THE "CUINSES/ZNS" CORE/SHELL QUANTUM DOT AND ITS APPLICATION IN LUMINESCENT SOLAR CONCENTRATOR

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Abstract - The CuInSeS/ZnS quantum dots with high photoluminescence quantum yield of 70% was proposed as a luminescent material in luminescent solar concentrator applications. This quantum dot has advantages of large Stocks shift of 0.43eV.The Luminescent solar concentrators was fabricated in dimension of 2.2 cm × 2.2 cm × 0.3cm by dispersing 0.3%wt. CuInSeS/ZnS quantum dots particles in a polymethylmethacrylate waveguide and its performance was evaluated. Results are showing that the CuInSeS/ZnS quantum dots - Luminescent solar concentrators provides a bright way for reducing of losses due to reabsorption in Luminescent solar concentrators. The maximum power conversion efficiency of 9.16% was obtained from the LSC doped with QDs, which is more than 3 folds to the LSC device without QDs.

Index Terms - Quantum Dots, Luminescent materials, Luminophores, LSC, Reabsorption, Solar cell.

I. INTRODUCTION

Luminescent solar concentrators (LSCs) were introduced in the 1970s as an approach to lowering the costs of solar power [1],[2].Such LSCs have received great interest recently because of their potential for achieving high optical concentration ratios without tracking the sun[3],[4].The general principle behind LSCs is illustrated in Fig.1. Waveguide-based LSCs can absorb short wavelength sunlight and then reemit it at longer wavelengths.

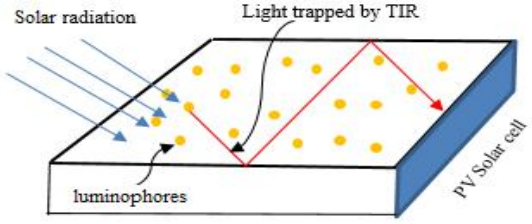


Fig.1. Working principle of luminescent solar concentrators.

Authors are acknowledging Ministry of higher education – Malaysia (MOHE) for supporting the work under research grant number 0153-AB-K88 and [FRGS/1/2015/TK10/UTP/03/2]. A large fraction of the emitted light is trapped in the waveguide through total internal reflection (TIR) and concentrated toward small silicon-PV cells attached to the edges of the waveguideTo date, numerous types of luminescent materials have been developed and tested for use in LSCs, including organic dyes[5],[6] quantum dots[7],[8] and rare earth materials[9],[10]. The LSCs fabricated using organic dyes are suffer from poor photo-stability and self-absorption which caused by overlap between their absorption and emission spectra. These deficiencies reduce the overall efficiency of LSCs and make them unsuitable to use in LSCs application.QDs are of particular interest for LSC luminophores because their absorption and emission may be tuned by varying the size, shape, or composition of them. Recently inorganic core/shell quantum dots (QDs) are especially well suited to address the problem of reabsorption due to their large stoke shifts. In this work, we use CISeS/ZnS core/shell quantum dots to reduced reabsorption losses and increased device efficiency. We study on CISeS/ZnS quantum dots with emission at 890 nm (1.39 eV), which is near optimal to the band gap of silicon photovoltaics (1.12eV). The waveguide was fabricated at 0.3%wt. Of QD concentration and the device efficiency were measured.

II. EXPERIMENTAL IMPLEMENTATION

The tests have been achieved by preparation of LSC sample which were then subjected to a tests using UV/VIS spectrometry, Photoluminescence Spectroscopy, Ocean Optics spectrometer, IV-Curve equipment and solar simulator.

A. Sample Preparation

LSC was fabricated with dimension of 22 cm × 22mm ×3mm comprising 0.3%wt. of CuInSeS/ZnS QDs. All samples were prepared under polymerization process using methyl methacrylate (MMA) as monomer, polymethylmethacrylate (PMMA), azobisisobutyronitrile (AIBN) as an initiators and a standard water-bath method, for more detail refer to reference [14]. After finishing the polymerization process, finally the PMMA sheet was removed from the mold and was cut to appropriate size by laser cutter. Fig. 2.illustrates LSC mold with 3mm thickness and after being cut by laser.

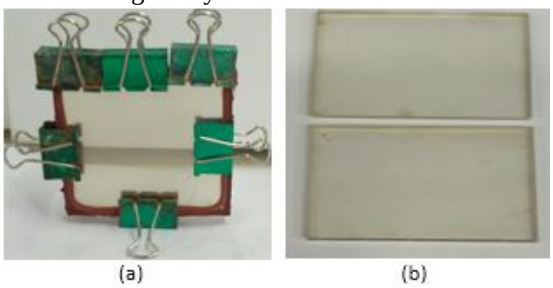


Fig. 2. a) LSC mold with 3mm thickness, b) after cutting by laser

B. Edge Attachment of Cells

Si-Solar cell was attached against one of its edges by using adhesives. Here, we used Cyanoacrylate and Araldite as their refractive indexes are close match to that of the PMMA sheet.Fig.3. illustrates LSC sheet with attached Solar cell.

