Eco-friendly $AgBiS_2$ Nanocrystal / ZnO Nanowire Heterojunction Solar Cells with Enhanced Carrier Collection

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Solution-process compatibility and size-dependent bandgap tunability of colloidal quantum dots (CQDs) make them low-cost promising materials for next generation solar cells. Among CQD-based solar cells, devices formed with PbS CQDs and ZnO exhibit impressive performance. However, researches of eco-friendly CQDs-based solar cell are still limited. $AgBiS_2$ colloidal nanocrystals (NCs) with a wide absorption band (0.4-1.2 μm) are one of the alternatives to PbS CQDs. However, the power conversion efficiencies (PCEs) of planar-type solar cells using $AgBiS_2$ NCs (ITO / ZnO dense layer / $AgBiS_2$ NC layer/ hole transport layers (eg. PTB7:MoOx) / Ag) have been at most approximately 6% mainly due to the short carrier diffusion length of $AgBiS_2$ [1].

In this work, we paid attention to nanowire (NW) structures, with the aim of elongation of carrier diffusion length, and we also applied widely used and less-expensive hole transport materials. We then fabricated NW-type solar cells (ITO / ZnO NW: $AgBiS_2$ mixture / $AgBiS_2$ overlayer / P3HT / Au) by using different ZnO NW lengths and the overlayer thicknesses to study charge collection in $AgBiS_2$ NW-type solar cells (NWSCs). ZnO NWs were synthesized by a hydrothermal method, and the length of ZnO NW was controlled by the reaction time [2]. As a reference, planar-type solar cells (NPSCs) using ZnO layers with different thicknesses were also constructed.

PCE values of NPSCs increase as $AgBiS_2$ layer becomes thicker and reach to a maximum value of 2.06% at 100 nm. And PCE then decreases with thickening $AgBiS_2$ layers due to the limited carrier diffusion length of $AgBiS_2$ layer. Whereas in the case of NWSCs, the highest PCE of 4.14% is obtained at an overlayer thickness of 120 nm, which is close to the optimal thickness of planar cell, the performance improvement of NWSC is due to the ZnO NW / $AgBiS_2$ NC mixture region. Moreover, the NWSC gives a maximum EQE value of 80%, twice as high as the EQE value of NPSC-41%. This indicates that ZnO NW / $AgBiS_2$ NC mixtures are useful to achieve efficient light harvesting and efficient carrier collection simultaneously. A J_{sc} of 20.54 mA/cm^2 is obtained for NWSC, which is higher than previously-reported $AgBiS_2$ solar cells (eg. J_{sc} = 15.10 mA/cm^2, V_{oc} = 0.46 V, FF = 57%, and PCE = 3.99% [1]). In addition, at least 3-month air stability has been confirmed in NWSCs.

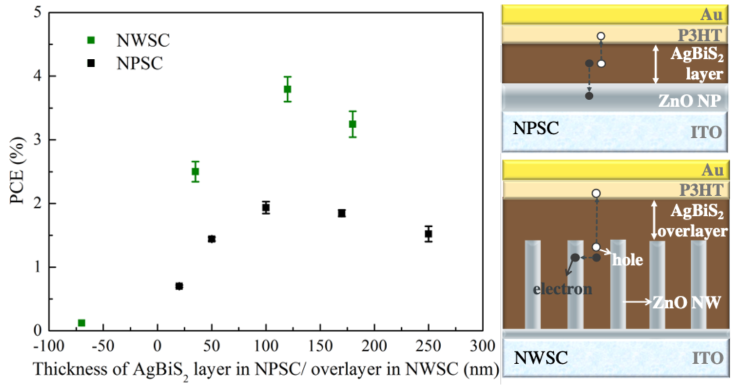

Figure 1. PCE dependence of thickness of $AgBiS_2$ layer in NPSC and thickness of $AgBiS_2$ overlayer in NWSC (with the same length of ZnO NW) (left); Scheme of structures of NPSC and NWSC (right).

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[2] H. Wang, T. Kubo, J. Nakazaki, T. Kinoshita, H. Segawa. *J. Phys. Chem. Lett.* 2013, **4**, 2455. S