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Enhancing quasi solid-state dye-sensitized solar cell performance using mixed-polymer gel electrolytes: the influence of low and high molar-weight polymers

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Gel polymer electrolytes (GPEs) based quasi solid-state dye-sensitized solar cells (DSSCs) have attracted attention due to their relatively high chemical and physical stability, ionic conductivity, better mechanical properties, and enhanced safety. This study investigated the possibility of improving DSSC performances by preparing new GPEs using polyethylene oxide (PEO) with its low molar weight counterpart, polyethylene glycol (PEG). The studied plasticized gel electrolyte included organic solvents, ethylene carbonate (EC) and propylene carbonate (PC), a binary mixture of salts, LiI and Hex_4NI, and performance enhancers, 1-methyl-3-propylimidazolium iodide (MPII) and 4-tert-butylpyridine (4TBP), with the polymer matrix, $C_{2n}H_{4n+2}O_{n+1}$, having molar weights 40,000 (PEG) and 4,000,000 (PEO). The electrolyte was synthesized using the hot press method. The correctly weighted chemicals were stirred for about one hour at room temperature and then heated to about 100 °C for 10 min. Then after the sample cooled down to 40 °C iodine was added, and stirring was continued for an hour. The study aimed to optimize the DSSC performance by varying the weight (wt.) ratio of PEO and PEG in the electrolyte. The ionic conductivities of the GPEs were determined using impedance analysis through Nyquist plots. The electrolyte that contains 100 wt% of PEG with respect to the total polymer weight exhibited the highest ionic conductivity (0.826 S m^{-1}) and viscous liquid-type nature. Conversely, the electrolyte with a 100 wt% PEO is in solid form and displayed the lowest ionic conductivity (0.351 S m^{-1}). The mixed polymer electrolyte with a 1:1, PEO:PEG wt. ratio showed an intermediate conductivity and a good gel nature. Also, the conductivity of the GPEs behaves according to the Vogel-Tamman-Fulcher (VTF) relation. The DSSCs were assembled using N719 dye-sensitized TiO_2 nano-particle multi-layer photoelectrode and Pt counter electrode. The solar cell characterization results showed that the cells achieved the highest power conversion efficiency (PCE) of 7.09% for the 1:1, PEO:PEG wt. ratio with a J_{sc} of 13.80 mA cm^{-2}. The PCE values were relatively lower for the 3:1 (6.29%), and 1:3 PEO:PEG wt. ratios (5.99%). The lowest PCE out of the five compositions investigated was observed for the 100 wt% PEO content, which can be a result of the solid nature and poor conductivity of the electrolyte. The results demonstrated a notable advancement in performance with an improvement of 23.86% and 21.61% when compared to single polymer electrolytes comprising of PEO and PEG, respectively. In conclusion, the presence of both low and high-molar-weight polymers in the electrolyte has a significant impact on the performance of DSSCs. The study continues to fine-tune polymer composition and understand the efficiency-enhancing mechanism in mixed-phase gel polymer electrolytes.

Keywords: Dye-sensitized solar cells, Gel polymer electrolyte, TiO_2 multilayer

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