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Influence of 1-methyl-3-propylimidazolium iodide on I_3^-/I^- redox behavior and photovoltaic performance of dye-sensitized solar cells

Shi Chengwu[a,b], Dai Songyuan[a,*], Wang Kongjia[a], Pan Xu[a], Guo Li[a], Zeng Longyue[a], Hu Linhua[a], Kong Fantai[a]

[a]Institute of Plasma Physics, Chinese Academy of Sciences, P. O. Box 1126, Hefei, Anhui 230031, PR China
[b]School of Chemical Engineering, Hefei University of Technology, Hefei, Anhui 230009, PR China

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Abstract

In this paper, we investigated redox behavior of I^- and I_3^- in 3-methoxypropionitrile (MePN) with different concentrations of 1-methyl-3-propylimidazolium iodide (MPII) and iodine by cyclic voltammetry and electrochemical impedance spectroscopy. It was found that the apparent diffusion coefficient (D) values of triiodide and iodide ions, the serial resistance (R_s) and the charge-transfer resistance (R_{ct}) decreased slightly with increase of the concentration of I_3^- in MePN containing 1.4 M MPII. Moreover, the R_{ct} and D values of triiodide and iodide ions affection on dye-sensitized solar cells (DSCs) should be considered as a whole. The DSCs with the electrolyte (1.4 M MPII, 0.1 M LiI, 0.1 M I_2, 0.5 M TBP, in MePN) gave short circuit photocurrent density (J_{sc}) of 14.44 mA/cm^2, open circuit voltage (V_{oc}) of 0.72 V, and fill factor (FF) of 0.69, corresponding to the photoelectric conversion efficiency (η) of 7.17% under one Sun (AM1.5).

Keywords: Dye-sensitized; Solar cell; 1-methyl-3-propylimidazolium iodide; Redox behavior

*Corresponding author. Tel.: +86 551 5591377; fax: +86 551 5591310.
E-mail address: sydai@ipp.ac.cn (D. Songyuan).

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1. Introduction

Dye-sensitized nanoporous TiO_2 solar cells (DSCs) have been extensively studied due to the high photo-electric conversion efficiency up to 10% [1–10]. One of main components of DSCs is an electrolyte containing the I_3^-/I^- redox couple. It is known that alkylimidazolium iodides are essential components of electrolytes to achieve good performance of DSCs. First, the presence of alkylimidazolium cations contributes to enhancement of conductivity of the I_3^-/I^- electrolyte. Second, the multilayer adsorption of alkylimidazolium cations on the TiO_2 surface of DSCs leads to the increase of electron diffusion coefficient with increasing concentration of these cations, which dramatically improves cell performance [5,7]. Although alkylimidazolium cations have been widely used in DSCs, there is no detailed study on the influence of 1-methyl-3-propylimidazolium iodide on the I_3^-/I^- redox behavior and the photovoltaic performance of DSCs.

In this article, we investigated redox behavior of I^- and I_3^- in MePN containing different concentrations of MPII and iodine by cyclic voltammetry and electrochemical impedance spectroscopy. The photovoltaic performance of DSCs with MPII in MePN was measured.

2. Experimental section

Materials: Anhydrous lithium iodide, 4-tert-butylpyridine (TBP) and 3-methoxypropionitrile (MePN) were purchased from Fluka, and used as received. 1-methyl-3-propylimidazolium iodide (MPII) was synthesized from 1-methylimidazole (Fluka) and propyl iodide (Fluka) [11] and its purity was confirmed by 600-MHz ^{1}HNMR(DMX-600, Bruker, Switzerland).

DSCs assembly: Briefly, the TiO_2 (anatase) colloidal solution was prepared by hydrolysis of titanium tetraisopropoxide [12]. The TiO_2 paste was printed on transparent conducting glass sheets (TEC-8, LOF) by using a screen-printing technique and sintered in air at 450 °C for 30 min to form a nanostructured TiO_2 electrode. The film thickness was about 10 μm, which was determined by a profilometer (XP-2, AMBIOS Technology Inc. USA). A 4-μm-thick light scattering layer was used in this study. After cooling to 80 °C, the films were immersed in a anhydrous ethanol solution with 5.0×10^{-4} M *cis*-dithiocyanate-*N,N*′-bis-(4-carboxylate-4-tetrabutylammonium carboxylate-2,2′-bipyridine)ruthenium (II) (N719) overnight. The excess of N719 dye in TiO_2 films was rinsed off with anhydrous ethanol before assembly. The counter electrode was platinized by spraying H_2PtCl_6 solution to TCO glass and fired in air at 410 °C for 20 min. Then, it was placed directly on the top of the dye-sensitized TiO_2 film. The gap between the two electrodes was sealed by thermal adhesive films (Surlyn, Dupont). The electrolyte was filled from a hole made on the counter electrode and the hole was later sealed by a cover glass and thermal adhesive films. The total active electrode area of DSCs was 0.16 cm^2.