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Deciphering Dye-Sensitized Solar Cells: Inspiring Students to Explore the Green Energy World through Inquiry-Based Teaching

Hsiao-Chien Liu 1,2*, Meng-Yu Tsai 1,2

1National Changhua Senior High School, Taiwan.R.O.C

2The Chemical Educational Resource Center of Taiwan, Taiwan.

Introduction

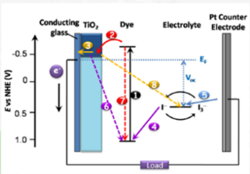
Exhaustion of petrochemical energy sources has inflicted severe damage upon the Earth, necessitating the search for more environmentally friendly and sustainable alternative energy solutions. Green energy has emerged as a global consensus, with solar cells standing out as one of the most promising sources. Solar cells offer numerous advantages, including safety, noise-free operation, pollution-free energy generation, efficient resource utilization, long-term usability, lightweight design, and cost-effectiveness. Despite the relatively lower stability compared to traditional solar cells, dye-sensitized solar cells exhibit remarkably high photoelectric conversion efficiency, reaching up to 30% (as opposed to the 7~17% range of commercial solar panels) under low-cost indoor or semi-outdoor conditions. This underscores the significant role of dye-sensitized solar cells in energy applications. Through an inquiry-based practical course, we aim to guide students in comprehending the assembly, principles, and application range of dye-sensitized solar cells, thereby fostering their interest in exploring the fascinating realm of green energy.

Teaching Objectives

1.Understand assembly, principles, and techniques of dye-sensitive solar cells.
2.Generate exploration topics, predict outcomes, plan experiments.
3.Collect plant samples, prepare for experimentation.
4.Measure voltage and current with different plant sensitizers.
5.Analyze plant species' impact on voltage and current.
6.Draw conclusions, assess optimization potential, identify research directions.

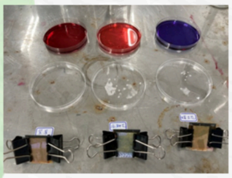
Teaching activities

1.Elucidation of the operational mechanism of dye-sensitized solar cells



1.Dye absorbs sunlight, transitioning to an excited state.
2.Electrons from dye enter TiO2's conduction band.
3.Electrons move through circuit to counter electrode.
4.Oxidized dyes receive electrons from electrolyte, returning to ground state.
5.Oxidized electrolyte accepts electrons from external circuit, returning to ground state.

2. Dye-sensitized solar cell assembly and testing



A B C

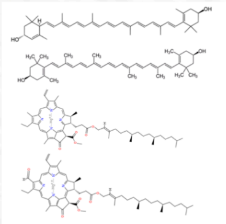
The measured voltage values for comfrey (A), roselle (B), and butterfly pea (C) were 0.655V, 0.413V, and 0.004V, respectively.

3. Collect plant samples from everyday life or the campus environment and prepare them for experimental analysis.

1 Camphor trees, Taiwan eucalyptus, magnolia, osmanthus, and sweet potato leaves were selected as the plant samples.
2. Column chromatography: 1st stage - 9:1 n-hexane:acetone, 2nd stage - 7:3 hexane:acetone.

4.Measuring voltage and current variations in dye-sensitized solar cells across different plant species

(1) Collecting diverse plant dyes through column chromatography and spectroscopically identifying distinct pigment species.



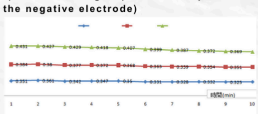
Lutein

Zeaxanthin

Chlorophyll a

Chlorophyll b

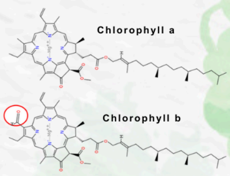
(2) Optimizing Encapsulation and Efficiency Evaluation of Dye-Sensitized Solar Cells
(DSSC: Utilizing Pt paint for the positive electrode and micronano TiO2 for the negative electrode)



Blue: carotenoids
Red: Chlorophyll a
Green: Chlorophyll b

Experimental Results

1.Carotenoids absorb light at 445-455nm, while chlorophyll a and b absorb at 430-450nm. The higher HOMO energy level promotes electron transfer to TiO2.
2.Chlorophyll a and b have a shorter wavelength distribution in their absorption spectrum, which aligns with the energy gradient of HOMO and LUMO.The observed higher discharge voltage supports the hypothesis.
3.The presence of an additional aldehyde group on chlorophyll b enhances its polarity, enabling stronger interactions with TiO2 and other chlorophyll b molecules. This results in an increased discharge voltage.



Conclusions and Future Research Prospects

1.Voltage order: chlorophyll b > chlorophyll a > carotenoids.
2.This approach enhances student understanding and aims to improve solar cells by creating artificial chlorophyll. Natural chlorophyll's limitations include oxidation and dependence on ultraviolet light.
3.By adding electron-pushing groups and a bridging base, we aim to enhance transfer and voltage, creating a flexible and affordable solar cell that surpasses traditional options. This aligns with SDG 7 for clean, affordable energy.

References

1. National Taiwan University, Department of Chemistry, Organic Chemistry Teaching and Research Group. (2008). General Chemistry Laboratory for Universities, 12th Edition. National Taiwan University Press: Taipei City, Taiwan. (Thin-Layer Chromatography)