Characterization of Dye-sensitized solar cell using synthetic organic dyes.

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***Abstract-** Cocktail dye solar cells represent a variation of dye-sensitized solar cells (DSSCs), employing a multi-dye approach to broaden solar spectrum absorption. DSSCs belong to the third-generation solar cell category, emulating natural photosynthesis by employing light-absorbing dyes to convert light into electricity. In the context of cocktail dye solar cells, the utilization of several dyes with distinct absorption spectra serves to amplify solar cell efficiency. Each dye is meticulously designed to capture specific segments of the solar spectrum, and the integration of multiple dyes extends the range of absorbed wavelengths. While cocktail dye solar cells hold promise as a renewable energy technology, their efficacy and cost-effectiveness necessitate further exploration through ongoing research and development endeavors.*

***Keywords:** Cocktail dyes, dye solar cell, solar cell, solar energy, performance parameters*

I. Introduction

In recent years, dye-sensitized solar cells (DSSCs) have drawn a lot of attention as a potential replacement for traditional silicon-based solar cells. A transparent conductive oxide (TCO) substrate, a porous layer of a semiconductor material, and a sensitising dye molecule that absorbs light to produce electrical current make up the sandwich-like structure of DSSCs. The effectiveness of light harvesting and electron injection are directly impacted by the dye molecule, making it a critical factor in DSSC performance. The effectiveness of DSSCs has recently been improved using a variety of techniques, such as the use of novel dye molecules and the optimisation of device production methods.

Cocktail dyes, which are mixtures of two or more distinct dye molecules, are one possible strategy to increase the effectiveness of DSSCs. Cocktail dyes are designed to combine the benefits of various dye molecules, such as their excited-state lifetimes, absorption spectra, and electron injection efficiencies, to produce a synergistic effect that improves the overall performance of DSSCs. Recent research have shown that cocktail dyes can successfully be used to increase DSSC efficiency.

The goal of this paper is to give a thorough overview of current developments in the use of cocktail dyes to improve the performance of DSSCs. We will start by going over the core ideas behind DSSCs and how sensitising dyes function in them. After that, we'll go over the many cocktail dyes that have been discussed in the literature and the methods used to improve their effectiveness. We will also draw attention to the drawbacks and restrictions of using cocktail dyes, such as the potential for dye aggregation and the requirement for exact dye ratio management. Finally, we'll wrap off by talking about cocktail dyes' possible future uses and applications in the creation of effective and affordable DSSCs.

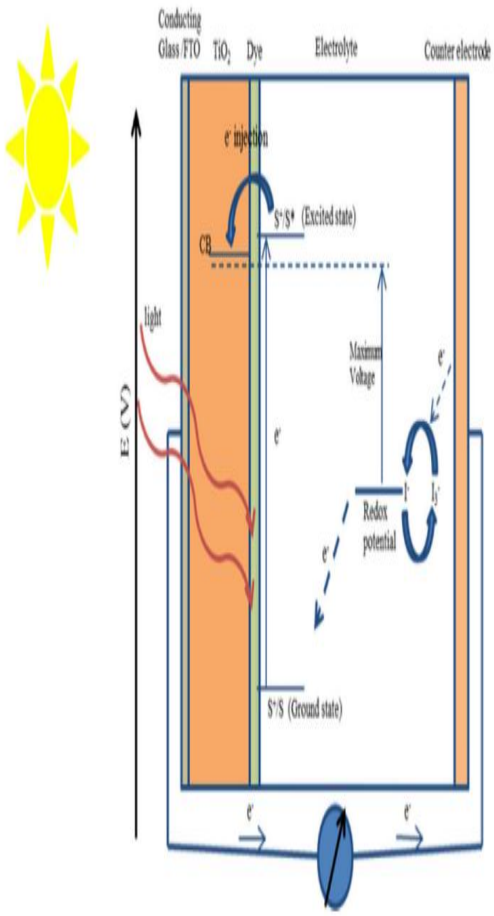

Fig.1. Dye-sensitized solar cell [1]

