A study on solar cell efficiency incrementBy PbSe quantum dots, ZnO nanocrystal & TiO2 nanorod – An Overview

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Abstract— A colloidal synthesis of lead selenide, zinc oxide, and titanium dioxide heterostructures, consisting of small diameter lead selenide and zinc oxide nanocrystals grown onto the surface of titanium dioxide nanorods, is being used to harness solar power at a higher efficiency than currently available.
Keywords—solar energy; solar panel; lead selenide; titanium dioxide; zincoxide.

I. INTRODUCTION

The world's major energy sources [1] are non renewable and increasing its demand, thus are not expected to last long. Besides being non-renewable, these sources includes mainly of fossil fuels, contribute tremendously to the perennial problem of global warming. The eminent depletion and pollution problems of the above energy sources make the international community focus attention on alternative sources of energy, especially solar energy appears highly promising. Solar energy is emitted from the sun primarily as electromagnetic radiation in the ultraviolet to infrared and radio spectral regions. The sun has a reasonable constant life time with a projected constant radiative energy output of over 10 billions (1010) years[2] . A solar cell performs two major functions: photogeneration of charge carriers in a light absorbing material and separation of the charge carriers to a conductive contact that will transmit the electricity. Solar cells are electronic devices used for the direct conversion of solar energy to electricity, using the photovoltaic (PV) effect. Fundamental properties of nanostructured materials are currently extensively studied because of their potential application in numerous fields which includes electronic devices, opto electronics, optics, tribology, biotechnology, human medicine and others[3,4]. Nanostructured materials contain structures with dimensions in the nanometer length scale which includes polycrystalline materials with nanometer sized crystallites, materials with surface protrusions spatially separated by few nanometers granular or porous materials with grain sizes in the nanometer range or nanometer sized metallic clusters embedded in a dielectric matrix. The motivation for using nanostructured materials emerges from their specific physical and chemical properties.Enhancing the regular crystalline structure using nanocrystalline materials can increase the absorbance of all incident solar spectra in the form of thin films or multilayered solar cells. This increase requires an electrolyte to transfer the charge from the photo-acceptor to the electrodes in dye-basedand polymer solar cells, whereas in nanoparticlebasedcells, the particles should be sufficiently close to one another to transfer the charge directly.Recently, significant progress has been made in improving the overall efficiencies of solar cell structures, including the incorporation of quantum dots (QDs) and nanocrystalline materials. A reported timeline of solar cell conversion efficiencies from 1975 to 2015 is shown in Fig.2. The objective of the work is to know the applications towards the motivation for using nanostructured materials in solar energy conversion. (Vasanthy and Jeganathan 2007, Vasanthy et.al., 2008, Raajasubramanian et.al., 2011, Jeganathan et.al., 2012, 2014, Sridhar et.al., 2012, Gunaselvi et.al., 2014, Premalatha et.al., 2015, Seshadri et.al., 2015, Shakila et.al., 2015, Ashok et.al., 2016, Satheesh Kumar et.al., 2016).

II. WHY QUANTUM DOTS?

In the so-called hot-injection technique, the precursors are rapidly injected into a hot and vigorously stirred solvent containing organic surfactant molecules that can coordinate with the surface of the precipitated QD particles. This method is usually employed toQDs. The organic surfactant molecules play the key role intuning the kinetics of nucleation and growth by preventing or limiting particle growth via Ostwald ripening. Following the similar growth process, a number of nanocrystals have been synthesized, including CdS , CdTe these nanocrystals have been fabricated into PV devices. The nanocrystals used in PV devices are rod-shaped CdSe and CdTe nanocrystals prepared by air-free hot-injection techniques.

