Electrophoretic deposition of quantum dots for photovoltaic applications

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The push to develop third-generation solar cells that overcome the Shockley−Queisser efficiency limit for a single absorber, 31%, is one of the most fascinating challenges in the energy research field [1]. In this aspect, semiconductor quantum dots (QDs) have been extremely attractive because of their size-dependent properties [2]. However, in most cases films of as-synthesized QDs have poor electrical conductivity and these QDs must undergo ligand exchange before they are used for photovoltaic applications [3]. Although ligand exchange of QDs has been well developed by solution processing, post-ligand exchange has been usually carried out during layer-by-layer deposition that is used to achieve the desired thickness [4]. However, this process requires many (5-20) repeated steps in photovoltaic applications and such ligand exchange has been limited to ligands such as ethanedithiol [3]. In this study, we investigate an alternative method based on electrophoretic deposition (EPD) for thin film fabrication of QDs after ligand exchange by solution processing.

CdSe QDs (or nanocrystals NCs) can be prepared with high quality by solution processing; they and their ligand chemistry have been intensively studied. The exchange of the initial ligand in CdSe QDs with pyridine demonstrates the high yield of ligand exchange [4]. In our study, the ligand exchange of CdSe QDs from TOP/TOTO/phosphonate to pyridine was performed as reported earlier [4]. The ligand exchange was confirmed by FT-IR, PL, UV-absorbance, and EDS. We found that pyridine-capped CdSe QDs were well dispersed in pyridine and chloroform solvents and we deposited films of these CdSe QDs by using EPD methods reported earlier [5]. Interestingly, whereas EPD forms films of TOP/TOTO/phosphonate-capped CdSe QDs on both electrodes [5], these films formed only on the negative Au electrode, which may imply that pyridine-capped CdSe QDs are only positively charged. We used this process as one step in forming photovoltaic test structures: ZnO was spin coated on ITO and then a film of CdSe QDs was deposited by EPD. Then, a CuPc/MoOx/Au layer was deposited by thermal evaporation. Figure 1(a) depicts the layer structure and (b) shows the J-V curve of the assembled photovoltaic device, which is seen to have a 0.53% power conversion efficiency (PCE).

In this talk, we will discuss details of this new approach to fabricate photovoltaic devices by using EPD to deposit thin films of QDs.

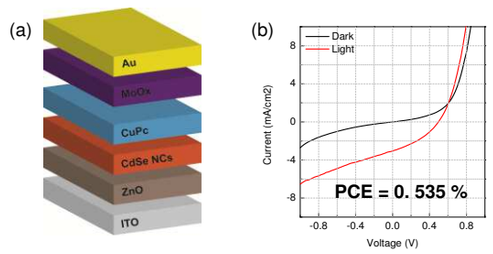

Figure 1. (a) Schematic of photovoltaic device fabricated using electrophoretic deposition of CdSe QDs. (b) J-V characteristics of the photovoltaic device. The CdSe QDs are ~5.7 nm in diameter.

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