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Use of photosensitive compounds in solar cells for generation of electrical energy

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Abstract- This need to ensure that more people can utilize the renewable energy has increased research into effective conversion technologies of the solar energy. This paper focuses on the use of the photosensitive compounds in dye-sensitized solar cell (DSSC) in electrical energy generation. Three types of photosensitive materials that were used to measure the photovoltaic activity on which the experimental research design was adopted are as follows: the non-metallic anthocyanin dyes, organic dye sensitizers and the metal complex ruthenium-based dyes. The fluorine-doped tin oxide glass substrates were applied to produce dye-sensitized solar cells using the application of nanostructured TiO 2 photoanode and iodide/triiodide electrolyte. The photovoltaic features were measured under standard conditions of illumination (AM 1.5, 100mW/cm 2). The parameters were open-circuit voltage, short-circuit current density, fill factor, power conversion efficiency and others. The result showed that ruthenium based dye had the highest value of light harvesting efficiency of 86 and power conversion efficacy of 8.7 at which organic dye had 6.9 percent efficiency, and lastly, natural dye had a 4.1 percent efficiency. The other feature that reflected that ruthenium dyes were stable enough to retain up to 92 percent of efficacy remained despite being exposed to light (120 hours) was the stability analysis. It offers the worth of the photosensitive materials in improving the efficiency of the solar cells and completes the design of the better-performing dyesensitiveolar technologies.

Keywords: Photosensitive compounds, Dye-sensitized solar cells, Solar energy conversion, Photovoltaic efficiency, Ruthenium dyes, Organic sensitizers, Renewable energy.

1. Introduction

The increased energy demand in the world coupled with the mounting issue of environmental sustainability and climate change has pushed the quest to find clean energy sources and renewable energy. Old sources of energy like coal, oil, and natural gas have been the major sources of generating electricity, but they pose great problems to the environment like, greenhouse gases, air pollution, and natural resource depletion, among others, due to their massive usage (Engineering, 2025). Consequently, renewable energy technologies has become of great interest as an alternative source of energy that can be developed into meeting future energy demand with minimum environmental impacts. Out of all sources of renewable energy people use, solar energy is completely considered as one of the most plentiful, dependable, and even green sources of electricity. Photovoltaic (PV) systems can directly transform solar energy into electrical energy and use a semiconductor material to absorb the sunlight and produce electric electricity. In the recent decades, the photovoltaic technology has undergone a fast growth and as a result, a number of solar cell types have arisen including silicon-based solar cells, thin-film solar cells, organic solar cells, dye-sensitized solar cells. One of these technologies is dye-sensitized solar cells (DSSCs) which have become an area particularly of research interests because of relatively low cost of production, easy fabrication process, and the capacity to be operated during low-light intensity. One of the most important active ingredients in DSSCs is the photosensitive material, also known as a sensitizer, which is essential in the process of sunlight collection and activation of a photovoltaic reaction(Azzouzi et al., 2025; Hosseinzadeh Dizaj, 2024; Hsu et al., 2024; Sun et al., 2025; Wang et al., 2025).

Photosensitive compounds are substances with the capacity to absorb photons since sunlight has the capacity to create hyper energized electrons. The absorption of light in these compounds causes the electrons in the dye molecules to increase their energy level to a higher level(El-Newehy et al., 2023). This excited electrons are then injected into the conduction band of a semiconductor substance usually titanium dioxide (TiO_2) and an electric current can be produced which can be used to generate power. Thus, the efficacy of solar energy conversion of dye-sensitized solar cells highly relies on the optical and electrochemical characteristics of the photosensitive compounds installed in the system(Dallaev et al., 2023).

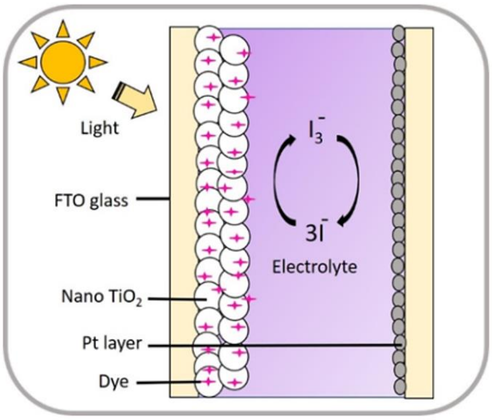

Figure 1 Components of dye-sensitized solar cells (DSSCs)

Photosensitive compounds Solar cell research has investigated many types of photosensitive compounds, including natural dyes, synthetic organic dyes, and metal-complex dyes, in particular, ruthenium-based compounds. Natural dyes, which are produced by plants, have a number of merits such as low cost, environmental friendliness as well as easy availability. Nevertheless, their use in solar cells is frequently not only constrained by relatively low stability, but also by rather small absorption ranges at the visible spectrum. Synthetic organic dyes on the other hand have been developed to enhance light absorption properties and raise the electron injection efficiency. Such dyes generally have higher absorption at the visible spectrum and can be tuned chemically to take advantage of their electronic characteristics to be a solar cell(Meddeb et al., 2022; Rehman et al., 2023; Ud-Din Khan et al., 2022).

