***Systematic characterization of the effect of Ag@$TiO_2$ nanoparticles on the performance of plasmonic dye-sensitized solar cells***

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The use of plasmonic nanoparticles (NPs) in dye-sensitized solar cells (DSSCs) in an effort to enhance their power conversion efficiencies (PCEs) increases light absorbance of the cells but also affects their electron dynamics. This has contributed to the failure of plasmonic NPs to make the expected high impact of PCE enhancement. Herein, we investigated the wide range effects of plasmonic NPs on the performance of DSSCs, using extended characterization and a systematic approach. We prepared DSSCs using Ag@$TiO_2$ core-shell NPs-loaded $TiO_2$ photoanodes. Using a wide range loading concentration, we obtained panchromatic enhancement effect with two optimal Ag@$TiO_2$-doping concentrations (0.1 and 1 wt. %). They enhanced PCE via mainly: a) optimal band alignment for efficient charge injection; and b) a balance of the negative and positive effects of plasmonic NPs on cell performance parameters (open circuit voltage, fill factor, charge transfer resistance against recombination, electron life time and charge collection efficiency); respectively. The major cause of not obtaining very high PCE was charge recombination from high charge density. Thus, these observations might serve as invaluable guidance for the preparation of highly efficient plasmonic DSSCs.

**Table 1.** Effect of plasmonic NPs on the photoanode surface area and extracted I-V & EIS parameters.

| Sample (Ag@$TiO_2$ wt.) | BET SA ($m^2$ $g^{-1}$) | $J_{SC}$ (mA $cm^{-2}$) | $V_{OC}$ (V) | $FF$ | PCE (%) | $R_s$ (Ω) | $R_{CT}$ (Ω) | $\tau_n$ (ms) | $\eta_{CC}$ /% |
|---|---|---|---|---|---|---|---|---|---|
| **0%** | 44.2 | 9.74 | 0.709 | 0.531 | 4.66 | 20.1 | 4.8 | 5.04 | 19.3 |
| **0.1%** | 42.6 | 10.89 | 0.702 | 0.502 | 4.88 | 20.8 | 4.2 | 4.00 | 16.8 |
| **0.25%** | 40.4 | 9.04 | 0.722 | 0.546 | 4.54 | 20.6 | 7.1 | 5.04 | 25.6 |
| **0.5%** | 36.1 | 8.48 | 0.727 | 0.547 | 4.29 | 22.1 | 10.4 | 6.34 | 32.0 |
| **1%** | 34.7 | 8.93 | 0.744 | 0.591 | 5.00 | 20.0 | 7.1 | 6.34 | 26.2 |
| **5%** | 32.9 | 3.78 | 0.777 | 0.641 | 2.40 | 21.7 | 15.8 | 12.63 | 42.1 |