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Synthesis of a novel alkylimidazolium iodide containing an amide group for electrolyte of dye-sensitized solar cells

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1. Introduction

Dye-sensitized solar cells (DSSCs) convert sunlight to electricity with high conversion efficiency [1,2]. Although a light-to-electricity conversion efficiency of more than 11% has been achieved in liquid electrolyte-based DSSCs [3–5], the major drawback of these solar cells is their poor long-term stability owing to the evaporation of the liquid phase in the cells. To improve the stability of DSSCs, investigations have focused on replacing the liquid electrolyte by a solid-state medium, such as inorganic p-type semiconductors [6], organic hole-transport materials [7], room-temperature molten salts [8–10], polymer gel electrolytes [11,12], and solid polymer redox electrolytes [13,14].

Although solid-state electrolytes solve some problems, they show lower conversion efficiency than liquid electrolytes because of poor contact between the solid-state charge transport material and the dye-coated TiO₂ surface. Polymer gel electrolytes offer the advantages of low vapor pressure, good long-term stability, excellent contacting and filling properties between the nanostructured electrode and counter electrolytes have attracted intensive attention [15–23]. The various materials used as matrices for ionic gels and ionic polymer electrolytes to fabricate quasi-solid-state DSSCs have included ethylene oxide copolymer [24,25], polyvinyl pyridine cross-linked copolymer [26], vinyliden–propylene copolymer

ABSTRACT

A novel alkylimidazolium iodide containing an amide group, 1-(2-hexanamidoethyl)-3-methylimidazol-3-ium iodide (amido-ImI), was synthesized to act as the quasi-solid-state electrolyte of dye-sensitized solar cells (DSSCs). The DSSC with the amido-ImI electrolyte exhibited short-circuit photocurrent density (J_{sc}) and overall energy conversion efficiency (η) that were improved by 7.2% and 10.2%, respectively, compared to those obtained with the cell containing 1-hexyl-2,3-dimethylimidazolium iodide, a commonly used liquid electrolyte, at 100 mW cm⁻². Furthermore, the stability of the DSSC was enhanced by the presence of amido-ImI.

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[27], imidazole polymer [28], organic molecular [29], and inorganic particles [30]. Several molten salt-type polymers have been prepared by radical polymerization of vinyl derivatives containing imidazolium salts [31,32]. Kubo et al. [29] reported a highly stable DSSC (stable at 5% for almost 1000 h) using a gelated ionic liquid (IL) electrolyte based on 1-alkyl-3-methylimidazolium iodide.

Recently, growing attention has been paid to room-temperature ILs (RTILs), especially those containing imidazolium salts and pyridinium salts, due to their favorable properties such as thermal stability, non-flammability, high ionic conductivity, negligible vapor pressure, and possibly wide electrochemical window [33]. New electrolytic materials such as RTIL, gels and polymers are expected to be introduced for quasi-solid DSSCs in the future [34].

The unique properties offered by ILs such as non-volatility, nonflammability [35,36], high ionic conductivity [37] and gel-forming properties with polymers [38] have been reported to be beneficial in their application as DSSC electrolytes in order to achieve high temperature stability [39]. However, the conversion efficiency of the cells using ILs is lower than that of the cells using organic solvents, because the high viscosity of the ILs retards the physical diffusion of I⁻ and I₃⁻. An alkylimidazolium iodide which possesses a hydrogen bonding group has been considered as an alternative to overcome this drawback.

In this study, we synthesize a new alkylimidazolium iodide (amido-ImI) with the aim of enhancing the conductivities of I⁻ and I₃⁻. The influence of amido-ImI on the performance and long-term stability of the DSSC is investigated and compared to that of the DSSC with 1-hexyl-2,3-dimethylimidazolium iodide (ref-ImI), a commonly used liquid electrolyte, and the electrolyte contain-

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Fig. 1. Chemical structures of the imidazolium iodides: amido-ImI, ref-ImI and decyl-ImI.

ing 1-decyl-3-methylimidazol-3-ium iodide (decyl-ImI) having no amide group. The chemical structures of these imidazolium iodides are shown in Fig. 1.

2. Experimental

2.1. Materials

Anhydrous Lil, I₂, 4-*tert*-butylpyridine, 1-(3-aminopropyl)imidazole, imidazole, 1-bromodecane and trichloroethylene were purchased from Aldrich, sodium hydroxide, MgSO₄, CH₃OH and CH₂Cl₂ from Dae Jung, Korea, and hexanoyl chloride and iodomethane from Tokyo Chemical Industry. 1-Hexyl-2,3-dimethylimidazolium iodide was obtained from C-TRI, 3methoxypropionitrile, used as received, from Fluka, and N719 dye from Solaronix SA, Switzerland.

