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DESIGNING AND EXPERIMENTAL ANALYSIS OF DYE SENSITIZED SOLAR CELL USING TITANIUM DIOXIDE AND NATURAL DYE

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Abstract: This study explores the design and experimental analysis of a solar cell utilizing titanium dioxide (TiO2) as the semiconductor material and natural beetroot dye as the photosensitizer. The investigation encompasses the fabrication of a dye-sensitized solar cell (DSSC) by depositing a TiO2 film on a conductive glass substrate. The natural dye extracted from beetroot is employed to sensitize the TiO2, harnessing its light-absorbing properties. The DSSC is assembled by sandwiching the TiO2-coated glass with a counter electrode and an iodide-based electrolyte. Experimental measurements of open-circuit voltage (Voc) and short-circuit current (Isc) are conducted, and current-voltage (I-V) characteristics of the solar cell are analyzed under varying light conditions. The results demonstrate the feasibility of using natural beetroot dye as a photosensitizer in DSSCs and provide insights into the performance of such eco-friendly solar cells, contributing to the field of sustainable energy technologies.

Keywords: Renewable Energy; Solar Cell Designing; DSSC; Energy Conversion; Titanium Di oxide;

1. Introduction

The increasing global demand for clean and sustainable energy sources has driven extensive research and innovation in the field of photovoltaic. Solar cells, in particular, have emerged as a promising solution for harnessing abundant and renewable solar energy. Among various solar cell technologies, Dye-Sensitized Solar Cells (DSSCs) have garnered significant attention due to their cost-effectiveness, ease of fabrication, and versatility in materials. These cells employ photoactive dyes to absorb sunlight and convert it into electricity, making them a viable candidate for renewable energy generation.

Traditionally, synthetic dyes have been used as photosensitizers in DSSCs to enhance light absorption and electron transfer. However, the synthesis and use of synthetic dyes come with environmental concerns and cost implications. As a response to the growing emphasis on sustainable and eco-friendly energy technologies, this study delves into an alternative approach by employing a natural and readily available source as the photosensitizer – beetroot dye.

Beetroot, a common root vegetable, contains natural pigments known as betalains, which exhibit intense coloration due to their light-absorbing properties. The use of beetroot dye not only aligns with the principles of sustainability but also provides an opportunity to explore the viability of a natural photosensitizer in a DSSC. This study focuses on the design and experimental analysis of a solar cell using titanium dioxide (TiO2) as the semiconductor material and natural beetroot dye as the photosensitizer. The investigation encompasses the fabrication process, assembly of the DSSC, and systematic measurement and analysis of its performance under various lighting conditions.The results of this research hold the potential to contribute to the development of eco-friendly solar cells and broaden the horizon for sustainable energy generation. By leveraging the natural dye from beetroot, we aim to demonstrate the feasibility of an environmentally conscious approach to photovoltaic technology and provide valuable insights into the practical application of natural dyes in solar energy conversion.

A.Types of Solar Cell

Generally it is Classified Broadly into two categories, Inorganic and Organic

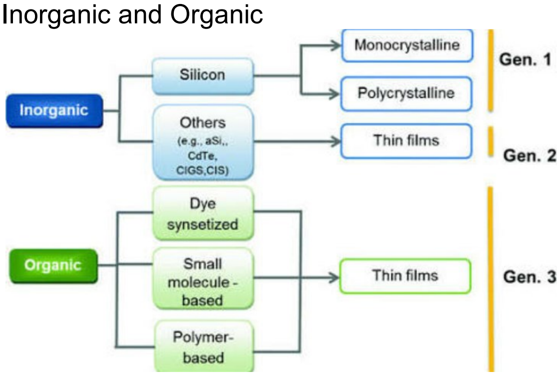

Figure 1.1 Solar cell classification

Sub Classified as,

- Monocrystalline Silicon Solar Cells (Mono-Si
- Polycrystalline Silicon Solar Cells (Poly-Si)
- Thin-Film Solar
- Organic Solar Cells.
- Bifacial Solar Cells
- Perovskite Solar Cells
- Multi-Junction Solar Cells
- Concentrator Solar Cells
- Tandem Solar Cells
- Cadmium Telluride (CdTe) Solar Cells
- Copper Indium Gallium Selenide (CIGS) Solar Cells
- Dye-Sensitized Solar Cells (DSSCs)

B. Common Challenges in designing of solar cell

According to research,

- Efficiency
- Cost
- Durability
- Stability
- Energy Storage.
- Manufacturability.
- Material Availability
- Land Use
- Aesthetics.
- Thermal Management
- Energy Conversion Efficiency at Low Light Levels
- Efficiency Drop at High Temperatures
- Economic Viability
- Intermittency.
- Environmental Impact
- Local Regulations.