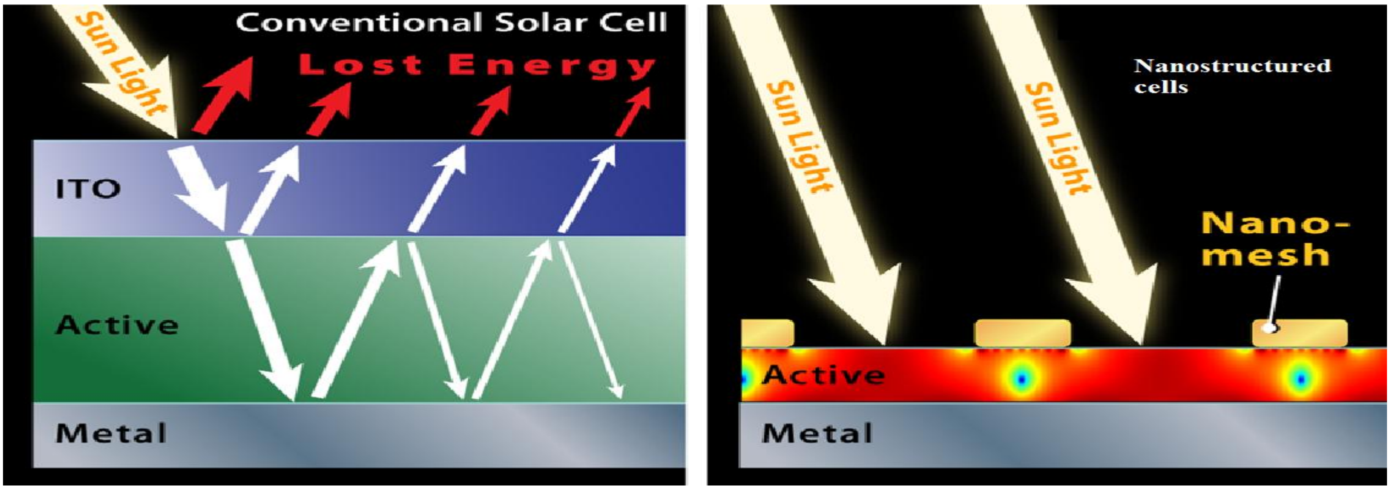

Figure 1 : Conventional and Nanostructured solar cells

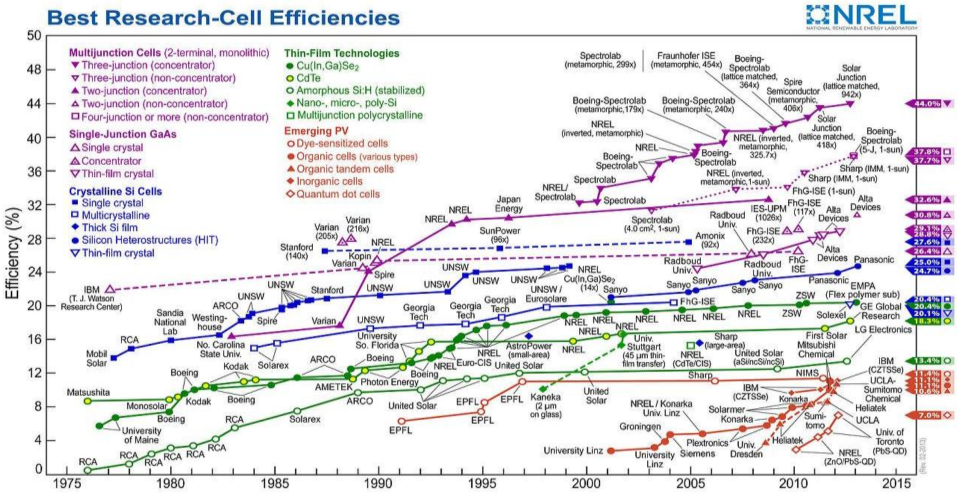

Figure 2:Highest efficiencies obtained till now

Titanium dioxide[5] is an important photovoltaic and photocalytic material, which is utilized in dye-sensitized solar cells and hydrogen production is encouraged by its low fabrication costs and minimal environmental hazards. Absorption of solar radiation within TiO2 generally requires extending its absorption range into the visible and near infrared by introducing an appropriate sensitizer that reduces TiO2 upon photoexcitation. To date, the most common strategy for the TiO2 sensitization involves modification of its surface with organic dyes. The use of semiconductor nanocrystals (NC) for this purpose is now being actively explored due to a number of advantages offered by inorganic NCs over organic sensitizers, including resistance to photobleaching and tenability of NC conduction levels. As shown in recent reports, successful modification of TiO2 with colloidal CdSe[6], PbS[7] and InAs[8] NCs has lead to heterostructures that exhibit photoinduced charge separation. In these processes, however, deposition of NC onto TiO2 still relies on organic linkers that are subject to photo-degradation. To avoid this problem several groups have attempted growth of CdS NCs onto TiO2 films in ionic solutions. While the observation of improved charge transport characteristics in these experiments was encouraging, the quality and size-distribution of fabricated NCs was inferior to those synthesized through colloidal techniques, making it difficult to control relative positions of electron energy levels in a donor-acceptor system .Here is demonstrated a colloidal approach to the synthesis of PbSe/TiO2 hetero-nanocrystals (HNCs), comprising 2-5 nm PbSe NCs grown on the surface of TiO2 nanorods (NRs). As a main benefit of colloidal injection techniques, the present approach allows for a controlled adjustment of the dot diameter during synthesis, which is critical for the offset between donor and acceptor conduction band edges. A significant lattice mismatch between fcc PbSeand TiO2 crystal phases ensures that the growth is characterized by the formation of small PbSe NC islands. One benefit associated with such growth is the possibility of several PbSe NCs per single TiO2 NR, which increases the light absorption cross section. Such growth supports the formation of small diameter PbSe NCs which is critical for the realization of a type II (staggered) heterojunction between PbSe and TiO2 materials.

