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Deposition of quantum dot shell on semiconductor particles: A strategy to suppress recombination in dye-sensitized solar cells based on ZnO

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Increment of band gap is a prominent result of the size quantization effects of semiconductor nano-particles. Here we report a technique to suppress recombination in dye-sensitized solar cells, which is a major problem of these devices, adopting this phenomenon.

ZnO particles of the size of ~5 nm were prepared according to a previously reported method. Briefly, zinc acetate 5.5 g was dissolved in a mixture of 50 ml of ethanol and 10 ml of tetramethyl ammonium hydroxide. Quantum (Q) size ZnO particles become visible when this solution was refluxed for 30 minutes. A measured quantity of Q size ZnO particles and ZnO powder were mixed, sprayed onto Conducting Tin Oxide (CTO) glass plates and sintered at 450 °C to make electrodes of ZnO. Dye sensitized solar cells were fabricated coating these electrodes with Mercurochrome dye and using I^-/I_3^- redox electrolyte.

A sharp absorption edge could be observed for ZnO colloid (~5nm) at 360 nm and the band gap absorption of ZnO powder (~200 nm) was at 382 nm. Using these values the band gaps of ZnO in two different sizes were calculated as 3.3 eV and 3.1 eV respectively.

For comparison, solar cells consisting only of ZnO colloid and Powder were constructed seperately. The photocurrent and photovoltage of the former cell is as high as 7.75 mA cm^{-2} and 520 mV. But the latter two produced very low photocurrents as 2.15 mA cm^{-2} and 0.465 mA cm^{-2}, although their photovoltages are comparable (489 mV and 499 mV respectively).

This significant enhancement in the solar cell with the quantum dot shell occurs due to two reasons. One is the high rate of dye adsorption on Q size particles. The other important reason is suppression of recombination of injected electrons by the ZnO quantum dot shell, which has a higher conduction band edge than the ZnO powder that prevents the leaking out of electrons to the electrolyte or reacting again with the dye cation.

Previously this has been achieved with the use of two types of semiconductors with graded band gaps or coating a thin insulating layer over the semiconductor particles. The importance of our finding is that we have used a single semiconductor grown in different sizes to achieve the same goal. This can be done for other semiconductor materials such as TiO_2 and SnO_2 etc. those frequently used to fabricate dye-sensitized solar cells.

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