C. Major issues while designing the solar cell using traditional method

Solar energy has risen to the forefront of the global renewable energy landscape, offering a sustainable and abundant source of power. Central to this clean energy revolution are solar cells, which convert sunlight into electricity. While the use of traditional silicon-based solar cells has become widespread, their design and implementation present a range of persistent challenges that demand innovative solutions.This introduction sets the stage for exploring the common challenges of designing solar cells using traditional methods. These challenges encompass a

2. Introduction to DSSC'S

Dye-Sensitized Solar Cells (DSSCs), also known as Grätzel cells after their inventor Michael Grätzel, are a type of photovoltaic device that converts sunlight into electricity. DSSCs are distinct from traditional silicon-based solar cells and offer several unique advantages and applications. Here are some key features and characteristics of Dye-Sensitized Solar Cells:

Working Principle: DSSCs work based on a different mechanism compared to traditional solar cells. They consist of a semiconductor material, often titanium dioxide (TiO2), coated with a photosensitive dye. When exposed to sunlight, the dye absorbs photons and generates excited electrons. These electrons are injected into the semiconductor, creating an electric current.

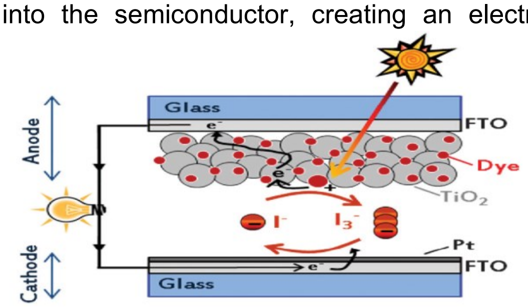

Figure 1.2 Working Process of DSSC

Flexibility and Transparency: DSSCs are typically lightweight and can be made flexible and even transparent. This flexibility allows for applications such as integrating solar cells into architectural elements like windows, facades, and clothing.

Cost-Effective Manufacturing: DSSCs can be manufactured using low-cost materials and processes. This makes them an attractive option for applications where cost is a primary consideration.

Low-Light Performance: DSSCs can generate electricity even in low-light conditions or indirect sunlight, which makes them suitable for indoor and low-light applications.

Eco-Friendly Materials: Many components of DSSCs, including the photosensitive dyes, can be made from environmentally friendly and non-toxic materials. This aligns with the growing demand for sustainable and green energy technologies.

Applications: DSSCs have found applications in a variety of niche areas. These include solar-powered windows, portable chargers, outdoor advertising, and consumer electronics, where the flexibility and transparency of DSSCs are valuable.

Variety of Dye Options: DSSCs can use a wide range of photosensitive dyes, including natural dyes like those from berries or synthetic dyes tailored for specific absorption spectra. This flexibility in dye choice can impact the cell's efficiency and aesthetics.

3. Designing Principle

A. Using Titanium Di- Oxide

TiO2 possesses several characteristics that make it particularly well-suited for PV applications. It exhibits exceptional optical properties, including a high refractive index and light-scattering capabilities. These features enable TiO2 to efficiently capture and direct incoming sunlight, ultimately enhancing the overall light absorption and conversion efficiency of solar cells. Additionally, TiO2's chemical stability and low toxicity render it an attractive material for long-term use in solar cell components.

In the context of PV technology, TiO2 is most commonly employed in dye-sensitized solar cells (DSSCs) and as a charge-transporting layer in perovskite solar cells. In DSSCs, TiO2 serves as the electron acceptor and transporter, playing a pivotal role in the separation and transfer of photo-generated electrons, a key step in the conversion of light energy into electrical current. Its versatility extends to the emerging field of perovskite solar cells, where TiO2 acts as an electron-selective contact layer, contributing to the efficient extraction of photogenerated charge carriers.

The integration of TiO2 into PV systems represents an ongoing effort to maximize energy conversion efficiency, reduce material costs, and ensure the long-term durability of solar cells. As research and development in PV technology continue to advance, TiO2 remains a vital component, contributing to the development of more sustainable and accessible solar energy solutions. This exploration into the application of TiO2 in PV technology underscores its significance in propelling the world toward a cleaner and more sustainable energy future.