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III. PREPARATION OF PBSE & TIO$_2$ MIXTURE

The first step in this procedure is to make the lead and selenium precursors. The lead is prepared by dissolving 0.45 grams of lead oxide with 1.8 mL of oleic acid and 7.45 mL of ODE in a three-neck flask. The flask is heated to 193 degrees under argon and maintained at that temperature for thirty minutes. The solution is cooled to 120 degrees Celsius prior to injection.

The selenium is prepared by dissolving 0.21 grams of selenium in 2.7 mL of TOP in a single neck flask under argon and sonicating at room temperature. The first step in making the titanium oxide rods is to combine 0.315 mL of oleic acid and 2.2 mL of oleylamine in a three-neck flask and heating to 120 degrees Celsius under vacuum for thirty minutes in order to degas the solution. After thirty minutes the solution is cooled down to 40 degrees Celsius and switched to argon flow. At this time 0.05 mL of titanium chloride is injected into the flask.

The solution is then heated to 290 degrees Celsius and the temperature is held for twenty-five minutes to promote the growth of the TiO2 rods. After this time period the solution is cooled to 180 degrees and the lead and selenium solutions are injected simultaneously. After the injection the solution is held at 160 degrees or five minutes and then the reaction is stopped by cooling the flask. No samples are taken due to the fact that this particular type of quantum dot is believed to photoluminescence in the ultraviolet range. After the solution is cooled to sixty degrees Celsius, 3 mL of anhydrous chloroform is added to prevent aggregation. Then the solution is added to a test tube and enough anhydrous ethanol is added until the mixture became cloudy, approximately three milliliters. This cloudiness indicates that the quantum dots have precipitated out. The solution is then centrifuged for fifteen minutes at which time there is a black and a cloudy layer. The black layer contains unreacted agents and is extracted and disposed of. The cloudy layer is the layer that contains the quantum dots and is diluted with approximately three mL of anhydrous chloroform and kept in a vial that has argon pumped into it.

