Plasmonic Photovoltaic Cells Based on Two-Dimensional Metal Halfshell Arrays

University of Tokyo, °Ling Wu, Gyu Min Kim, Hiroyasu Nishi, Tetsu Tatsuma
E-mail: tatsuma@iis.u-tokyo.ac.jp

Since our group found plasmon-induced charge separation (PICS) at the Au-TiO_2 interface,[1] many studies have focused on development of novel plasmonic materials and devices.[2-3] Recently, we applied ordered plasmonic halfshell arrays to PICS.[4] The prepared photoelectrodes with two-dimensional (2D) Au halfshell arrays on SiO_2@TiO_2 colloidal crystals give negative photopotential shifts and anodic photocurrents in wet cells. Here we developed solid-state cells by taking advantage of the 2D structure of the metal halfshell array, which serves both as a light absorber and a current collector.

The solid-state cells with dual functional metal halfshell arrays (Fig. 1a) showed good rectification behavior in the dark, suggesting that the interface between TiO_2 and the Au halfshell forms a Schottky junction. Under visible light irradiation (≥ 460 nm, 100 mW cm^{-2}), all the cells generated photovoltage between the transparent ITO electrode and the Au halfshell array electrode. Figure 1b shows IPCE action spectra for the cells with different TiO_2 shell thicknesses. A thick TiO_2 shell seems to be advantageous for efficient charge separation. Next, we compared the photovoltaic properties of a Au halfshell cell with those of a Ag halfshell cell. As shown in Fig. 1c, the photoresponses of the Ag halfshell cell were much larger than those of the Au halfshell cell. The maximum IPCE value for the Ag halfshell cell was 2.8% at 440 nm. The short-circuit photocurrents of the Au and Ag halfshell cells did not decrease under light irradiation for at least 2 h.

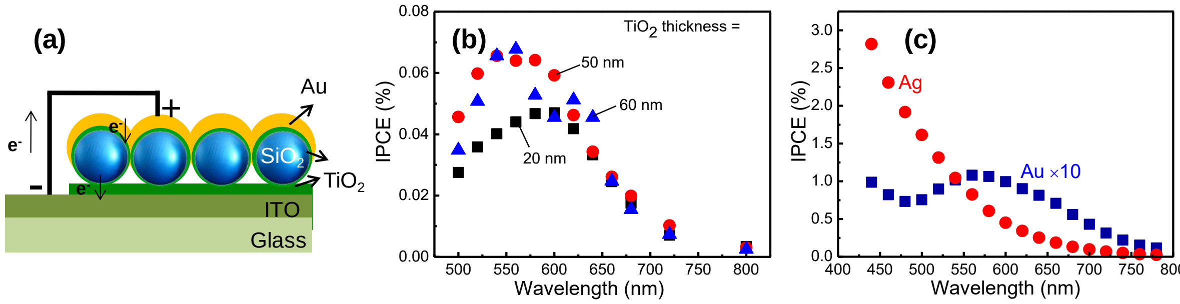

Fig. 1 (a) Schematic illustration of the solid-state cell with a Au halfshell array. (b) IPCE action spectra for the cells with the Au halfshell arrays. (c) The comparison of IPCE spectra between the Ag and Au halfshell cells.

References

[1] Y. Tian, T. Tatsuma, *J. Am. Chem. Soc.*, 127, 7632-7637 (2005).
[2] L. Wu, F. Li, Y. Xu, J. W. Zhang, D. Zhang, G. Li, H. Li, *Appl. Catal. B*, 164, 217-224 (2015).
[3] Y. Takahashi, T. Tatsuma, *Appl. Phys. Lett.*, 99, 182110 (2011).
[4] L. Wu, H. Nishi, T. Tatsuma, *APL Mater.*, 3, 104406 (2015).