Published By:
International Journal of Engineering
Research in Current Trends

II. Historical review

The concept of using a dye molecule to harvest light and produce electrical current in a semiconductor material was first put forth by Brian O'Regan and Michael Grätzel at the Swiss Federal Institute of Technology (EPFL) in the early 1970s, which led to the development of dye-sensitized solar cells (DSSCs). The natural process of photosynthesis in plants, where chlorophyll molecules absorb light and transform it into chemical energy, served as the model for the development of DSSCs. In order to sensitise a porous layer of titanium dioxide (TiO2) semiconductor material, Grätzel and his team at EPFL announced the first practical demonstration of a DSSC in 1991. The final product displayed a high photoconversion efficiency of about 7%, which was much greater than the efficiency of 1% for other kinds of photoelectrochemical cells that was previously reported. Since then, researchers from all over the world have been trying to develop new kinds of sensitising dyes and enhance the device fabrication processes in order to increase the effectiveness and stability of DSSCs. Use of cocktail dyes, which are mixtures of two or more distinct dye molecules, is one possible strategy to improve the performance of DSSCs. At the National Renewable Energy Laboratory (NREL) in the United States, Kai Zhu and his colleagues released the first study on the application of cocktail dyes in DSSCs in 2008. They sensitised a TiO2 layer using a mixture of the dye molecules D35 and D45 and attained a photoconversion efficiency of over 10%.Since then, a number of additional groups have reported using cocktail dyes to successfully improve the functionality of DSSCs. For instance, Masatoshi Yanagida and his team at Kyoto University in Japan were able to obtain a photoconversion efficiency of over 12% in 2010 by combining three dye molecules with the names TH305, TH306, and TH308. To further enhance the functionality of DSSCs, researchers have also been examining the use of alternative sensitising dyes, such as organic dyes, metal-free dyes, and perovskite dyes, in combination with conventional dye molecules. For instance, Shuangpeng Wang and his colleagues at Hefei University of Technology in China achieved a record-breaking photoconversion efficiency of 18.3% in 2016 by combining a perovskite dye and a ruthenium-based dye.
Cocktail dyes have shown some encouraging results, but there are still a number of difficulties and restrictions that come with using them. These include the possibility of dye aggregation, the requirement for exact dye ratio control, and our incomplete understanding of the underlying mechanisms governing the synergistic effect of the dye combination. Overall, the creation of cocktail dyes has advanced our effort to increase the effectiveness and performance of DSSCs. Cocktail dyes are anticipated to remain essential in the creation of effective and affordable DSSCs as researchers continue to investigate new categories of sensitising dyes and methods for device manufacture.

III. Performance parameter for dye-sensitized solar cell

The performance factors that generally define dye-sensitized solar cells include:
1. Photoconversion efficiency (PCE): This is the primary factor to consider when assessing a DSSC's overall performance. It is stated as a percentage and is defined as the electrical power output to incident light input ratio. Depending on the materials and device configurations employed, the PCE of DSSCs can range from a few percent to over 18 percent.

2. Short-circuit current density (Jsc): When the external load resistance is zero, or when there is a short circuit, this parameter indicates the greatest current density that the DSSC is capable of producing. Jsc is proportional to the effectiveness of electron injection from the sensitising dye and the amount of light absorbed by it.

3. Open-circuit voltage (Voc): This value denotes the highest voltage that the DSSC is capable of producing in the absence of an external load. It is based on the energy differential between the semiconductor material's conduction band and the dye's highest occupied molecular orbital (HOMO).

4. Fill factor (FF): The ratio of maximum power output to the product of Voc and Jsc is represented by this parameter. The internal resistance, recombination losses, and electrode surface area all have an impact on FF, which is a measurement of the efficiency of charge transfer and collection within the DSSC.

5. Incident photon-to-current conversion efficiency (IPCE): As a function of wavelength, this measure shows what proportion of incident photons are converted by the DSSC into electrical current. IPCE is a helpful metric for assessing the spectrum response of DSSCs and can offer information about the effectiveness of charge transfer and light harvesting.

The electrochemical impedance, the dark current, and the stability under various environmental conditions are additional variables that are frequently used to describe how well DSSCs work. Researchers can create more reliable and effective DSSCs for use in the conversion and storage of renewable energy by tuning these performance characteristics.