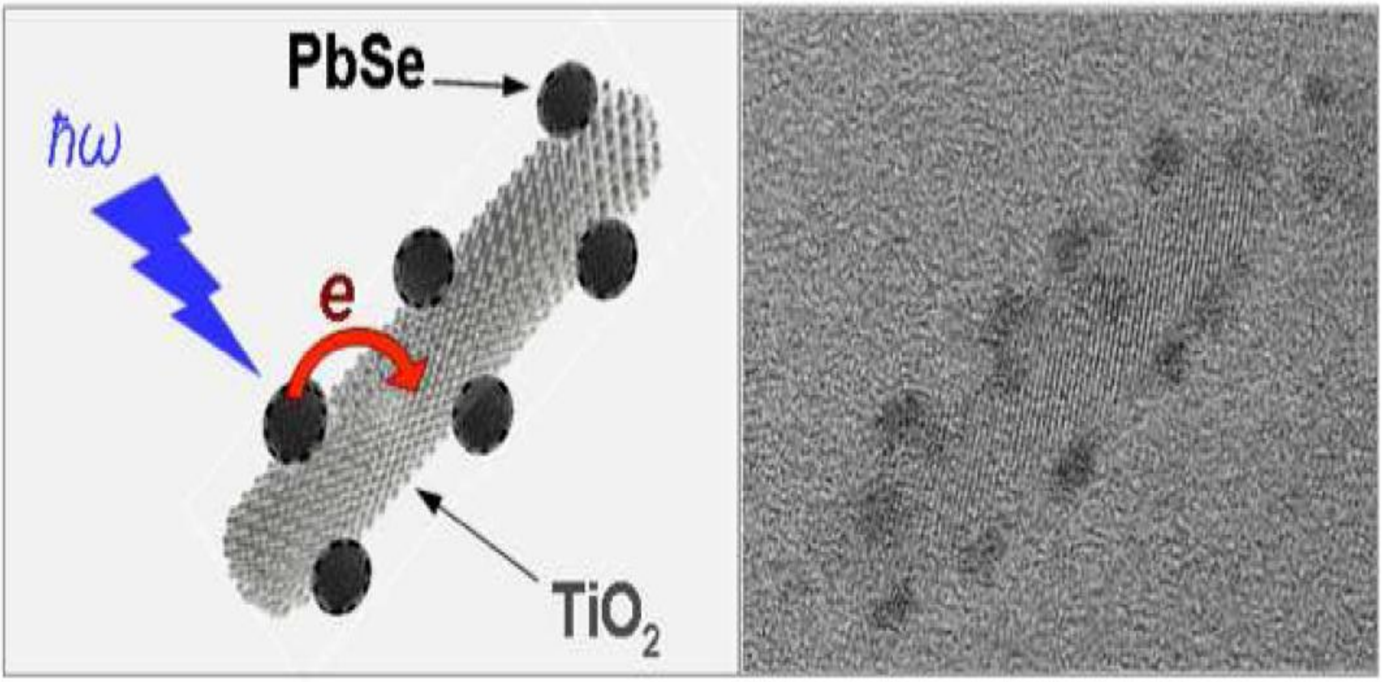

Figure 3: PbSe & TiO2 combining process as seen in a TEM.

A. *TEM analysis of PbSe&TiO$_2$*

Transmission electron microscopy analysis of PbSe/TiO2 HNCs reveals a difference between PbSe shapes forming on the surface of TiO2 NRs as a result of a single and multiple injections of Pb and Se precursors. The initial injection leads to the formation of several small-diameter PbSe sites per NR, with an average diameter of 1.8-3.0 nm. According to the TEM image of a typical PbSe/TiO2 structure, PbSe dots appear to be uniformly scattered over the entire NR surface and exhibit a moderate dispersion of sizes. A symmetric placement of PbSe dots on the surface of TiO2 can be explained in terms of fundamental energy requirements on the deposition of secondary material in hetero-epitaxial growth. Spatially isotropic addition of PbSe monomers onto TiO2 NRs initially results in the formation of a thin PbSe shell.

B. *Conclusion for preperation of PbSe&TiO$_2$*

This work demonstrates as all inorganic modification of the TiO2 surface with semiconductor NCs which should lead to improved light conversion efficiencies in photovoltaic applications. The growth of lead NCs is not limited to TiO2 NRs and can also be adapted to other nanostructured forms of TiO2 including porous films and nanotubes, whereby introducing a colloidal route to sensitization of TiO2 surfaces without organic linkers.

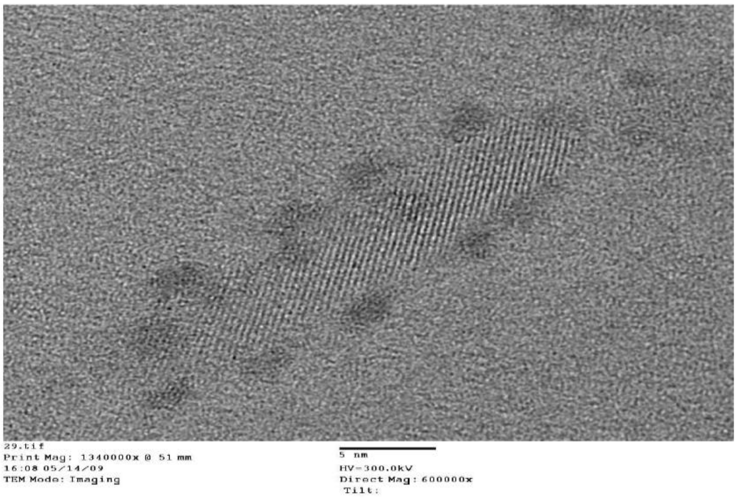

Figure 4: PbSe & TiO2 as seen in a TEM.

IV. OBSERVATION MADE

When solar panels are made using the prescribed nano materials we get an efficiency higher than the present.