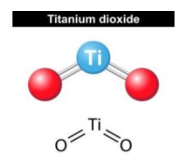

Figure 1.3 Titanium dioxide

B. Using as a Beetroot Dye

The pursuit of sustainable and eco-friendly energy sources has fueled innovation in the field of photovoltaic. Among the myriad solar cell technologies, Dye-Sensitized Solar Cells (DSSCs) have emerged as an intriguing avenue, harnessing the power of light to generate electricity. While DSSCs traditionally employ synthetic dyes as photosensitizers, the utilization of natural dyes has gained attention for its potential to enhance the sustainability and accessibility of solar energy. This introduction explores the compelling reasons behind employing beetroot as a natural dye in DSSCs and its implications for the future of renewable energy

Beetroot, a common root vegetable known for its vivid hue, conceals within its flesh a rich source of natural pigments, notably the betalains. It is these pigments that hold the key to its newfound role in solar energy conversion. Beetroot's utilization in DSSCs, as a natural dye, bears a multitude of advantages that extend well beyond its distinctive color. The decision to harness the red pigment's light-absorbing properties represents a conscientious stride towards sustainability.

One of the primary motivations for incorporating beetroot dye into DSSCs is its renewable and abundant nature. Beetroot cultivation is widespread, and the dye can be easily extracted without resorting to resource-intensive processes. This inherent renewability aligns perfectly with the sustainable energy ethos that underpins the global shift towards cleaner power sources.

Furthermore, beetroot's non-toxic and environmentally friendly character ensures that its application in DSSCs does not compromise safety or introduce harmful substances into the environment. This contrasts with certain synthetic dyes, which may contain chemicals of concern.

The cost-effectiveness of beetroot dye extraction and its potential to contribute to reducing overall DSSC production costs add to its appeal as a sustainable photosensitizer.

Additionally, beetroot's light absorption properties are well-suited for its role in solar energy conversion. The pigments within beetroot can effectively capture sunlight, providing a pathway for the efficient conversion of photons into electricity.

As this exploration unfolds, we delve into the unique attributes and advantages of employing beetroot as a dye for DSSCs. The potential of natural dyes to revolutionize the solar energy landscape beckons, promising more accessible, sustainable, and eco-friendly solar solutions for the future.

4. Procedure to Design and Experimental Analysis

A. Materials and Equipment:

- Titanium dioxide (TiO2) nanoparticles
- Natural beetroot dye (extracted from beetroot)
- Conductive glass or fluorine-doped tin oxide (FTO) glass
- Iodide-based electrolyte solution
- Counter electrode (usually platinum-coated)
- Sealing material (e.g., hot wax or epoxy)
- Multimeter or voltmeter
- Light source (e.g., a solar simulator)
- Beakers and glassware for solutions
- Masking tape
- Wires and alligator clips
- Safety equipment (gloves, safety goggles)

B. Preparing the TiO2 Electrode

Clean and prepare the conductive glass by cutting it to the desired size and cleaning it thoroughly. Prepare a TiO2 paste by mixing TiO2 nanoparticles with a suitable solvent to form a thick paste. Spread the TiO2 paste evenly onto the conductive glass and let it dry. This will create a porous TiO2 film, which will serve as the photo anode.

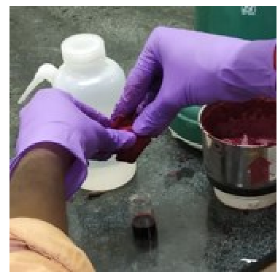

Figure 1.5 Extracting Beetroot Dye

Figure 1.6 Applying Beetroot Dye on the Tio2 Layer

C. Assembling the Solar Cell

Sandwich the TiO2-coated conductive glass with a piece of counter electrode using a separator soaked in the iodide-based electrolyte solution. Seal the edges of the assembly with a sealing material to prevent leakage and exposure to air.

