Physica E 123 (2020) 114206

Contents lists available at ScienceDirect

Physica E: Low-dimensional Systems and Nanostructures

journal homepage: http://www.elsevier.com/locate/physe

Biphasic TiO_2 nanoleafed nanorod electrode for dye-sensitized solar cell

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ARTICLE INFO

Keywords:
Hierarchical nanostructure
Titanium dioxide
Anataserutile
Nanoleafed nanorod array
Dye-sensitized solar cell

ABSTRACT

The thin-film of hierarchical rutile/anatase TiO_2 nanorod/nanoleafs on fluorine-doped tin oxide glass was prepared via a facile method. For this purpose, the hydrothermal method was used for the synthesis of rutile-phase nanorods on the TiO_2 seeded FTO, and aqueous chemistry was applied for growing anatase-phase nanoleafs on the nanorods. The structural, morphological, and optical properties of coating characterized, and the thin-film utilized as the photoelectrode for dye-sensitized solar cell. The energy conversion efficiency of the newly developed nanostructure was higher than that of TiO_2 nanorod thin-film by 40%. This increase could be ascribed to: (1) superior specific surface area providing dye-holding and light-scattering ability, (2) accelerating charge transport due to direct pathways for photogenerated charge carriers as a result of nanorods presence in the structure, and (3) improving charge separation at the junctions of rutile-phase nanorods and anatase-phase nanoleafs.

1. Introduction

Solar energy is an essential sustainable energy source because of its global availability, abundance, and cleanliness. It may be converted to chemical energy via the photocatalysis process or to electric energy through solar cells. Among various solar cells, dye-sensitized solar cells (DSSCs) have received much attention due to relatively high conversion efficiency, low-cost materials, and simple fabrication [1–5].

A variety of metal oxides have been investigated as photoelectrode [6–12]. Among them, titanium dioxide (TiO_2) has received much attention due to some superiorities such as being environmentally friendly, chemical/thermal stability, photocorrosion resistance, low cost, and availability [13–15].

The crystal structure and morphology of TiO_2 play important roles in the efficiency of DSSCs [16,17]. Rutile phase proposes a higher refractive index, better chemical stability, lower bandgap energy, and cheaper cost of production [18–20]. On the other hand, the anatase phase has superior mobility of electron-hole pairs, larger specific surface area, and improved surface hydroxyl density [21–23]. The biphasic TiO_2 structure represents the usability of both phases' characteristics and synergistic properties of individual phases. Moreover, a primary advantage of the simultaneous presence of two phases in structure is that different positions of valence/conduction bands energy levels of rutile and anatase result in the separation of photogenerated charge carriers. Thus the photoelectrochemical activity of TiO_2 would enhance [24,25]. TiO_2 morphology directly affects the electron mobility and specific surface area [26]. One-dimensional nanostructures such as nanorods, nanotubes, and nanowires provide direct pathways for photogenerated charge carriers leads to accelerate charge transport [27–31]. The limitations are insufficient dye-holding and light-scattering ability [32]. Three-dimensional nanostructures based on one-dimensional nanostructure such as nanobranched nanorod arrays offer a superior specific surface area and light-harvesting for overcoming to these drawbacks, meantime retain high transport capacity [33–35].

In this work, a thin-film of hierarchical rutile/anatase TiO_2 nanorod/nanoleafs on fluorine-doped tin oxide glass was prepared via a facile method, and the photovoltaic performance of this novel nanostructure as the electrode of the dye-sensitized solar cell was evaluated.

2. Materials and method

2.1. Materials

Fluorine-doped tin oxide glass (FTO) was supplied from Dyesol Company. Titanium butoxide, titanium tetrachloride, hydrochloric acid, acetone, 2-propanol, and sodium chloride were purchased from Merck. Ammonium hexafluo-rotitanate, chloroplatinic acid, and boric acid were obtained from Sigma-Aldrich. Iodine-based electrolyte contains

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https://doi.org/10.1016/j.physe.2020.114206
Received 22 March 2020; Accepted 14 May 2020
Available online 19 May 2020
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