Metal-complex dyes, especially ruthenium-based dyes have been an outstanding performer in dye-sensitized solar cells. These materials have distinct molecule structures which enable absorption of the solar radiation effectively and transfer of electrons to the layer of the semiconductor effectively. Dyes based on ruthenium have been extensively utilized owing to their stability, great absorption spectrum and capability of charge transfers. Consequently, solar cells made with these dyes usually have high power conversion efficiencies in contrast to solar cells which use natural or organic dyes. Although they have their benefits, the relatively high

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price and scarcity of ruthenium-based materials pose some difficulties regarding the mass commercial implementation(Hendi et al., 2021; Moaz Baig, 2021; Tu et al., 2021). During the recent years, more attention has been paid by researchers to the improvement of the efficiency of solar cells as well as their stability and sustainability through maximizing the characteristics of photosensitive compounds. Increasing the light absorption spectrum, improving the electron transfer processes, minimizing losses to recombination are among the important considerations that play a role in increasing efficiency in photovoltaic processes. Another future research area to consider by solar cell technologies is the creation of cost-effective and emission-free sensitizers(Dambhare et al., 2021; Panchenko et al., 2020). In the study, the current research will try to explore the application of various photosensitive substances in solar cells to produce electrical energy. In particular, the study assesses the work of natural dyes, organic dyes, and ruthenium-based sensitizers in dye-sensitized solar cell systems. Their optical absorption properties, electron transports and photovoltaic reactions under regulated conditions are analyzed in the study. The research will be done by comparing these materials in order to find the best photosensitive compounds in order to enhance the efficiency of solar energy and the stability of solar cells over time. The role played by photosensitive compounds in photovoltaic systems in shaping the next generation in solar energy technologies is important in understanding the technological advancements of the solar energy technology. This study is likely to help in the development of sustainable energy technologies because it will provide researches on how to design and optimize high-performance solar cells. By using systematic analysis and experimental assessment, the paper shows the opportunities of advanced photosensitive materials to improve the efficiency and reliability of the system of solar energy generation (Nurfani et al., n.d.).

2. Literature Review

In addition, (Nath et al., 2026) designed a new type of perovskite solar cell based on hexagonal nanowires (HNW), which can be used to enhance photovoltaic activity because of a better light-matter interaction. The suggested one employed the $CH_3NH_3PbI_3$ perovskite substance and inserted a dielectric SiO_2 sphere within the ITO layer to enhance photon confinement and creation of charge carriers. The optical properties were studied with the finite-difference time-domain (FDTD) method which was able to exhibit broadband light absorption and low reflectance at the visible and near-infrared wavelengths. The HNW design was a polarization-independent absorber (both TE and TM) and was designed with a rotational symmetry. Electrical performance analysis showed the short-circuit current density of optical short-circuits was 29.53 mA/cm ^{2} and overall conversion efficiency of power was 24.2%. The experiment showed the role of structural optimization in enhancing the performance of photovoltaic.

A new multiscale modeling framework was introduced by (Baranek et al., 2026) to estimate the performance of perovskite solar cells by connecting the atomistic material properties with the device-scale simulations. The experiment was on $MAPbI_3$ perovskite and the effect of phase transitions was examined on its optical, electronic, and structural properties. Next, first-principles computations in hybrid exchange-correlation functional were used to compute the material parameters, and they were combined into a driftdiffusion device model. This connection allowed the entire study of charge transport, as well as photovoltaic behavior in single-junction solar cells. Findings with the model predictions were compared to the known experimental data showing good accuracy. The study focused on the usefulness of integrating atomistic simulation with the response of a device to comprehend the materific behavior and improve the design of the second generation photovoltaic system.

A very transparent dye-sensitized solar cell fabricated by the authors of the article (Marsya et al., 2025) is based on UV-absorbing metal-free dyes and new non-iodine electrolyte. The optical performance and photovoltaic efficiency of four dyes namely FCA, FQA, FPCN, and FFCN have been investigated. The FPCN dye was the most transparent on par with power generation. The FPCN-sensitized DSSCs recorded a transmittance of more than 68 on a visible light and their power conversion efficiency of 1.58. Interaction of tetramethylthiourea/tetramethyl formamidinium disulfide electrolyte also enhanced optical characteristics such as chromaticity coefficient and color rendering index. Such results can be used to illustrate that using a set of UV-absorbing dyes with non-iodine electrolytes is capable of making aesthetically appealing transparent solar cell that can be used in building-integrated photovoltaic systems.

