Bandgap Engineering of Sol-Gel Synthesized Zn_{1-x}Mg_xO films as Electron-Transporting Layers for PbS Colloidal Quantum Dot Solar Cells

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Introduction

Colloidal quantum dots solar cells (CQDSCs) have recently reached promising power conversion efficiencies (η) of over 11%. We found that the tail of states in the conduction band of the normal metal oxide layer (ZnO or TiO_2) can limit the achievable CQDSC efficiency. In order to achieve high performance CQDSCs, there is a great need and growing interests to develop novel electron-transporting layer (ETL) materials with tunable bandgaps and energy levels, high transparency, and excellent carrier transporting properties. By continuously tuning the zinc oxide conduction band position via magnesium doping, we probe this critical loss pathway in ZnO–PbS CQDSCs and optimize the energetic position of the tail of states. This resulted in large enhancements in Voc (from 475 mV to 492 mV) and Jsc (from 24 mA/cm^2 to 26 mA/cm^2) as well as the energy conversion efficiency (from 6.08% to 7.10%).

Experimental Method

Colloidal PbS QDs were synthesized according to a modified literature method. ZnMgO were prepared by sol–gel method. The precursor was prepared by employing zinc acetate dehydrate and magnesium acetate tetrahydrate (0%, 5%, 10%, and 15% mol) as Zn and Mg source, respectively. The sol-precursor was spin coated at 3000 rpm for 30 s on FTO glass substrate, then annealed in oven at 290 °C for 30 min. Then, ZnMgO compact film was coated with PbS QDs. Finally, the device was then completed with an Au contact deposited via a shadow mask resulting in a device area of 0.16 cm^2.

Results and Discussion

The addition of Mg can either replace Zn^{2+} or form MgO secondary phase. As shown in XPS (figure 2), the binding energy peaks related to Mg 2p, as well as Zn 2p and O 1s, are observed for all Mg doped samples, demonstrating the successful doping of Mg elements and the formation of ternary oxide films of ZnMgO. But when x =0.2, the binding energy peak Mg 2P and Oxygen 1s position have changed, indicating addition of Mg may form MgO phase.