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Enhancing Performance of Dye-Sensitized Solar Cells Using Agricultural Waste-Derived Counter Electrode with Fused Silica

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Dye-Sensitized Solar Cells (DSCs) are a cost-effective alternative to traditional silicon-based solar cells, making them ideal for applications such as building-integrated photovoltaics (BIPV). Although dye-sensitized solar cells have lower efficiency than conventional solar cells, ongoing research focuses on enhancing cost-effectiveness by improving counter electrodes. Replacing expensive platinum (Pt) electrodes with cost-effective materials like activated carbon has gained attention due to its high electrocatalytic activity, large surface area, and efficient electron transfer. The integration of fused-silica into activated carbon structures further enhances mechanical stability and surface area, optimizing DSC performance. This study explores a sustainable method for DSC counter electrode fabrication using agricultural waste-derived materials. Fused-silica was extracted from rice husks through washing, acid treatment, and thermal treatment at 600 °C. Additionally, activated Palmyra shell charcoal (APSC) was produced via carbonization and steam activation, followed by fine grinding. A composite counter electrode was prepared by blending APSC with fused-silica and polyvinylpyrrolidone (PVP) in isopropanol, sprayed onto fluorine-doped tin oxide (FTO) glass through spray pyrolysis and sintered at 300 °C. DSCs were assembled using N719 dye-coated TiO_2 photoanodes with 0.20 cm^2 mask, liquid electrolyte (I^-/ I_3^-), and prepared composite counter electrode. Then solar cells were evaluated using SPD SS-25 LED solar simulator under AM 1.5 100 mW cm^{-2} solar irradiance. After following series of experiments, performance analysis revealed that the APSC:Si (4:1) composite electrode achieved a power conversion efficiency (PCE) of 6.31%, slightly higher than the APSC:Si (5:0) electrode (6.01%), but lower than the Pt-based electrode (7.25%). The enhanced performance of APSC:Si (4:1) is attributed to improved electrical conductivity and electron transfer due to fused-silica. While platinum remains the most efficient option, APSC-based electrodes provide a sustainable, cost-effective alternative, demonstrating the potential of renewable materials in solar energy applications.

Keywords – Dye-sensitized solar cells, Counter electrode, Fused-silica, Activated Palmyra Shell Charcoal