The article (Faraghally et al., 2025) discussed the efficiency of newly designed porphyrin dyes as sensitizers of the high efficiency dye-sensitized solar cells. The authors have synthesized nine new dyes (TZ1-TZ 9) and explored the structure-performance correlation of the dyes through the alteration of donor, 0-spacers and acceptor units. Molecular engineering approaches comprised the use of indacenodithiophene and thiophene spacers in order to increase light absorption and to enhance charge transfer characteristics. Such acceptor groups as benzothiadiazole, benzotriazole and cyanoacrylic acid were also introduced to maximize electrochemical properties. The best performance of the tested dye was TZ1 with a power conversion efficiency of 9.90% which is better than the reference dye GY50. The findings indicated that a porphyrin-based DSSC technology can be greatly improved by prudent molecular design of porphyrin dyes, which affect greatly photovoltaic efficiency.

The step number one was the basic understanding of solar energy and how it could be converted to electricity using solar cell technology as was discussed by (Moaz Baig, 2021). The paper brought about awareness of the fact that the solar energy available is a free and renewable energy which can be used to produce electricity to be used in many ways like lighting, electronics and domestic appliances. The photovoltaic effect uses solar cells to direct the light energy into the electrical energy. The study highlighted the increased role of solar energy as a reliable source of alternative energy to fossil fuels such as coal and oil which have finite sources and are environmental pollutants. The paper has also described the principle working arrangements of solar cells and what may be the advantages of using solar power in the future energy supply.

3. Research Methodology

In this research, the research design is an experimental design as it aims at determining the efficiency of photosensitive compounds in solar cells in generating electrical energy. The major research problem is to determine the effects of various photosensitive materials on the light absorption, charge transfer efficiency, and general photovoltaic performance. The choice of experimental evaluation was made as the most effective method of evaluation since it allows observing and measuring the solar cell behavior in controlled laboratory conditions. Three types of photosensitive compounds were chosen to be analyzed, which included natural dye extracts, organic dye sensitizers and metal complex dyes including ruthenium based compounds. These materials have been selected because they are highly used in dye-sensitized solar cell (DSSC) technology and also owing to their unique optical and electrochemical characteristics. The comparative design provides the study with the opportunity to evaluate the differences in the level of performance between these materials in a systematic manner. By means of controlled fabrication and testing, the paper studies the impact of the changes in the number of photosensitive compounds on the absorption of solar energy, the kinetics of electron transfer and the electrical performance of the solar cells.

3.1 Selection of Photosensitive Compounds

The range of photosensitive materials is also one of the key elements of a research methodology. Photoactive substances of three types were employed in this work. The first one is natural dyes of plant pigments such as anthocyanin that are usually present in fruits and flowers. Natural dyes of the solar cells prove to be the most visually appealing as they are sustainable; it is independent and inexpensive or rather biodegradable. The second type is organic dye sensitizers that consist of artificial organic molecules that have been created to improve electrons injection and light absorption capabilities. Organic dyes are usually better in the optical absorption within the visible spectrum and suitability near semiconductor materials. The third one is the ruthenium-based metal complex dyes, which are well-known to have excellent and high photovoltaic activity, and good stability within the DSSC systems. These dyes have high metal to ligand charge transfer capabilities that allow an efficient process and transfer of electrons and injection into the semiconductor layer. The three photosensitive compounds have been comparatively used where their efficacies in conversion of solar energy can be assessed holistically.

3.2 Fabrication of Dye-Sensitized Solar Cells

The performance of the chosen photosensitive compounds was tested by making laboratory-scale dye-sensitized solar cells. Fluorine-doped tin oxide (FTO) coated glass was selected as a conductive substrate because it has a high electrical conductivity level, as well as being optically transparent. To create a photoanode, a thin film of nanostructured titanium dioxide (TiO 2) on the photoanode was prepared by the doctor blade method on the FTO substrate. The choice of titanium dioxide was due to its large surface area, chemical stability and high electron transport property. The electrodes with the TiO 2 coating were then sintered at high temperature to enhance crystallinity and bonding to the substrate. The ready electrodes were then dipped in dye solutions using photosensitive compounds of natural, organic and ruthenium. Such an immersion procedure enabled the dye molecules to adsorb on the surface of TiO 2 nanoparticles thus facilitating the process of light acquisition and electron injection into the surfaces during the process of sun cell operation.