Table.1. Parameter for Dye-sensitized solar cell

WE/CE	Voc(mV)	JSC ($mAcm^{-2}$)	FF (%)	η (%)	Reference
WE: TiO2 doped with tungsten	730	15.10	67	7.42	[2]
WE: TiO2 doped with scandium	752	19.10	68	9.60	[3]
WE: TiO2 doped with indium	716	16.97	61	7.48	[4]
WE: TiO2 doped with boron	660	7.85	66	3.44	[5]
WE: TiO2 doped with fluorine	754	11	76	6.31	[6]
WE: TiO2 doped with carbon 730 20.38 57 8.55 [333]	730	20.38	57	8.55	[7]
WE: ONT/FTO 700 10.65 70 5.32 [334	700	10.65	70	5.32	[8]
WE: G-TiO2 NPs/TiO2 NTs 690 16.59 56 6.29 [335	690	16.59	56	6.29	[9]
WE: TiO2 doped with Cu	591	6.84	56	2.28	[10]
CE: PtCo	717	16.96	66	7.64	[11]
CE:Pt+SLGO	670	7.9	65	3.4	[12]
CE: PtMo	697	15.48	62	6.75	[13]
CE: $PtCr_{0.05}$	739	13.07	71	6.88	[14]
CE: Ni-PANI-G	719	11.56	64	5.32	[15]
CE: PANI nanoribbons	720	17.92	56	7.23	[16]
CE: $Pd_{17}Se_{15}$	700	16.32	65	7.45	[17]
CE: PtCuNi	758	18.30	69	9.66	[18]
CE: g-C_3N_4/G	723	14.91	66	7.13	[19]
CE: FeN/N-doped graphene	740	18.83	78	10.86	[20]

IV. Different type of natural, synthetic, organic dyes:-

Different types of dyes are used by dye-sensitized solar cells (DSSCs) to collect light and transform it into electrical energy. These colours can be broadly divided into three groups: organic, synthetic, and natural.Natural sources like plants, fruits, and vegetables are used to make natural dyes. These dyes are eco-friendly and renewable, which makes them a desirable choice for applications involving sustainable energy. The anthocyanins from berries, betalains from beets, and chlorophyll from spinach are a few examples of natural colours employed in DSSCs.

In the lab, chemical reactions are used to create synthetic colours, which are typically sourced from petroleum-based sources. These dyes are suitable for enhancing the functionality of DSSCs because they provide a great degree of control over their chemical structure and characteristics. Porphyrin, phthalocyanine, and dyes based on ruthenium are a few examples of synthetic dyes utilised in DSSCs. Organic dyes are a subcategory of dyes that often result from chemical processes and contain molecules with a carbon base. These dyes are a popular option for DSSCs because they strike a good mix between environmental friendliness and tunability. The subcategories of organic dyes include those with no metals, those based on carbazoles, and those based on triphenylamine. In terms of optical characteristics, charge transfer effectiveness, and other factors, each type of dye has advantages and limits. . For instance, compared to synthetic and organic dyes, natural dyes frequently have poorer light absorption and lower stability, whereas synthetic dyes frequently need time-consuming and expensive production processes. On the other side, organic dyes offer a compromise between environmental sustainability and adaptability but may show less stability in some environmental circumstances.

In general, the selection of a dye is based on the particular needs of the DSSC application, such as cost, efficiency, stability, and environmental impact. To create more effective and robust DSSCs for practical applications, researchers are always experimenting with new types of dyes and refining current ones.

Conclusion

In conclusion, using cocktail dyes to improve the performance of dye-sensitized solar cells (DSSCs) has shown promise. Cocktail dyes can increase light absorption, improve charge separation, and reduce charge recombination, which increases the photoconversion efficiency (PCE) of DSSCs by combining various dyes with complimentary optical and electrical properties.

Cocktail dye performance in DSSCs is influenced by a number of variables, including dye selection and proportion, solvent solution, and device architecture. Cocktail dyes have been shown to greatly improve the PCE of DSSCs in recent research, with reported values surpassing 14%.

However, more investigation is required to improve cocktail dye performance and address issues with their real-world applications, like stability and scalability. Additionally, DSSCs' environmental sustainability and carbon footprint can be improved by using natural and eco-friendly colours in cocktail dye formulations.

Overall, there is a lot of promise for cocktail dyes to improve DSSC performance and further the creation of sustainable energy solutions.

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