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Influence of electrolyte on the photovoltaic performance of a dye-sensitized TiO_2 solar cell based on a Ru(II) terpyridyl complex photosensitizer

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Abstract

We have investigated the influence of electrolyte composition on the photovoltaic performance of a dye-sensitized nanocrystalline TiO_2 solar cell (DSSC) based on a Ru(II) terpyridyl complex photosensitizer (the black dye). We have also spectroscopically investigated the interaction between the electrolyte components and the adsorbed dye. The absorption peaks attributed to the metal-to-ligand charge transfer transitions of the black dye in solution and adsorbed on a TiO_2 film, were red-shifted in the presence of Li cations, which led to an expansion of the spectral response of the solar cell toward the near-IR region. The photovoltaic performance of the DSSC based on the black dye depended remarkably on the electrolyte composition. We developed a novel efficient organic liquid electrolyte containing an imidazolium iodide such as 1,2-dimethyl-3-*n*-propylimidazolium iodide or 1-ethyl-3-methylimidazolium iodide (EMImI) for a DSSC based on the black dye. A high solar energy-to-electricity conversion efficiency of 9.2% ($J_{sc} = 19.0\,mA\,cm^{-2}$, $V_{oc} = 0.67\,V$, and $FF = 0.72$)

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was attained under AM 1.5 irradiation (100 mW cm^{-2}) using a novel electrolyte consisting of 1.5 M EMImI, 0.05 M iodine, and acetonitrile as a solvent with an antireflection film.

Keywords: Dye-sensitized solar cell; Ru complex; TiO_2 electrode; Electrolyte; Imidazolium iodide

1. Introduction

Dye-sensitized nanocrystalline TiO_2 solar cells (DSSCs) have been intensively studied during the last decade both because these unconventional solar cells exhibit high performance and because they offer the possibility for low-cost production of devices [1–5]. Ruthenium polypyridyl complexes have been used in DSSCs as efficient photosensitizers [6–11]. The DSSC that exhibits the best solar-cell performance so far is one based on trithiocyanato 4,4′4″-tricarboxy-2,2′:6′,2″-terpyridine ruthenium(II) (the so-called black dye), owing to its wide absorption region, which extends to 900 nm [9]. Detailed studies of the solar cell performance, spectroscopic measurements, and electron transfer kinetics of DSSCs based on the black dye have been reported [9,12]. Nevertheless, the reports on the effect of electrolyte composition on the photovoltaic performance of DSSCs based on the black dye are quite few.

To further improve the performance of DSSCs based on the black dye and to clarify the factors determining the performance, we have investigated the effects of electrolytes on solar cell performance. The electrolytes normally used in DSSCs based on Ru-complex photosensitizers contain several components, such as 0.6 M (mol dm^{-3}) 1,2-dimethyl-3-*n*-propylimidazolium iodide (DMPImI), 0.1 M LiI, 0.1 M I_2, and 0.5 M 4-*tert*-butylpyridine (TBP) in acetonitrile [9]. Several imidazolium salts have been found to play an important role in improving the photovoltaic performance of DSSCs based on liquid electrolytes [13–18] and on quasi-solid-state electrolytes [19–23]. Recently, we have developed novel organic liquid electrolytes that contain an imidazolium iodide, iodine, and acetonitrile as an organic solvent. We reported that these electrolytes performed better than a conventional electrolyte containing LiI and TBP for DSSCs based on the black dye [24]. In this paper, we report the effect of cations contained in the organic liquid electrolytes on the photovoltaic performance of a DSSC based on the black dye, and we also report the good performance of a novel electrolyte containing an imidazolium salt. In addition, we report an interaction between the black dye and Li cations measured by UV–vis and FT–IR absorption spectroscopies.

2. Experimental

2.1. Preparation and characterization of dye-sensitized TiO_2 thin films

TiO_2 colloids were prepared by the method reported by Grätzel and co-workers [14,18]. The two colloids, 60% w/w of acidic TiO_2 colloid and 40% w/w of basic