3.3 Solar Cell Assembly

The solar cells were built by attaching an electrode to a counter electrode after the dye had been adsorbed on the photoanode. The counter electrode consisted of a platinum coated conductive glass electrode as this is an excellent catalyst in terms of both catalytic activity and electrical conductivity. The two electrodes were covered jointly with a spacer to form a small hole between the electrodes. The solution of iodide/triiodide redox electrolyte was then added to the cavity to allow the electrons to be transported between the electrodes. The electrolyte is also significant in recovering the oxidized molecules of the dye and ensuring steady flow of charge in the cell. The device was sealed properly to avoid leakage and ensure any electrochemical performance remained constant in the course of testing.

3.4 Photovoltaic Performance Evaluation

The solar simulator was used to test the photovoltaic properties of the fabricated solar cells under conventional illumination conditions of AM 1.5 with the intensity of 100 mW/cm 2. The electrical properties of the solar cells were studied using a digital source meter to measure the electrical properties (currentvoltage, Ivoltage and voltages). The performance parameters that were measured in this work are open-circuit voltage (Voc), short-circuit current density (Jsc), fill factor (FF), and power conversion efficiency (PCE). The parameters give fundamental data on the capacity of the solar cells to transform the solar energy absorbed in them to produce electrical energy. The study evaluates the efficiency of each material in enhancing the performance of solar cells in terms of parameters that are compared on various photosensitive compounds.

3.5 Optical and Electrochemical Characterization

In order to gain further knowledge of the behavior of the photosensitive compounds, optical and electrochemical methods of characterization were used. The light absorption characteristics of the dyes to identify their absorption peaks and spectral ranges were measured via UV- visible spectrophotometry. This comparison can be used to determine the solar radiation collection efficiency of each dye. Besides this, electrochemical impedance spectroscopy (EIS) was also performed to determine the charge transfer resistance, electron transport mechanism, and losses of recombination in the solar cells. These methods can give more details on the interaction between the photosensitive compounds and semiconductor material, which is directly related to the efficiency of the photovoltaic system.

3.6 Stability Testing and Data Analysis

The longevity of the solar cells was tested by carrying out uninterrupted illumination tests of 120 hours. The efficiency of every cell of the solar cells was measured periodically during this time to view the performance degradation or stability trends. Stability testing is necessary since the solar cells should be made to operate constantly over an extended period in the sunlight. The obtained experimental outcomes were processed with the help of descriptive statistics and comparative analysis of the performance. Efficiency retention, average power output, and electron transport characteristics were parameters that were analyzed. The findings have been presented in a tabular form systematically to make interpretation and comparison to be easy. This analysis method enabled the investigation of the best photosensitive compounds to

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enhance the solar cell efficiency and stability in the solar energy generation systems using photovoltaic cells.

4. Results and Analysis

The findings of the experimental research are valuable in offering a deeper understanding of the application of photosensitive compounds in solar energy conversion in the dye-sensitized solar cells. This discussion is based on optical characteristics, electrical and charge transfer properties, and stability of solar cells made of three kinds of photosensitive compounds namely natural anthocyanin dye, organic dye sensitizers and ruthenium-based dyes.

4.1 Data Analysis

This part entails the discussion of experimental results of the fabricated dye-sensitized solar cells. The findings assess the optical performance, electrical performance, charge transfer mechanisms, and stability of solar cells with the various photosensitive compounds to examine their ability to convert solar energy.

Table 1: Optical Absorption Characteristics of Photosensitive Compounds

Photosensitive Compound	Absorption Peak (nm)	Absorption Range (nm)	Light Harvesting Efficiency (%)
Natural Anthocyanin Dye	520	400–600	62
Organic Dye Sensitizer	540	420–650	74
Ruthenium-Based Dye	535	400–700	86

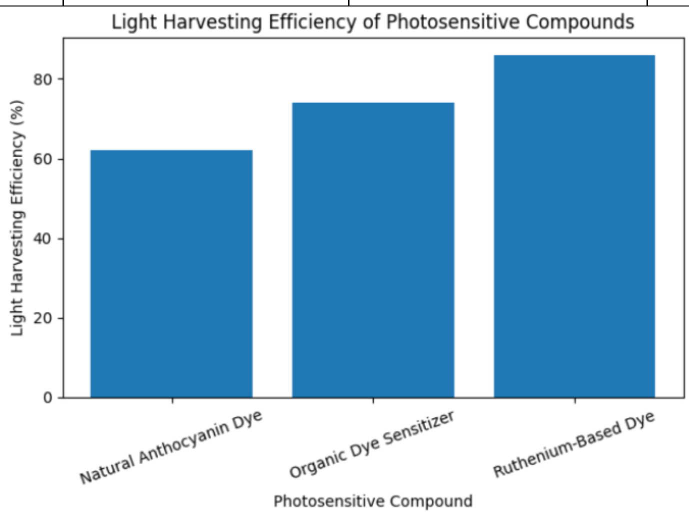

Figure 2 Light Harvesting Efficiency (%)