2.2. Synthesis of 1-(2-hexanamidoethyl)-3-methylimidazol-3-ium iodide (amido-Iml)

First, *N*-hexamideimidazole was synthesized by stirring the required quantity of 1-(3-aminopropyl)-imidazole with 1 N NaOH and CH₂Cl₂. Hexanoyl chloride was added dropwise to the stirred solution, which was allowed to stir overnight and again treated with excess of NaOH and CH₂Cl₂. The formed organic layer was washed with water and dried over MgSO₄. Finally, it was extracted with CH₂Cl₂ and evaporated to obtain the product, which was separated by silica column chromatography using CH₃OH or CH₂Cl₂ as the eluent. The obtained *N*-hexamideimidazole was confirmed by a Varian ¹H NMR (Oxford AS 400), mass spectroscopy and Fourier transformed infrared (FT-IR) spectrometers (Bomen MB-04). *N*-hexamideimidazole synthesized

from 1-(3-aminopropyl)-imidazole was characterized using FT-IR spectroscopy. The stretching vibrations of the NH₂ peak at 3200–3400 cm⁻¹ were preserved in the spectrum of 1-(3-aminopropyl)-imidazole, but the peak for the NH₂ group of the 1-(3-aminopropyl)-imidazole disappeared, indicating the formation of *N*-hexamideimidazole.

¹H NMR (300 MHz, CDCl₃, ppm): 0.87–0.91 (3H, –CH₃), 1.28–1.33 (4H, –CH₂–CH₂–), 1.58–1.67 (2H, –CH₂–), 1.90–2.10 (2H, –CH₂–), 2.13–2.20 (2H, –CH₂–), 3.25–3.30 (2H, –CH₂–), 3.98–4.02 (2H, –CH₂–), 6.96 (1H, –CH=), 7.08 (1H, –CH=), 7.54 (1H, –CH=).

Amido-ImI was then synthesized from *N*-hexamideimidazole as the starting material. *N*-hexamideimidazole (8.3 mmol) was dissolved in 10 ml of trichloroethylene, to which 0.98 ml (10.0 mmol) of iodomethane was added dropwise under an Ar atmosphere. The resulting solution was heated to reflux for 3 h with constant stirring and concentrated under vacuum. The residual salt was extracted with water and trichloroethylene followed by evaporation. The resulting product was dried under vacuum to obtain a white solid. The formation of the amido-ImI was finally identified by ¹H NMR (Fig. 2) and mass spectroscopy.

 ^{1}H NMR (300 MHz, D₂O, ppm): 0.65–0.69 (3H, –CH₃), 1.08–1.09 (4H, –CH₂–CH₂–), 1.35–1.40 (2H, –CH₂–), 1.88–1.91 (2H, –CH₂–), 2.01–2.06 (2H, –CH₂–), 3.01–3.05 (2H, –CH₂–), 3.71 (3H, –CH₃), 4.02–4.06 (2H, –CH₂–), 7.27 (1H, –CH=), 7.30 (1H, –CH=), 8.55 (1H, –CH=).

2.3. Synthesis of 1-decyl-3-methylimidazol-3-ium iodide (decyl-ImI)

First, 1-decyl-1H-imidazole was synthesized from imidazole and 1-bromodecane. A tetrahydrofuran (THF) solution of imidazole (86 mmol) was added to a suspension of oil-free NaOH (95 mmol) and allowed to stir for 1 h at $60 \,^{\circ}$ C. To the stirred solution, bro-



Fig. 2. ¹H NMR spectrum of amido-ImI.

Photovoltaic parameters and charge transfer resistance (*R*_{ct}) of the DSSCs fabricated using electrolytes with the imidazolium iodides (ImI) and viscosity of the electrolytes.^a.

