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Education and solar conversion: Demonstrating electron transfer

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Abstract

A simplified solar cell fabrication procedure is presented that uses natural anthocyanin or chlorophyll dyes extracted from plants. This procedure illustrates how interdisciplinary science can be taught at lower division university and upper division high school levels for an understanding of renewable energy as well as basic science concepts. Electron transfer occurs on the Earth in the mitochondrial membranes found in living cells, and in the thylakoid membranes found in the photosynthetic cells of green plants. Since we depend on the results of this electron and energy transfer, e.g. in our use of petroleum and agricultural products, it is desirable to understand and communicate how the electron transfer works. The simplified solar cell fabrication procedure, based on nanocrystalline dye-sensitized solar cells, has therefore been developed so that it can be inexpensively reproduced and utilized in the teaching of basic principles in biology, chemistry, physics, and environmental science. A water-based solution of commercial nanocrystalline titanium dioxide (TiO_2) powder is used to deposit a highly porous semiconductor electron acceptor. This acceptor couples the light-driven processes occurring at an organic dye to the macroscopic world and an external electrical circuit. Materials science and semiconductor physics are emphasized during the deposition of the sintered TiO_2 nanocrystalline ceramic film. Chelation, complexation and molecular self-assembly are demonstrated during the attachment of the dye molecule to the surface of the TiO_2 semiconductor particles. Environmental chemistry and energy conversion can be linked to these concepts via the regenerative oxidation and reduction cycle found in the cell. The resulting device, made in under 3 h, can be used as a light detector or power generator that produces 0.4–0.5 V at open circuit, and 1–2 mA per square cm under solar illumination.

Keywords: Education; Nanocrystalline materials; Electron transfer; Photoelectrochemistry; Titanium dioxide; TiO_2; Dye sensitized solar cells

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