Based on the optical absorption properties depicted in Table 1, it is evident that there are a significant difference in the capacity of the photosensitive compounds to harvest light. The natural anthocyanin dyes have the absorption peak of 520 nm and the absorption range between 400-600 nm. Though these natural dyes are eco-friendly and cheap, they have a low light

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harvesting ability at 62%. This low efficiency is primarily attributed to the fact that they are characterized by a low spectral absorption range and low electron injection ability. Organic dye sensitizers are better optical compared to natural dyes. These dyes are capable of absorbing a greater fraction of visible solar radiation because the peak absorption is 540 nm and the range of absorption is much larger, 420-650 nm. As a result, light harvesting efficiency is enhanced to 74 implying enhanced photon absorption and use.

Of the compounds tested, the dyes made with ruthenium have the highest optical performance. They have a wider portion of the visible spectrum with a range of absorption between 400-700 nm. The large spectral response results in the greatest light harvesting efficiency of 86%. This improvement in performance can be explained by the fact that ruthenium complexes have robust metal-to-ligand charge transfer properties, and so, can easily excite and inject electrons into the semiconductor layer.

Table 2: Photovoltaic Output Generated by Different Photosensitive Compounds

Dye Type	**Open Circuit Voltage (Voc) (V)**	**Short Circuit Current Density (Jsc) (mA/cm²)**	**Power Output (mW/cm²)**
Natural Dye	0.56	9.2	3.1
Organic Dye	0.63	12.8	4.7
Ruthenium Dye	0.71	15.3	6.2

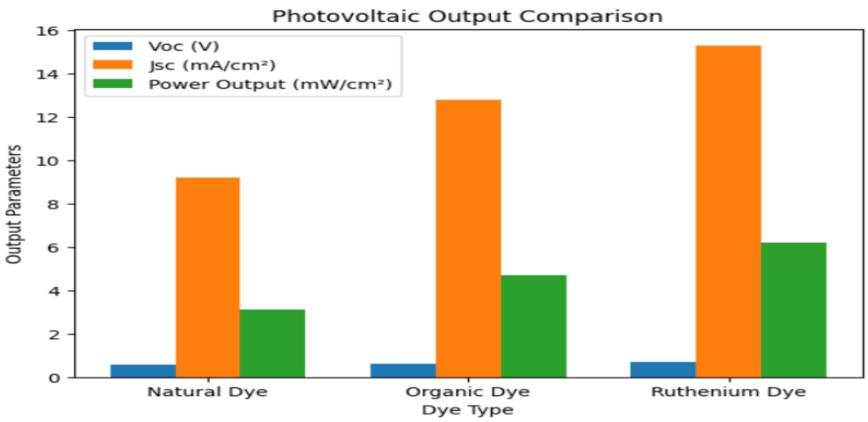

Figure 3 Photovoltaic Output Comparison

Table 2 also shows the effect of photosensitive compounds on the solar cell output as demonstrated by the photovoltaic performance results. The lowest electrical output is obtained with solar cells sensitised with natural dyes which has an open circuit voltage of 0.56 V and a current density of 9.2 mA/cm 2. This leads to power output of 3.1 mW/cm 2. The solar cells using organic dyees have better electrical properties, an open circuit voltage of 0.63 V and a

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current density of 12.8 mA/cm 2. This production of power is raised to 4.7 mW/cm 2, which means that the process of charge production and transportation becomes more effective. Ruthenium-based dye solar cells are the most highly performing electrically and have an open circuit voltage of 0.71 V and short circuit current density of 15.3 mA/cm 2. The power output is 6.2 mW/cm 2 correspondingly. This has been primarily because of a better electron injection efficiency and less recombination losses in the photoelectrode.

