Effects of Photo-luminescence-Efficiency of CdSe/ZnS Core-Shell Quantum Dots for Photo-voltaic Performance for Silicon Solar-cells

Seung-Wook Baek, Hyun-Min Seung, Jae-Hyoung Shim, Min-Ha Choi, Gon-Sub Lee, and Jea-Gun Park*

Department of Electronic Engineering, Hanyang University, Seoul 133-791, Korea

In recent study, silicon solar cell performance has been great progressed due to mature understanding about silicon material properties and fabrication process optimization etc. However, the power-conversion-efficiency (PCE) of silicon solar cells has increased slowly for last 10 years. In order to overcome the current limitation of the PCE of silicon solar-cells, the following technologies has been studied such as nano-structures on surface for light confinement, selective emitter or local back contact structures for better absorption of the sun light etc. Thus, a novel technology to improve the PCE of silicon solar-cells should be introduced. In our study, we investigated how CdSe/ZnS core/shell quantum dots implemented on <111> textured p-type silicon solar-cells enhance the PCE of silicon solar-cells. In particular, we will review the effect of photo-luminescence (PL) efficiency on the PCE of silicon solar cells implemented with core/shell quantum dots.

In order to synthesize core/shell quantum dots, cadmium oxide (0.4 mmol), oleic acid (17.43 mol), Zinc acetate (4 mmol) and 1-octadecene (62.5 mmol) were added into the three necked flask. The mixture was heated and distilled at 150 ^{o}C under nitrogen atmosphere after vacuumed to remove acetic acid. Selenium and sulfur solution was prepared separately by dissolving selenium (2.3 mmol) and sulfur powder (4mmol) in each tryoctylphosphine solution (3.36 mmol). Perfectly dissolved selenium and sulfur solution was obtained by heated each solution to 100 ^{o}C. Subsequently, distilled mixture was heated up to 310 ^{o}C. Then, selenium and sulfur solution were rapidly transferred to reaction flask and reacted for 30 minutes to complete reaction. After completion, the mixture was cooled to room temperature and quantum dots were precipitated by centrifugation after addition of hydrophilic solvent such as ethanol. In this process, the supernatant was discarded and precipitates were re-dispersed in chloroform. The PL emission spectra of quantum dots were tunable by changing selenium and sulfur precursor injection sequence; e.g., simultaneous injection of selenium and sulfur, selenium first followed by sulfur, or sulfur first followed by selenium. The green-wavelength-light emission QDs were obtained by injecting selenium and sulfur solution at once, as shown in Fig. 1(a). The red-wavelength-light emission QDs were observed when the selenium first was injected and followed by Sulfur. The blue-wavelength-light emission QDs were observed when sulfur was first injected and followed by selenium.

CdSe/ZnS core/shell QDs were spin-coated on the silicon dioxide film grown on silicon wafer. The absorption and photo-luminescence for three types (blue, green and red) of CdSe/ZnS core/shell QDs were measured, as shown in Fig.2. The absorbance of blue-wavelength-light emission QDs started from 237 to 480 nm in wavelength and increased with the QD concentration, as shown in Fig. 2(a). In addition, the blue-wavelength-light emission QDs emitted the blue light with 454 nm in wavelength. The correlation between absorbance and PL peak indicates that blue-wavelength-light emission QDs absorb the light with less than 480 nm in wavelength and emits the blue light with 454 nm in wavelength, which conducts the energy-down-conversion. The absorbance of green-wavelength-light emission QDs started from 250 to 570 nm in wavelength and increased with the QD concentration, as shown in Fig. 2(a). In addition, the green-wavelength-light emission QDs emitted the green light with 534 nm in wavelength. The correlation between absorbance and PL peak indicates that green-wavelength-light emission QDs absorb the light with less than 570 nm in wavelength and emits the green light with 534 nm in wavelength, which conducts the energy-down-conversion. The absorbance of red-wavelength-light emission QDs started from 245 to 700 nm in wavelength and increased with the QD concentration, as shown in Fig. 2(a). In addition, the red-wavelength-light emission QDs emitted the red light with 653 nm in wavelength. The correlation between absorbance and PL peak indicates that red-wavelength-light emission QDs absorb the light with less than 700 nm in wavelength and emits the red light with 653 nm in wavelength, which conducts. CdSe/ZnS QDs are spin-coated on <111> SiN_X (anti-reflective layer) p-type silicon solar-cell. The surface reflectances of them were shown in Fig.3. Surprisingly, the surface reflectance decreased with the core/shell QD concentration at ultra, indicating the occurrence of energy-down-conversion through core/shell quantum. In our presentation, we will show the external quantum efficiency as a function of wavelength and photo-voltaic performance for p-type silicon solar-cells implemented with blue, green, red-light emitting CdSe/ZnS QDs.

Fig.1. Blue, green, and red light emission after illumination of 254-nm UV light for CdSe/ZnS QDs

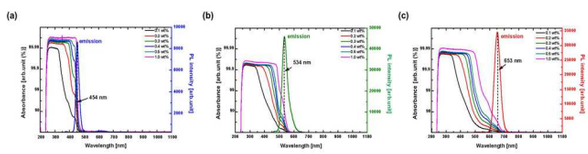

Fig. 2. The UV-visible absorbance and photo-luminescence intensity for blue, green, and red light emitting QDs

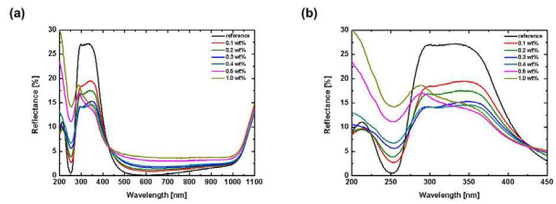

Fig. 3. The results of reflectance of p-type silicon solar cell implemented with green-light emitting CdSe/ZnS QDs

Reference

[1] M. Tuan Trinh. et al., Nature Photonics 6, 316–321 (2012)

[2] Nozik, A. J, *Physica E* **14**, 115–120 (2002)

* This work was financially supported by the grant from the "Next-generation Substrate technology for high performance semiconductor devices (No. KI002083)" of the Ministry of Knowledge Economy (MKE), the Brain Korea 21 Project in 2012.