ImI (0.7 M)	Viscosity (mPas)	$J_{\rm sc}$ (mA cm ⁻²)	V _{oc} (V)	FF	η (%)	$R_{\rm ct}(\Omega{\rm cm}^{-2})$
Ref-ImI	1.48	14.43	0.71	0.52	5.37	6.45
Amido-ImI	1.91	15.47	0.74	0.52	5.92	5.20
Decyl-ImI	2.37	12.40	0.70	0.53	4.62	-

^a Electrolyte consisted of 0.7 M imidazolium iodide, 0.1 M LiI, 0.05 M I₂, and 0.5 M 4-tert-butylpyridine in 3-methoxypropionitrile.

modecane (90 mmol) was added dropwise and stirred overnight at 60 °C. Then the solvent was removed in a rotary evaporator and H₂O (250 ml) was added to the residue. The resulting product, obtained by extraction with CH₂Cl₂ and evaporation, was separated by silica column chromatography using CH₃OH or CH₂Cl₂ as the eluent. The obtained 1-decyl-1H-imidazole was confirmed by a Varian ¹H NMR (Oxford AS 400), mass spectroscopy and FT-IR spectrometers (Bomen MB-04).

Decyl-ImI was then synthesized from 1-decyl-1H-imidazole as the starting material. 1-Decyl-1H-imidazole (0.058 mol) was dissolved in 100 ml of trichloroethylene, to which 6.8 ml (0.069 mmol) of iodomethane was added dropwise under an Ar atmosphere. The resulting solution was heated to reflux for 3 h with constant stirring and concentrated under vacuum. The residual salt was extracted with water and trichloroethylene followed by evaporation, after which the product was dried under vacuum to obtain a white solid. The formation of decyl-ImI was finally identified by ¹H NMR and mass spectroscopy.

¹H NMR (300 MHz, CDCl₃, ppm): 0.86–0.89 (3H, –CH₃), 1.10–1.35 (18H, –CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–CH₂–, 4.13 (3H, –CH₃), 7.34 (1H, –CH=), 7.44 (1H, –CH=), 10.18 (1H, –CH=).

2.4. Characterizations of the electrolyte

Three different types of electrolyte were prepared for the DSSCs: amido-ImI, decyl-ImI and ref-ImI electrolytes. The amido-ImI electrolyte consisted of amido-ImI, 0.1 M LiI, 0.05 M I₂, and 0.5 M 4-tert-butylpyridine in 3-methoxypropionitrile. The decyl-ImI and ref-ImI electrolytes were prepared with decyl-ImI and ref-ImI instead of amido-ImI, respectively. The viscosity of the electrolytes was measured under an Ar atmosphere using an SV-10 viscometer. The electrical conductance was then measured using the complex impedance technique [40] at 25 °C. The cells consisted of two identical, Pt-sputtered, fluorine-doped tin oxide (FTO) electrodes. The electrolyte resistance was measured using a Solartron instrument (Model 1287) with a 1260 frequency response analyzer controlled by a computer. The frequency limits were typically set between 10^{-2} Hz and 10^{6} Hz. The AC oscillation was 10 mV. The data were analyzed by Z-plot software. Chronoamperometric curves were obtained from the acetonitrile solutions containing 0.7 M imidazolium iodide, 0.05 M I₂, 0.1 M LiI, and 0.5 M 4-tert-butylpyridine using an EG&G PARC 263A potentiostat, with an electrochemical cell consisting of a Pt electrode, a Pt-wire auxiliary electrode and an Ag/AgCl reference electrode.

2.5. Preparation of TiO₂ electrodes

Dye-coated TiO₂ films were prepared as the working electrodes for the DSSCs as follows [41]. In each case, a thin buffer layer of non-porous TiO₂ was deposited on a cleaned FTO conducting glass, purchased from Libbey-Owens-Ford (TEC 8, 75% transmittance in the visible region), from 5% titanium(IV) butoxide in ethanol by spin coating at 3000 rpm. The thin layer coated FTO glass was cleaned and annealed at 450 °C. Dyesol titania paste, purchased from Dyesol Ltd., was deposited on the above-pretreated FTO glass by the doctor blade technique, using two scotch tapes to limit the thickness of the film. The film was dried for 10 min at 70 °C, followed by removing the tape and coating the film with 2% TiCl₄ solution by the spin coating method and annealing it at 450 °C for 30 min. A porous TiO₂ film with a thickness of about 10 μ m was thus produced. The annealed film was sensitized with N719 dye by immersing it for 24 h in an ethanol solution of N719 dye (0.3 mM of (Ru(II)L₂(NCS)₂:2TBA, where L = 2,2'-bipyridyl-4,4'-dicarboxylic acid, Solaronix SA). A 2-electrode sandwiched DSSC was fabricated according to the procedure described elsewhere [41]. The DSSC had an active area of 0.4 cm × 0.4 cm. The electrolyte consisted of 0.05 M I₂, 0.1 M Lil, 0.7 M amido-ImI, and 0.5 M 4-*tert*-butylpyridine in 3-methoxypropionitrile. Reference DSSCs were also prepared under identical conditions with 0.7 M ref-ImI.