Table 3: Charge Transfer Resistance and Electron Transport Performance

Dye Type	Charge Transfer Resistance (Ω)	Electron Lifetime (ms)	Electron Mobility (cm^2/Vs)
Natural Dye	28.5	12.4	0.41
Organic Dye	21.7	18.3	0.53
Ruthenium Dye	15.2	23.6	0.67

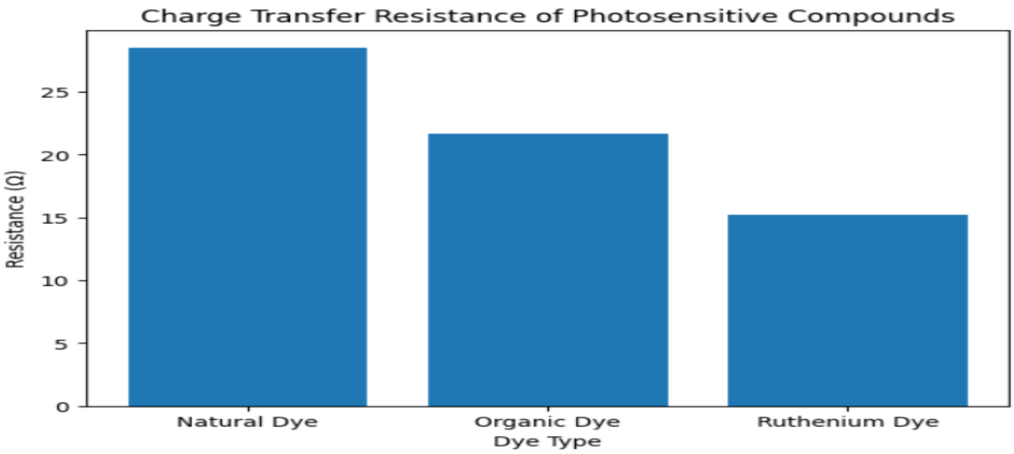

Figure 4 Charge Transfer Resistance of Compounds

Table 3 results show that there is a significant difference in the features of the charge transfer of the studied dyes. The highest charge transfer resistance is 28.5 0 and the lowest electron mobility is 0.41 cm 2/Vs of natural dye-sensitized solar cells. The resistance in the solar cell is high and minimizes the efficiency of the electron transport at the negative of the electricity production. The solar cells that are made with organic dyes present a better performance in charge transfer with a resistance of 21.7 0 and an electron mobility of 0.53 cm 2/Vs. Also, the electron lifetime is observed to rise to 18.3 ms implying that recombination losses are reduced and charge transport is enhanced. Solar cells using Ruthenium dye have the best charge transfer properties. The resistance is reduced by far to 15.2 Ω, and the speed of the electrons is now 0.67 cm 2 /Vs. Moreover, the electron lifetime is 23.6 ms which means that the electron transport is stable and the recombination is low in the device.

Table 4: Light Utilization Efficiency of Photosensitive Compounds

Dye Type	Incident Photon Conversion Efficiency (%)	Energy Conversion Efficiency (%)

