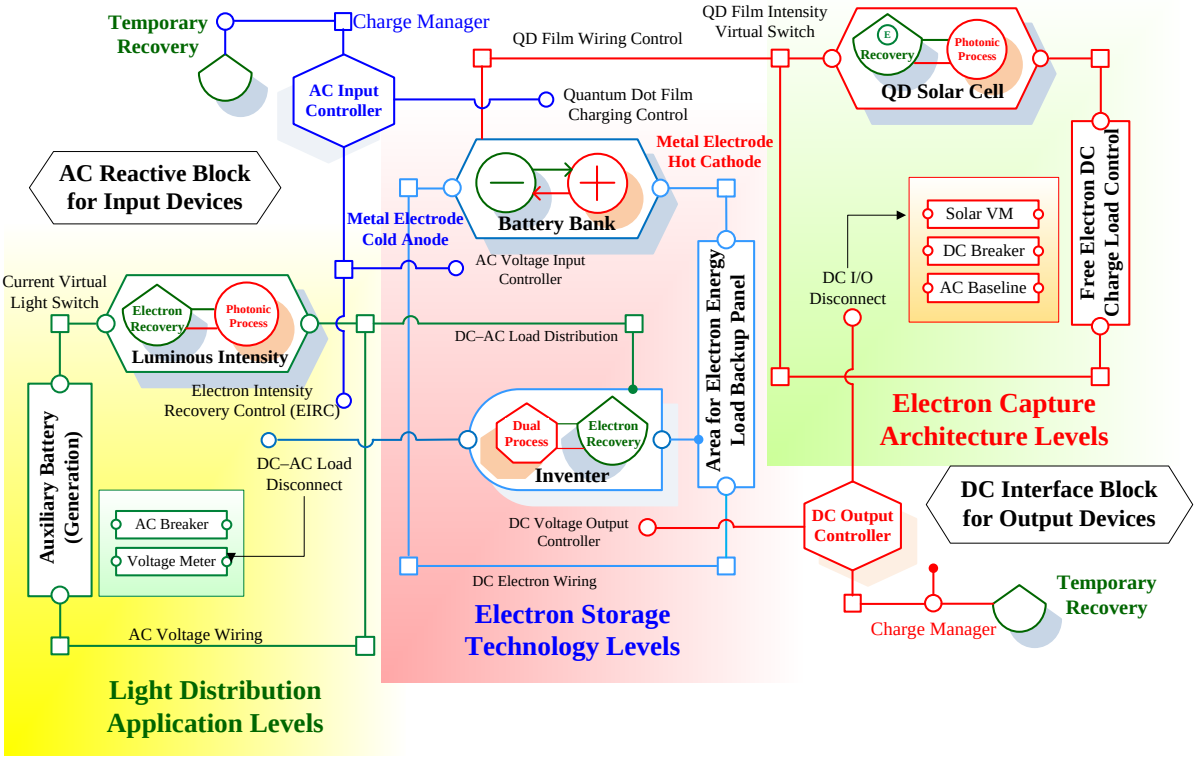

Fig. 1, Schematic Layer of Operating Principal Diagram of Proposed Electron Energy Band Levels for Solar Hybrid Quantum Dot Processor of Luminous Intensity Application [40]

IV. Parameters Influence Open Circuit Voltage Efficiency

In the principle revisions, an important goal of the model simulations is to calculate parameters influence exact function that can predict the Förster radius in the engineered protein of bio−Reassembled bR in relation to semiconductor of hybrid material as the ultimate efficiency F_o of solar cells. The determined equation could be generalized according to open circuit voltage [49], [50]:

$$F_o = \frac{E_g \times Q_s}{P_{in}}$$

where Eg is here the energy needed to produce one electron−hole pair, *Qs* is the number of photons per unit of time with energy higher than *Eg*, and P_{in} is the total incident power. In a typical solar cell, however, the efficiency *F* is a fraction of the ultimate efficiency F_o that is given here in Shpaisman et al., [51]:

$$F = t_s \times r \times m \times F_o \quad (3)$$

The equation provides t_s as the probability to produce an electron−hole pair from a photon with energy *Eg* (or higher). While the probability t_s depends on the size of the active absorption layer; when the quantity is determined as:

$$r = \frac{V_{oc}}{E_g} \quad (4)$$

This quantity *r* parameter is expressed for the ratio of the open-circuit voltage V_{oc} and the band gap; and *m* is the impedance matching factor depending on internal cell resistances. These model parameters are applied for more efficient system, and must simultaneously be optimized in relation to all parameters (F_o, *t, r, and m*). Ideally, the ratio *r* should be valued in close to one to express how induce energy is captured and used without losses as so; deviations are minimized in the charge-separation process. Where the efficiency is E_F in the Fermi level (in the dark) and E_{qF} is the quasi−Fermi level under illumination. Thus, the open circuit voltages have approximate ratio as so,

$$V_{oc} = E_{qF} - E_F \quad (5)$$

where, the parameter (*r*) can then be calculated from first−principals simulation as in equation no. (4) [52].

The model need more detail applications to provide exact simulations. Otherwise, the QD absorption layer replaced with a hybrid layer composed of QDs and bR molecules, and fluorescence emission of QDs can be selected to ensure maximal spectral edge intersection with bR absorption [53].

A. Orientation Control of Thin Membrane Film with KPFM

The degree of orientation achieved upon the preparation of highly oriented monolayers of bR-containing TMs and QD-TM hybrid materials should be carefully controlled if an efficient photovoltaic device needs to be prepared. Our suggested approach to the quality control of flame-annealed atomic smooth coating with PMs is based on the Kelvin probe force microscopy (KPFM) technique. KPFM allows the distribution of the surface potential of a sample to be plotted with a high spatial resolution simultaneously with its topographic imaging [54] and was proved to be efficient for studying different photosensitive membranes [55], including thin membrane films TMs [56].

The main criteria of the quality of the thin film surface coating with the TMs are its high density, homogeneity, and high degree of orientation of the TMs sedimentation. KPFM allows all of these parameters to be controlled simultaneously. The procedure of the quality control of the thin film surface coating and degree of TM orientation should be performed under the conditions of controlled humidity (50−70%); the obtained highly oriented films may be further dried and used in liquid-free BSSC-based devices. The homogeneity of coating density can be estimated using the statistical methods of roughness standard analysis as density functional theory (DFT) and diffusion quantum Monte Carlo (DQMC) [57].

V. Conclusion

Inexpensive solar cells are utilizing nanotechnology to help preserve the environment. Coating existing roofing materials with its plastic photovoltaic cells which are inexpensive enough to cover a home's entire roof with solar cells, then enough energy could be captured to power almost the entire house. If a large portion of urban blocks did apply the solar systems in generation electricity, this then reduce dependence on the electric grid (fossil fuels) and help to reduce pollution.

Inexpensive solar cells would also help provide electricity for rural areas or third world countries. Since the electricity demand in these areas is not high, and the areas are so distantly spaced out, it is not practical to connect them to an electrical grid. However, this is an ideal situation for solar energy.

Cheap solar cell system is used for lighting, hot water, medical devices, and even cooking. It would greatly improve the standard of living for millions, possibly even billions of people. In addition to flexible roller-processed model, solar cells have the potential to turn the sun's power into a clean, green, convenient source of energy Even though the efficiency of Plastic photovoltaic solar cell is not very great, but covering cars with ballistic photovoltaic solar cells or making solar cell windows could be generate the power and save the fuels and also help to reduce the emission of carbon gases.

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reliance application structure in sustainability energy.

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