2.6. Photovoltaic performance

The photocurrent density–voltage (*J–V*) curves of the DSSCs fabricated with the amido-ImI, decyl-ImI and ref-ImI electrolytes were obtained using a Keithley M236 source measure unit. A 300 W Xe arc lamp (Oriel) with an AM 1.5 solar simulating filter for spectral correction served as the light source, and its light intensity was adjusted to 100 mW cm⁻² using a Si solar cell. Thermally sealed cells were used to test the long-term stability of the DSSCs. The sealed cells were stored in a desiccator and subjected to electrochemical measurements every 24 h in order to study their long-term stability.

3. Results and discussion

3.1. Characterization of the amido-ImI

The recorded viscosities of the three electrolyte solutions are given in Table 1. The viscosity of the electrolyte solution in which ref-ImI was replaced with amido-ImI was increased. The electrolyte containing decyl-ImI showed the highest viscosity of 2.37 mPas. The dependence of the electrical conductance (κ) of the electrolyte solutions on the amido-ImI concentration, given in Table 2, showed that κ increased with increasing amido-ImI concentration, despite the high viscosity of the corresponding solutions.

3.2. Photovoltaic performance

Fig. 3 presents the *J*–*V* curves of the DSSCs with the electrolytes based on different amido-ImI concentrations at AM 1.5 illumination. The results are summarized in Table 2. The short-circuit photocurrent density (J_{sc}) increased with increasing concentration from 0.4 M to 0.7 M. The performance was optimized for the electrolyte containing 0.7 M amido-ImI, with J_{sc} , open-circuit voltage (V_{oc}), fill factor (FF), and overall energy conversion efficiency (η) values of 15.47 mA cm⁻², 0.74 V, 0.52, and 5.92%, respectively. However, the J_{sc} and η values decreased with further increase in the amido-ImI concentration above 0.7 M.

Fig. 4 compares the *J*–*V* curves of the DSSCs based on the amido-ImI, decyl-ImI and ref-ImI electrolytes at 0.7 M concentration and the results are included in Table 1. As it can be seen in the table, the DSSCs constructed with the amido-ImI electrolyte exhibited J_{sc} , V_{oc} and consequently η values that were improved by 7.2%, 4.2% and

Table 2
Photovoltaic parameters and R_{ct} of the DSSCs fabricated using electrolytes with different amido-ImI concentrations and electrical conductance (κ) of the electrolytes. ^a .

Amido-ImI (M)	$J_{\rm sc}$ (mA cm ⁻²)	V _{oc} (V)	FF	η (%)	$R_{ m ct}(\Omega{ m cm}^{-2})$	$\kappa ({ m mScm^{-1}})$
0.4	11.31	0.72	0.58	4.71	8.08	0.74
0.5	13.07	0.74	0.50	4.80	6.80	0.88
0.6	14.36	0.76	0.52	5.71	5.76	1.04
0.7	15.47	0.74	0.52	5.92	5.20	1.15
0.8	13.62	0.73	0.48	4.71	5.68	1.06

^a The same electrolyte as in Table 1.



Fig. 3. J-V curves of the DSSCs vs. amido-ImI concentration. The light intensity was 100 mW cm⁻².

10.2%, respectively, compared to those obtained with the DSSC containing the ref-ImI electrolyte under AM 1.5 simulated Xe light of 100 mW cm⁻². However, in the case of the DSSC with the decyl-ImI electrolyte, the $J_{\rm Sc}$ and η values were lower than those of the amido-ImI and ref-ImI electrolytes, which were attributed to the higher viscosity and lower electrical conductance of the decyl-ImI electrolyte compared to those of the ref-ImI and amido-ImI electrolytes. The FF remained the same, regardless of the electrolytes.

We also investigated the effect of incident light intensity on the performance of the DSSC fabricated with 0.7 M amido-ImI. The J-V curves as a function of the incident light intensity ranging from 60 mW cm⁻² to 100 mW cm⁻² are shown in Fig. 5, which reveals that the $J_{\rm Sc}$ showed a linear response with $V_{\rm oc}$, FF remained essentially constant over the light intensity range. These results indicated that the light absorption and charge carrier diffusion were not lim-



Fig. 4. J-V curves of the DSSCs fabricated with amido-ImI, ref-ImI and decyl-ImI at 100 mW cm⁻². The concentrations of the imidazolium iodides were 0.7 M. Inset shows the corresponding J-V curves obtained without using 4-*tert*-butylpyridine.

ited by the presence of 0.7 M amido-ImI up to the incident light intensity of 100 mW cm^{-2} .