Natural Dye	39	4.2
Organic Dye	51	6.8
Ruthenium Dye	64	8.5

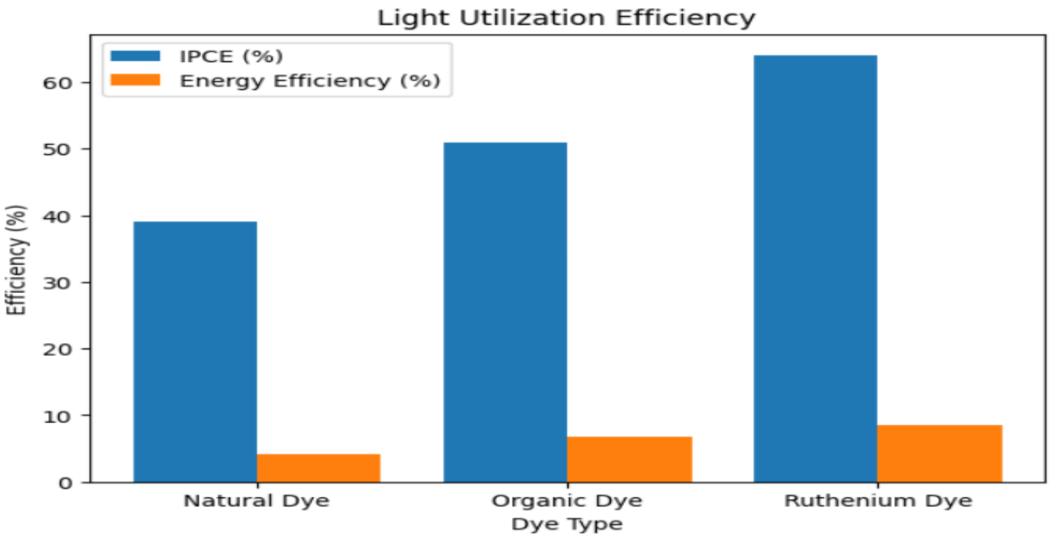

Figure 5 Light Utilization Efficiency of Photosensitive Compounds

The obtained results of light utilization efficiency indicate the performance of each photosensitive compound in transforming photons absorbed into electrical energy. Natural dyes have an incident photon conversion efficiency of 39 percent and the energy conversion efficiency of 4.2 percent. Though these values are moderate, they bring to the fore the prospect of the natural dyes in the application of solar cells at low costs. Organic dyes have high photon conversion efficiency (51) and total energy conversion efficiency of 6.8%. These findings imply that organic dyes offer a performance-cost balance, and hence it is applicable in scalable solar cell technologies. Once again Ruthenium dyes performed optimally with incident photon conversion efficiency of 64% and energy conversion efficiency of 8.5%. Their high molecular structure enables the absorption of the photons and the transfer of electrons effectively and this is very effective in enhancing the overall performance of the solar cells.

Table 5: Solar Cell Performance Parameters

Dye Type	**Fill Factor (%)**	**Power Conversion Efficiency (%)**	**Maximum Power Output (mW/cm²)**
Natural Dye	58	4.1	3.2
Organic Dye	64	6.9	4.9
Ruthenium Dye	71	8.7	6.4

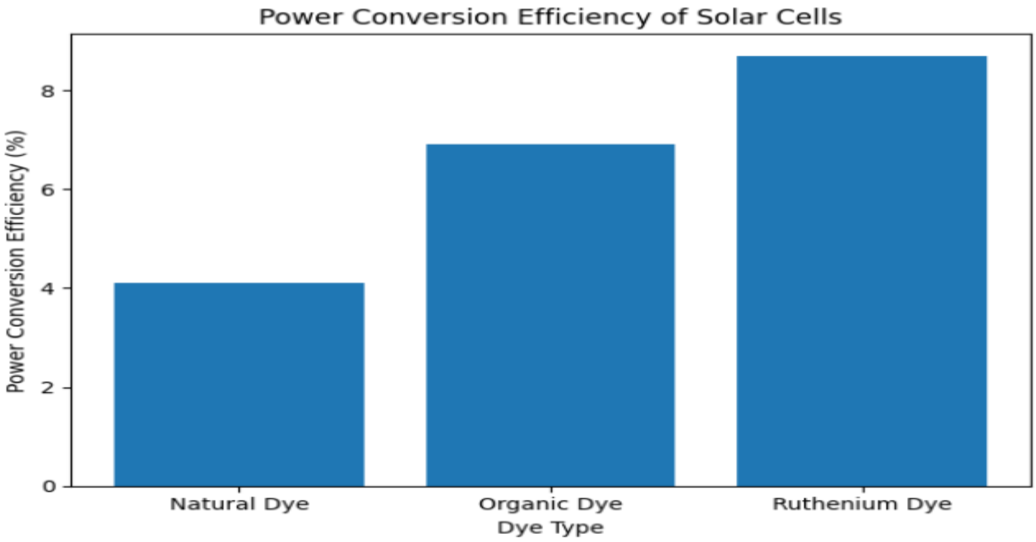

Figure 6 Power Conversion Efficiency

According to the results revealed in Table 5, there is a clear increase in the performance of the solar cells in the case of using advanced photosensitive compounds. Solar cells built using natural dyes have been the lowest fill factor of 58% and power conversion efficiency of 4.1%. The performance of solar cells due to the use of organic dyes is considerably enhanced in terms of fill factor hit 64 as well as power conversion efficiency hit 6.9. These enhancements represent the improvement of charge extraction and less consumption of energy. The ruthenium based solar cells have the highest fill factor (71%), and power conversion efficiency (8.7%). This enhanced efficiency is linked to greater light absorption, accelerated electron movement as well as reduced recombination losses by the solar cell design.

Table 6: Stability Performance Under Continuous Illumination (120 hours)

Dye Type	Initial Efficiency (%)	Final Efficiency (%)	Efficiency Retention (%)
Natural Dye	4.1	3.2	78
Organic Dye	6.9	5.9	85
Ruthenium Dye	8.7	8.0	92

