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Fabrication of Dye-Sensitized Solar Cells Based on Natural Pigments Extracted from the *Bixa Orellana* Seeds

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Dye-sensitized solar cells (DSCs) have gained attention as a viable alternative to conventional silicon-based solar cells, offering advantages such as low-cost fabrication, flexibility, and reasonable efficiency. Operating on a principle similar to natural photosynthesis, DSCs employ light-absorbing dyes to convert solar energy into electricity. While synthetic dyes like Ruthenium-based N719 and N3 have been the standard, their expense and environmental impact have spurred interest in natural alternatives. In this study, we introduce *Bixa orellana* (annatto) seed extract as a novel, sustainable sensitizer for DSCs. The extraction process involved heating annatto seeds in absolute ethanol (100 mL) at 80°C, producing a reddish-orange solution containing the carotenoid pigments bixin and norbixin. The photoanode was prepared using a TiO_2 P25-based paste (0.65 g TiO_2, 5 ml titanium isopropoxide, 5.5 ml acetic acid, and 5 ml distilled water), which was deposited via drop-casting and sintered at 500°C for 30 minutes. The complete DSC assembly consisted of the dye-coated TiO_2 photoanode, a platinum counter electrode, a mask with a window size of 0.20 cm^2, and an I^-/I_3^- liquid electrolyte. Under standard AM 1.5G illumination (100 mW cm^{-2}), the fabricated cell achieved a power conversion efficiency (PCE) of 0.47%. The incident photon-to-current efficiency (IPCE) spectrum showed a maximum response of ~ 40%, confirming effective light absorption by the bixin/norbixin dye. UV-Vis spectroscopy further validated the presence of these carotenoids, supporting their role as photoactive sensitizers. These findings demonstrate the feasibility of *Bixa orellana* pigments as cost-effective, eco-friendly alternatives to synthetic dyes in DSC applications. Future research could focus on optimizing dye extraction and device architecture to enhance performance, contributing to more sustainable solar energy technologies.

Keywords: *Bixa Orellana*, dye-sensitized solar cells, natural dye, bixin, norbixin, drop casting