3.2.1. J_{sc} increase

The increase in the J_{sc} value of the DSSC with amido-ImI compared to that with ref-ImI (Table 1) was attributed to the structural change of the electrolyte associated with the formation of hydrogen bonds among the amido-ImI molecules. Amido-ImI contains an amide group through which the molecules are connected to one another by hydrogen bonds. Given the increase in the electrical conductivity with increasing amido-ImI concentration, the formation of hydrogen bonds apparently creates conducting channels for the charge carriers, I_3 - and I-, which facilitate the ionic transport through the electrolyte, and, consequently, leads to an increase in J_{sc} compared to that with the reference electrolyte containing ref-ImI.

The J_{sc} increase was supported by the chronoamperometric plots shown in Fig. 6. The plots were obtained with two electrochemical cells containing either amido-ImI or ref-ImI, with each cell containing 1 mM I₂, 10 mM LiI, and 0.1 M LiClO₄ in acetonitrile. The figure reveals that the diffusion-limited currents (i_d), described in Eq. (1) [42], for both the oxidation of I⁻ and the reduction of I₃⁻ were larger for the cell with amido-ImI than for that with ref-ImI. This indicated that the diffusion of the charge carriers was more facilitated in the amido-ImI electrolyte than in the ref-ImI electrolyte. The smaller increase in i_d for the reduction of I₃⁻ relative to that for the oxidation of I⁻ was attributed to the 10-fold lower concentration of I₃⁻ than I⁻ in the electrolyte.

$$i_{\rm d} = \frac{nFAD^{1/2}C}{\pi^{1/2}t^{1/2}} \tag{1}$$

where n is the electron transfer number per molecule, F the Faraday constant, A the surface area of the electrode, D the diffusion coefficient, C the concentration, and t is the time.



Fig. 5. *J*-*V* curves of the DSSCs fabricated with 0.7 M amido-ImI at various incident light intensities.



Fig. 6. Chronoamperometric curves of the electrochemical cells assembled with the ref-ImI and amido-ImI electrolytes in acetonitrile.

The variation of J_{sc} according to the electrolyte composition was further evidenced by electrochemical impedance spectroscopy. Fig. 7 compares the Nyquist plots of the DSSCs with ref-ImI at 0.7 M and with amido-ImI at its different concentrations. The first semicircle represents the impedance related to the charge transfer process occurring at the Pt/electrolyte interface in the DSSC [43,44]. The smallest charge transfer resistance (R_{ct}) value (Table 2) with 0.7 M amido-ImI was well correlated with the highest J_{sc} value of the corresponding DSSC. This reduced charge transfer resistance with amido-ImI implied an easier electron transfer [44] from the counter electrode to the I_3^- ions, and thus confirms the enhanced



Fig. 7. Nyquist plots of the DSSCs fabricated with ref-ImI at 0.7 M and with amido-ImI at various concentrations. The plots were recorded over a frequency range of $0.05-10^5$ Hz with an AC amplitude of 5 mV.

 J_{sc} for the pertinent DSSC, compared to the J_{sc} values of the cells with other amido-ImI concentrations (Table 2) and with ref-ImI at 0.7 M (Table 1).

3.2.2. V_{oc} enhancement

The enhanced V_{oc} value of the DSSC with amido-ImI relative to that with ref-ImI and decyl-ImI (Table 1) was related to the adsorption of amido-ImI to the hydrophilic surface of the TiO₂ particles through the amide group. This adsorption enabled the long hydrophobic alkyl chain in amido-ImI to suppress the back electron transfer from the TiO₂ conduction band and the FTO/TiO₂ interface to the I₃⁻ ions in the electrolyte by reducing the direct contact between the TiO₂ surface and the electrolytic solution [45], thereby



Fig. 8. Variation of the photovoltaic parameters of the DSSCs assembled using the ref-Iml (black squares) and amido-Iml (red dots) electrolytes over a period of 21 d. The concentrations of the imidazolium iodides were 0.7 M. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 3

Photovoltaic parameters of the DSSCs fabricated without using 4-tertbutylpyridine.^a.

