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Nanotube-based Dye-sensitized Solar Cells

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Dye-sensitized solar cells (DSCs) have drawn great academic attention due to their potential as low-cost renewable energy sources. DSCs contain a nanostructured TiO2 photoanode, which is a key-component for high conversion efficiency. Particularly, one-dimensional (1-D) nanostructured photoanodes can enhance the electron transport for the efficient collection to the conducting substrate in competition with the recombination processes. This is because photoelectron colletion is determined by trapping/detrapping events along the site of the electron traps (defects, surface states, grain boundaries, and self-trapping). Therefore, 1-D nanostructured photoanodes are advantageous for the fast electron transport due to their desirable features of greatly reduced intercrystalline contacts with specified directionality. In particular, anodic TiO2 nanotube (NT) electrodes recently have been intensively explored owing to their ideal structure for application in DSCs. Besides the enhanced electron transport properties resulted from the 1-D structure, highly ordered and vertically oriented nanostructure of anodic TiO2 NT can contribute additional merits, such as enhanced electrolyte diffusion, better interfacial contact with viscous electrolytes.

First, to confirm the advantages of 1-D nanostructured material for the photoelectron collection, we compared the electron transport and charge recombination characteristics between nanoparticle (NP)- and nanorod (NR)-based photoanodes in DSCs by the stepped light-induced transient measurements of photocurrent and voltage (SLIM-PCV). We confirmed that the electron lifetime of the NR-based photoanode was much longer than that of the NP-based photoanode. In addition, highly ordered and vertically oriented TiO2 NT photoanodes were prepared by electrochemical anodization method. We compared the photovoltaic properties of DSCs utilizing TiO2 NT photoanodes prepared by one-step anodization and two-step anodization. And, to reduce the charge recombination rate, energy barrier layer (ZnO, Al2O3)-coated TiO2 NTs also applied in DSC. Furthermore, we applied the TiO2 NT photoanode in DSCs using a viscous electrolyte, i.e., cobalt bipyridyl redox electrolyte, and confirmed that the pore structure of NT array can enhance the performances of this viscous electrolyte.

Keywords: Solar cell, Dye-sensitized solar cell, TiO2, nanotube