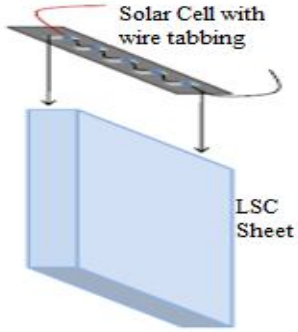


Fig.3.LSC sheet with attached Si-Solar cell

C. Characterization of LSC

In order to measure absorption and photoluminescence spectra of the LSC sample, the UV/VIS Spectrometry with the scan range of 200-800nm and resolution of 1.0nm andEdinburgh FLS920 Spectrofluorometer with both visible (Hamamatsu R928) and infrared (Hamamatsu R5509) photomultiplier detectors were used. To take into account the re-absorption and its impact on the measured PCE% the Ocean optic spectrometer and IV-Curve characterization is done respectively. To take the PL spectra of each LSC sample at variable optical path lengths from 0-2.2cm.The effect of Re-absorption loss was investigated by using Ocean Optics spectrometer at variable optical path lengths of the LSC sample as illustratedinFig. 4.

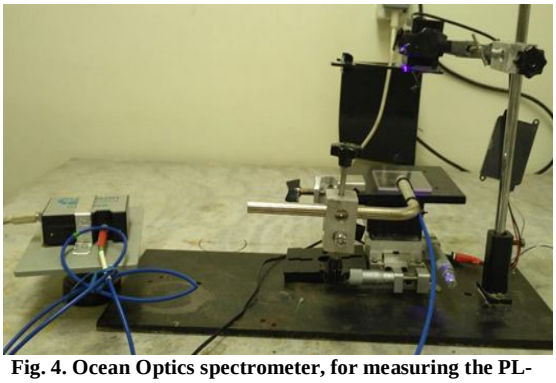


Fig. 4. Ocean Optics spectrometer, for measuring the PL-Spectra at variable optical path lengths of the sample.

III. RESULT AND DISCUSSION

The optical properties (absorption and emission spectra) of LSC samples are indicated in Fig. 5. Both absorbance and emission spectra (blue and red line) have been normalized. The peak are remarked at 750 nm and 890 nm respectively with large Stocks shift 0.43 eV. The CuInSeS/ZnS particles have an ability to convert sunlight with wavelength of below 750 nm into about 890 nm, which could be collected by the silicon solar cells more effectively.

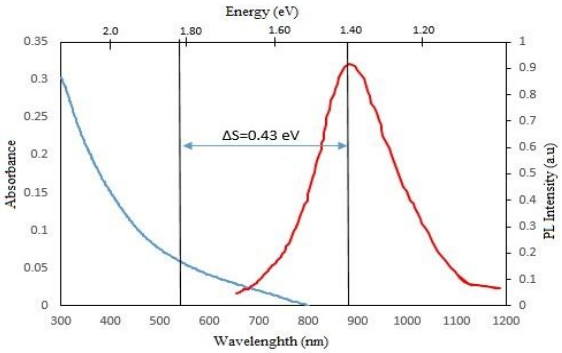


Fig. 5. Absorbance and PL- spectrum of CuInSeS/ZnS core/shell quantum dot.

The effect of reabsorption loss at variable optical path lengths from 0-2.2cm in LSC sample indicates inFig6. The photoluminescence spectra collected at the edge of LSC with 532 nm excitation from edge of the sample by increasing distance (d from 0-2.2cm). It is observed that by increasing the distance, the curve of normalized PL-spectra has a bit changes which shows the losses due to reabsorption are not significant.

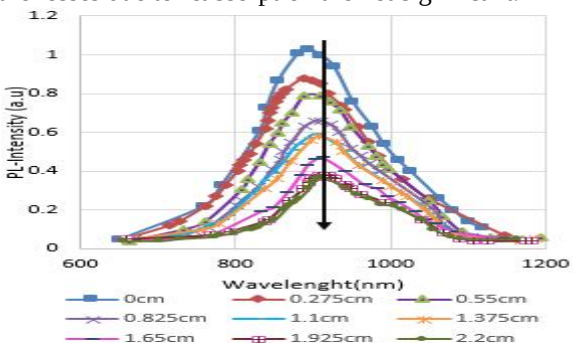


Fig6. The PL spectra measured from the edge of LSC sample by increasing distance from 0 to 2.2cm