ImI (0.7 M)	$J_{\rm sc}$ (mA cm ⁻²)	$V_{\rm oc}({ m V})$	FF	η (%)
Ref-ImI	15.87	0.63	0.44	4.4
Amido-ImI	14.72	0.67	0.54	5.3
Decyl-ImI	11.63	0.64	0.47	3.5

 $^{\rm a}$ Electrolyte consisted of 0.7 M imidazolium iodide, 0.1 M LiI, and 0.05 M I_2 in 3-methoxypropionitrile.

increasing V_{oc} according to Eq. (2) [46]:

$$V_{\rm oc} = \left(\frac{kT}{e}\right) \ln\left(\frac{J_{\rm sc}}{J_{\rm o}}\right) \tag{2}$$

where J_0 is the exchange current density and is related to the rate of the back electron transfer. Furthermore, the adsorption of amido-ImI to the surface of the TiO₂ particles can also increase V_{oc} by the negative shift of the flatband potential (V_{FB}) of the dye-coated TiO₂ electrode, similarly to 4-*tert*-butylpyridine [47]. Under Fermi level pinning, these two parameters are linked by Eq. (3) [48]:

$$V_{\rm oc} = \left| V_{\rm FB} - V_{\rm red} \right| \tag{3}$$

where $V_{\rm red}$ is the reduction potential of the I_3^-/I^- redox couple. Assuming that $V_{\rm red}$ remains the same regardless of the presence of amido-ImI in the electrolyte, the negative shift of $V_{\rm FB}$ can increase the $V_{\rm oc}$ value of the DSSC. To investigate whether the adsorption of amido-ImI enhanced the corresponding $V_{\rm oc}$ value, $V_{\rm oc}$ was measured again without using 4-*tert*-butylpyridine in each electrolyte. Values of 0.63 V, 0.67 V and 0.64 V were measured for the DSSCs with ref-ImI, amido-ImI and decyl-ImI, respectively, as shown in Table 3 and the inset of Fig. 4. This result confirmed that amido-ImI did indeed enhance $V_{\rm oc}$ by adsorption as 4-*tert*-butylpyridine.

3.3. Long-term stability

The electrolyte based on amido-ImI, with an amide group in its hydrophobic alkyl chain, was expected to contribute to the stability of DSSCs through the suppression of solvent evaporation. Fig. 8 compares the changes in the photovoltaic properties of the solar cells with time. Remarkably, the DSSC based on the ref-ImI electrolyte lost more than half (52%) of its initial J_{sc} value after 21 d, while the Jsc of the cell fabricated with amido-ImI was reduced by only 20% after the same period. The concentration of the imidazolium iodides was set at 0.7 M. The differences in V_{oc} and FF were negligible compared with that of J_{sc} . As a result, the overall energy conversion efficiencies of the DSSCs with amido-ImI and ref-ImI were decreased to 73% and 65%, respectively, after 21 d, suggesting that the amido-ImI electrolyte offers better stability than that of the conventional liquid electrolyte containing ref-ImI. In particular, the enhanced stability in J_{sc} was attributed to formation of hydrogen bonds among the amido-ImI molecules. This hydrogen-bond formation increases the viscosity of the organic solution, and thus improves the solvent conserving ability of the electrolyte. The improved stability of the DSSC with amido-ImI, compared to that with ref-ImI, was attributed to this solvent holding ability.

4. Conclusions

The DSSC with an electrolyte containing a newly synthesized amido-ImI, 1-(2-hexanamidoethyl)-3-methylimidazol-3ium iodide exhibited a short-circuit photocurrent density (J_{sc}) and overall energy conversion efficiency that were improved by 7.2% and 10.2%, respectively, compared to those obtained with the DSSC with ref-ImI, i.e., 1-hexyl-2,3-dimethylimidazolium iodide. The amido-ImI-induced enhancement of J_{sc} was attributed to the formation of hydrogen bonds among the amido-ImI molecules in the electrolyte, which increased the electrical conductivity of the charge carriers, I_3^- and I^- , and reduced the charge transfer resistance of the DSSC. The increase in the open-circuit voltage was attributed to the adsorption of amido-ImI on the surface of the TiO₂ electrode, thereby reducing the back electron transfer from the conduction band of TiO₂ and the FTO/TiO₂ interface to the I_3^- ions in the electrolyte arising from the presence of a long hydrophobic chain of amido-ImI. The DSSC with the amido-ImI electrolyte exhibited better stability than that with the ref-ImI electrolyte.

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