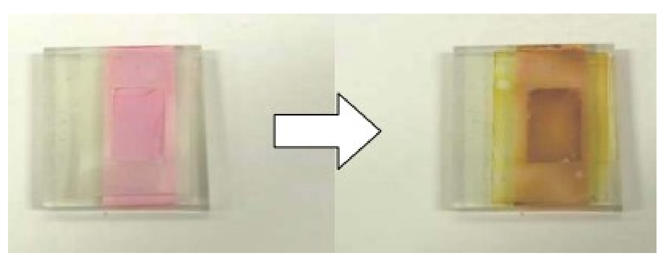

Figure a

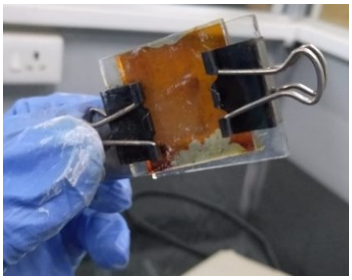

Figure 1.7 (a&b) Final product for testing

D. Testing the Solar Cell

Figure 1.8 Testing Process

Connect the solar cell to a multimeter or voltmeter to measure its open-circuit voltage (Voc) and short-circuit current (Isc).Expose the solar cell to a light source, preferably a solar simulator with controlled intensity and spectrum. Record the current-voltage (I-V) curve of the solar cell under different light conditions.

E. Data Analysis:

Analyze the I-V curves to determine the efficiency of the solar cell. Calculate conversion efficiency. Compare the performance of your DSSC with other types of solar cells or variations using different dyes.

Specimen	Major Component Present	Voc	Isc	%
Beetroot	Betalains	0.56	0.95	0.145
Blueberry	Anthocyanin	0.392	0.96	0.47
Red frangipani flowers	Not Known	0.495	0.94	0.65

5 .Conclusion

The design and experimental analysis of a solar cell using titanium dioxide (TiO2) in conjunction with natural beetroot dye as the photosensitizer mark a significant stride in the pursuit of sustainable energy solutions. This innovative approach, which bridges the realms of traditional semiconductor materials and renewable organic compounds, holds the promise of enhancing both the efficiency and eco-friendliness of solar energy generation.The choice of TiO2, a well-established semiconductor, as the foundation for this solar cell design underscores its reliability and performance.

The utilization of beetroot dye in Dye-Sensitized Solar Cells (DSSCs) highlights its abundance, renewability, and non-toxic nature. These attributes make it an ideal candidate for sustainable energy technologies, as it aligns perfectly with the principles of eco-friendliness and cost-effectiveness. As the results of the experimental analysis unfold, they shed light on the potential of this innovative solar cell technology. While the efficiency of natural dye-based DSSCs may not always match that of their synthetic counterparts, the journey towards optimizing this technology continues. Researchers and innovators are actively exploring pathways to enhance the efficiency, stability, and long-term performance of solar cells utilizing natural dyes.

In conclusion, the endeavor to design and experimentally analyze a solar cell using TiO2 and natural beetroot dye as key components embodies the spirit of innovation in the pursuit of sustainable energy solutions.

6 .Future Work

Future work in the field of designing and experimentally analyzing solar cells using titanium dioxide (TiO2) with natural beetroot dye as a photosensitizer holds great promise. Here are some potential avenues for further research and development:

- **Enhancing Efficiency:** One of the primary focuses of future work should be on improving the efficiency of Dye-Sensitized Solar Cells (DSSCs) using beetroot dye. Researchers can explore ways to optimize the dye extraction process, investigate novel beetroot varieties, or fine-tune the TiO2 structure to boost conversion efficiency.

- **Stability and Durability:** Investigating methods to enhance the stability and long-term durability of beetroot-based DSSCs is crucial. This involves addressing issues related to dye degradation, electrolyte stability, and the impact of environmental factors on cell performance.
- **Material Compatibility:** Exploring the compatibility of beetroot dye with other materials and components of DSSCs, such as counter electrodes and electrolytes, to ensure the seamless integration of this natural dye into the overall system.
- **Scaling Production:** Investigating methods to scale up the production of beetroot-based DSSCs while maintaining efficiency and cost-effectiveness. This could involve optimizing manufacturing processes and ensuring a consistent supply of beetroot dye.
- **Energy Storage Integration:** Exploring energy storage solutions that complement beetroot-based DSSCs to provide uninterrupted power during periods of low light, such as nighttime or cloudy days.
- **Environmental Impact Assessment:** Conducting comprehensive life cycle assessments to evaluate the environmental impact of beetroot-based DSSCs, from production to disposal, and comparing it to other solar cell technologies.
- **Market Adoption and Commercialization:** Investigating market opportunities and strategies for the commercialization of beetroot-based DSSCs, including potential partnerships with industry players and investment in production facilities.

The future of solar cell technology using natural dyes like beetroot is promising, and ongoing research and innovation will continue to unlock its potential. The development of sustainable and efficient solar cells that harness the power of natural materials represents a step towards a more environmentally friendly and renewable energy future.

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