To determine the power conversion efficiency (PCE) of the LSC samples, the solar I-V curve equipment and a solar simulator with 1.5 AM is used during this experiment. The LSC samples (QDs-LSC-PV and pure PMMA-PV), were prepared in the same size and are integrated with the same commercial Silicon-PV cell. The relative parameters, such as open-circuit voltage (Voc), short-circuit current (Isc), fill factor (FF), power conversion efficiency (PCE) and maximum electrical power (Pmax) are shown in

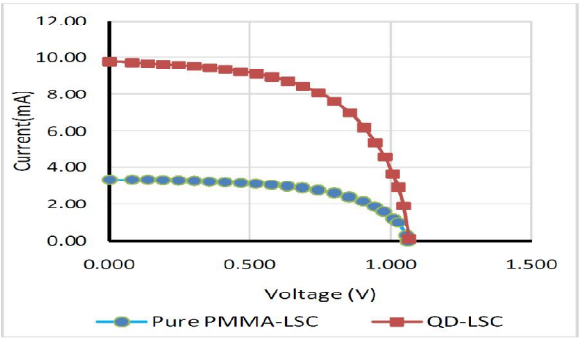


Fig.7.a, b).andTable 1.

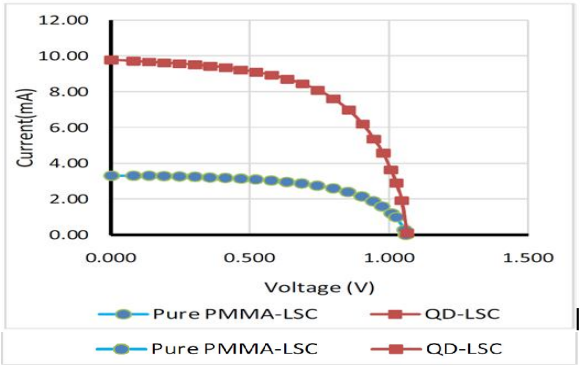


Fig.7.a) Relation of current and photo-voltage (I-V) of the LSCs with and without QDs.

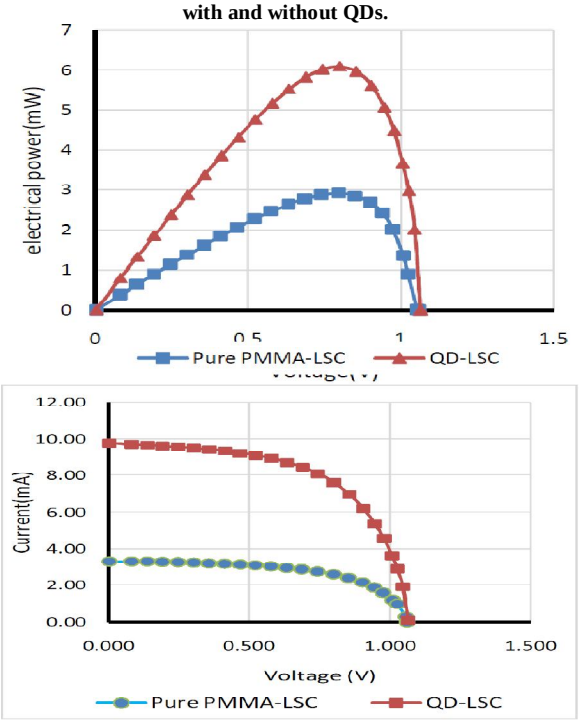


Fig.7.a) Relation of current and photo-voltage (I-V) of the LSCs with and without QDs.

Table 1: The performance of QDs-LSC-PV and pure PMMA-PV devices

Type	Isc (mA)	Voc (V)	FF (%)	PCE (%)	P_{max} (mW)
ure A-LSC	3.31	1.060	50.7	2.70	2.91
QDs-LSC	.78	1.065	58	9.16	6.

We observed that by adding CuInSeS/ZnS QDs in the pure PMMA waveguide, the current increases significantly. The value of Isc and Voc, increase from 3.31mA and 1.06V to 9.78mA and 1.065V with pure PMMA-PV and QDs-LSC-PV with the same Silicon solar cell respectively. The power conversion efficiency and maximum electrical power of 9.16% and 6.09mW was obtained from the LSC doped with QDs respectively, which is more than 3 folds to the LSC device without QDs.

CONCLUSION

In this research, the CuInSeS/ZnS QDs with large Stokes shift (140nm) has been proposed. The combination of large stock shift and broad solar absorption of this quantum dot quantum dot allows us to overcome the reabsorption loss in the LSC sheet. When PMMA is doped with quantum dot, the Isc, Voc, FF, PCE and P_{max} are 9.78 mA, 1.065 V, 58%, 9.16% and 6.09mW respectively. Therefore, the results of the current paper reveal through an organized study on the optical properties of PMMA doped with CuInSeS/ZnS QDs that are often appropriate for LSC applications.

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