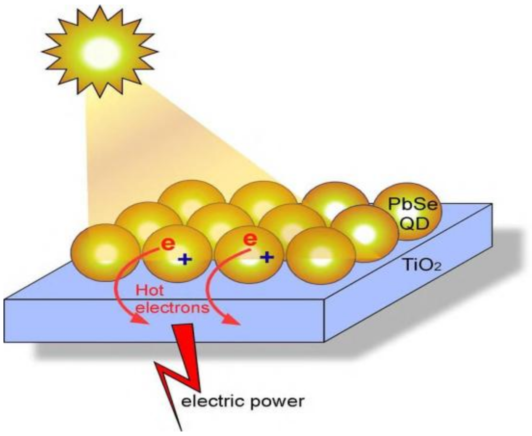

Figure 5:The old proposal scheme(PbSe & TiO2)

V. OUR PROPOSAL SCHEME

In our ongoing study we are going to prepare a hetro colloidal structure containing ZnO and PbSe and TiO2. The high electron mobility of ZnO compared to titanium oxide makes it the ideal electron selective contact layer in polymer solar cells.[9] However, the metal oxide layers used in most studies are processed under high temperatures to increase their crystallinity for better charge carrier mobility.[10]This disqualifies them to be used for printed plastic electronics. To be used in plastic solar cells, the devices need to be processed under low temperatures using simple methods, maintain flexibility, and retain a thin form factor. These requirements can be easily fulfilled by using an inverted device architecture with low temperature solution-processed n -type metal oxide layer with high electron mobility to select and transport electrons. Zinc oxide nanoparticles (ZnO NPs) have been shown to be easily processed into thin layer via spin coating at room temperature.[11]These ZnO NPs also have good electron mobility (~0.066cm2/Vs) without the need of additional post-thermal treatment.By incorporating a low temperature solution-processed thin layer of ZnO NPs as the electron selective contact layer, we were able to fabricate environmentally stable inverted polymer solar cells on ITO-coated flexible plastic substrates. Stability and performance of unencapsulated inverted devices using high temperature sol-gel processed ZnO layer on ITO/glass, ZnO NPs on ITO/glass as well as ZnO NPs on ITO-coated plastic substrates were compared to those of the conventional devices using LiF/Al as the electrode on glass substrate. It has also been previously reported that the photoluminescence emission spectra from ZnO nanoparticles occurs due to the radiative energy loss of electrons from singly charged Zn interstitial and oxygen vacancies to the valence band confirming the existence of native impurity type in ZnO nanoparticles [12-14]. Therefore, impurities reduction upon annealing could lead to lower charge scattering or lower resistance in ZnO layers as more perfect crystals are formed. In the resulting hetrastructure the efficiencies would be higher than the previously proposed scheme at least by 10 to 15%.

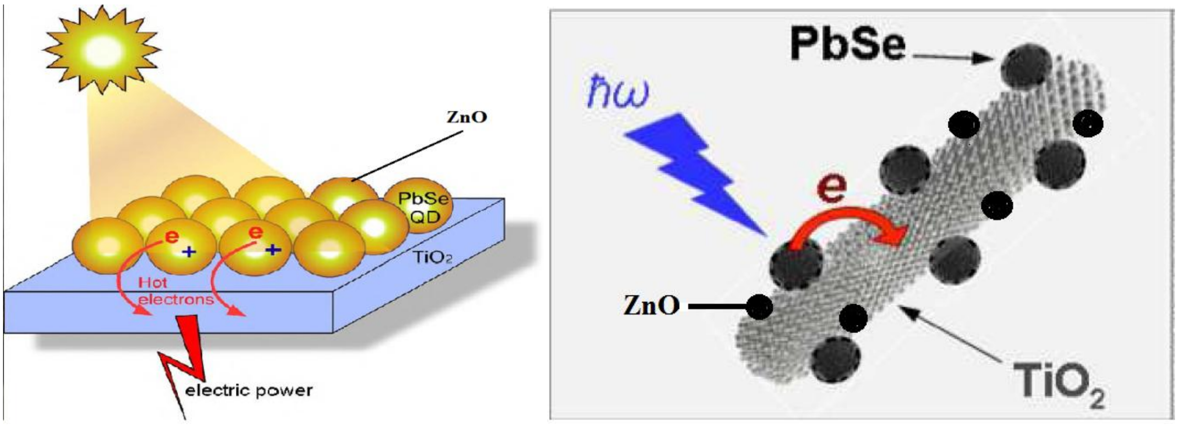

Figure 6:Our proposal scheme(PbSe ,ZnO & TiO2)

VI. CONCLUSION

The study reveals that quantum dots slowed the loss of energy as heat when PbSe , ZnO & TiO2 are mixed and used for absorbing solar power the efficiency obtained is higher than the present solar power generators.

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