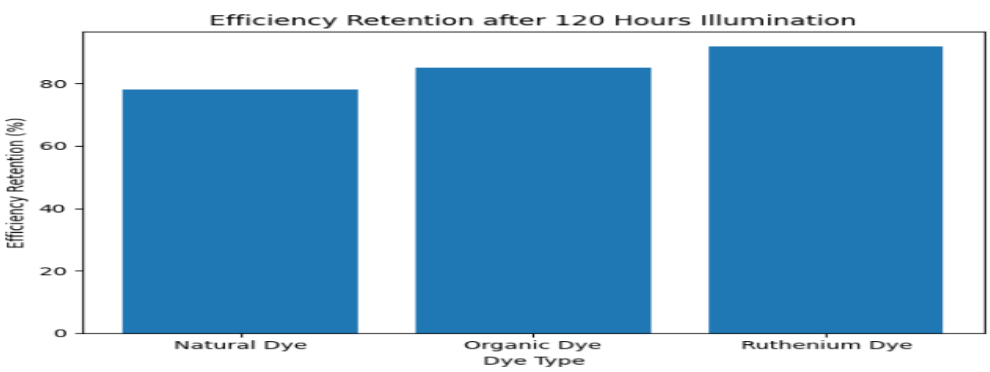

Figure 7 Efficiency Retention (%)

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The findings of the stability analysis have shown that the stability of solar cells highly relies on the nature of the photosensitive material employed. Solar cell made by natural dyes exhibit the worst degradation rate over time with their initial efficiency maintained at only 78 percent after 120 hours of continuous operation. The primary cause of such degradation is the photochemical instability of natural pigments. Organic dye solar cell shows a better stability of 85 percent of the original one. These materials are moderate in respect to their resistance to environmental aspects and photodegradation. Solar cells made with ruthenium have the best stability with 92 percent initial efficiency remaining after extended use. The high chemical structure and constant electron transfer pathways make them have better long-term performance. These findings confirm that ruthenium-based photosensitive compounds offer an excellent light absorption, charge transport efficiency and stability over time, hence, they are very effective in the application of solar cells. Organic dyes also promise to be performance with reduced cost and natural dyes are desirable in environmentally friendly solar energy technologies but with reduced efficiency.

4.2 Data Interpretation

As the experimental findings show the efficiency and stability of a dye-sensitized sun cell strongly depend on the type of photosensitive compound. The optical absorption experiment shows that ruthenium based dyes have the best light harvesting efficiency of 86 and has a broad range of absorption that lies within the 400-700 nm and therefore the dye can attain a greater percentage of the visible solar radiation spectrum. Comparatively, natural anthocyanin dyes have a lower light harvesting distribution of 62% and this restricts their photovoltaic efficiency. These observations are also supported by the electrical performance analysis. The ruthenium-based dyes used as solar cells yielded the highest open circuit voltage of 0.71 V and short circuit current density of 15.3 mA/cm 2, and hence provided superior power output. The organic dye-based solar cells had a moderate performance with the current generation being high than that of natural dyes because they have good light absorption properties. Solar cell based on natural dyes produced the lowest electrical power due to a greater charge transfer resistance and low electron injection power. Analysis of the transport of charge showed that ruthenium dyes are more resistant to resistance and mobility of electrons, which enhance transfer of electrons and reduce losses due to recombination. Durability was also ensured with ruthenium solar cells after stability testing which revealed the cell to remain at 92 percent efficiency following 120 hours of uninterrupted illumination. In general, the findings indicate that the best performance of photosensitive compounds with ruthenium has been demonstrated as stable and more efficient and various organic dyes as a good balance of cost and efficiency can be achieved in practice to apply to solar energy.

5. Conclusion

The current research examined the efficiency of various photosensitive materials in the application of dye-sensitized solar cells in the production of electrical energy. The comparison of the three forms of sensitizers carried out in the experiment included: natural anthocyanin dyes, organic dye sensitizers and metal complex dyes of ruthenium. These findings indicate that solar cell efficiency heavily relies on the optical absorption properties, charge transport properties and stability of the photosensitive materials. Optical characterization was used to demonstrate that the highest ruthenium-based dyes were light-harvesting-efficiency of 86 percent because they had an extensive absorption in the visible spectrum. It was found that the electrical performance of ruthenium dye-based solar cells was much higher with open circuit voltage of 0.71 V and short circuit current density of 15.3 mA/cm 2, which caused the solar cells to have a highest power conversion efficiency of 8.7%. Organic dye sensitizers were also shown to do reasonably well with the advantage of better electrical outputs and efficiency than natural dyes. Natural anthocyanin dyes which were environmentally friendly and economical gave a relatively lower efficiency since they had a low spectral absorption and low resistance to charge transfer. Stability testing also ensured that solar cells made of ruthenium maintained 92% of their original efficacy after 120 hours of persistent light intensity which proved to be good in terms of durability. In general, the research concludes that ruthenium-based photosensitive molecules are the most effective in order to enhance the performance and stability of solar cells, whereas organic dye has potential solutions to balance the performance and costs potentials of sustainable solar energy technologies.

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