

Abstract

With the increasing global demand for alternative energy, photovoltaic (PV) technology has undergone remarkable evolution extending over four PV generations. Currently, dye-sensitized solar cells (DSSCs), which fall within the 3rd generation are more versatile and relatively less costly compared to the dominant crystalline silicon (Si) technologies. These DSSCs bear the hope of becoming the future solution to the energy crisis. However, the poor catalysis within the electrodes makes DSSCs relatively inefficient hence ineffective for full commercial utilization. This study investigated the use of composite counter electrodes (CEs) by incorporating graphene (Gr) and/or plasmonic gold (Au) nanoparticles (NPs) with the aim to improve the efficiency of the conventional platinum (Pt) based DSSCs. Gold nanoparticles (AuNPs) in colloidal form with an average size of ~ 12 nm were prepared by chemical reduction method. The size evaluation was done using the resulting localized surface plasmon resonance (LSPR) peak wavelength values (518- 520 nm) based on the UV-Vis spectra data. Graphene modules prepared by chemical vapor deposition (CVD) on a glass/Fluorine-doped tin oxide (FTO) were used as electrode substrates in this work. These modules depicted G and 2D bands at 1380 and 1700 cm^{-1} respectively under Raman spectroscopy, indicating low defect state of the Gr. Four different sets of composite CE modules namely FTO/Pt (CE1), FTO/Gr/Pt (CE2), FTO/Gr/AuNPs (CE3) and FTO/Gr/AuNPs/Pt (CE4) were prepared. The CEs recorded transmittance above 70% under UV-Vis spectroscopy, meeting requirements for back-electrode application in DSSCs. Photoanode (PA) modules consisting of titanium dioxide (TiO_2) on the FTO/Gr substrate were prepared by the doctor-blade method. Three DSSC modules were assembled based CEs CE2, CE3 and CE4 and their PV performance compared to the reference cell based on CE1. Both Gr and AuNPs were found to possess PV properties and enhanced the resulting DSSCs by 13.4 and 10.1% respectively. The DSSCs containing Pt (CE1, CE2, and CE4) performed better in terms of power conversion efficiency (PCE) due to the increased short circuit current densities (J_{sc}) and fill factors (FF). However, change in the open-circuit voltage (V_{oc}) was negligible. The CE4 based cell design presented the best PCE at 4.62%, In this composite DSSC, the J_{sc} (9.92 mA/cm^2), V_{oc} (0.68 V) and FF (0.69) values recorded representing 13.9%, 0.8% and 9.0% increase respectively compared to CE1. This represented a 24.9% PCE enhancement, which is the synergistic effect of Gr and AuNPs as a composite. This remarkable performance could be due to increased electrocatalytic activity resulting from the graphene matrix within the electrodes. It is also partly attributed to the

suppressed carrier recombination resulting from the LSPR property of the Au contacts anchored on the Gr surface in the CE structure.