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Comparison of Photoelectric Conversion Efficiencies of DSSCs Sensitized with Velvet Red Rose and Ivy Rose Dye

Kadife Kırmızı Gül ve Sarmaşık Gül Boyası ile Duyarlılaştırılan Boya Duyarlı Güneş Pillerinin Fotoelektrik Dönüşüm Verimlerinin Karşılaştırılması

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Abstract

In this study, extracts from velvet red rose and ivy rose were used as sensitizers in dye-sensitized solar cells. XRD analyses confirmed the anatase structure of the TiO_2 thin film. SEM photographs showed that the nanospheres were in tight contact with each other, allowing for greater dye absorption on the TiO_2 surface. It was understood from the UV-vis analysis that the velvet red rose dye exhibited a wider absorption in the visible region. The I-V characterizations showed that cell sensitized with velvet red rose dye exhibited higher cell performance (η=0.12) than DSSC sensitized with ivy rose dye.

Keywords: Dye-sensitive solar cells, Natural dyes, Photovoltaic performance

Özet

Bu çalışmada, kadife kırmızı gül ve sarmaşık gül bitkisinden elde edilen özütler, boya duyarlı güneş pillerinde duyarlılaştırıcı olarak kullanıldı. XRD analizleri, TiO_2 ince filmin anataz yapısını doğruladı. SEM fotoğrafları, nanokürelerin birbirleriyle sıkı temas halinde olduğunu ve TiO_2 yüzeyinde daha fazla boya emilimine izin verdiğini gösterdi. UV-vis analizinden, kadife kırmızı gül boyasının görünür bölgede daha geniş bir absorpsiyon sergilediği anlaşıldı. I-V karakterizasyonları incelendiğinde kadife kırmızı gül boyası ile duyarlı hale getirilen hücrenin sarmaşık gül boyası ile duyarlı hale getirilen hücre'ye göre daha yüksek hücre performansına (η=0.12)sahip olduğu görüldü.

Anahtar kelimeler: Boya duyarlı güneş pilleri, Doğal boyalar, Fotovoltaik performans

1. Introduction

Photovoltaic technology is attractive because it converts light energy directly into electrical energy [1]. The high cost and non-reversible nature of silicon-based solar cells have made it inevitable for new technologies to emerge in this field [2]. In this field, dye-sensitized solar cells (DSSCs)are very attractive due to their ease of manufacture and low cost [3]. A typical DSSC; consists of a photoanode layer, counter electrode, sensitizing dye, redox electrolyte, and counter electrode [4].

Sensitizing dyes produced from some natural plants exhibit remarkable absorption in the visible region. This feature positively affects the performance of DSSCs [5]. The highest cell yields for DSSCs were achieved with Ru-based dyes [6]. However, these dyes' high costs and toxic properties have accelerated the studies on alternative sensitizers [7]. In this context, dyes extracted from natural plants are promising for DSSCs. Natural dyes containing some flavonoid groups provided high power conversion efficiency in DSSCs [8]. Although many rose species have been used as sensitizers in DSSCs, no study using velvet red rose and ivy rose species has been reported before. In a study reported by Roy et al.,

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efficiency values of up to 2.09 % were achieved in DSSCs sensitized with *Rose bengal* dye [9]. In another study by Siregar et al., Mg-modified photoanodes achieved efficiency values as high as 3.53 % in DSSCs sensitized with *Rose myrtle* [10]. In a different study reported by Waghmare et al., TiO_2-ZrO_2 based photoelectrodes were sensitized with *Rose bengal* and the highest cell performance was recorded as 0.038 % [11]. In this study, it was investigated how sensitizers extracted from velvet red rose and ivy rose affected the performance of DSSCs. Photographs of the flowers from which the dyes were extracted can be seen in Figure 1.

Figure 1. a) Red velvet rose b) Ivy rose

2. Research Significance

In this study, the effect of dyes extracted from velvet red rose plants and ivy rose plants on DSSCs was investigated. The aim of this study is how sensitizers produced from different species of two plants of the same genus affect power conversion efficiency. In this context, two different rose species were extracted using the Soxhlet method. It was determined that there were significant changes in the photovoltaic parameters of DSSCs produced using two different sensitizers. This is because the sensitizing sizes have different phenolic contents. In particular, dyes with high anthocyanin content show better cell performance in DSSCs. The highlights of this study are given below.

Highlights:
- DSSC sensitized with velvet red rose dye showed superior cell performance.
- Velvet red rose dye exhibited a wider range of absorption in the visible region.
- The open circuit voltage (Voc=0.5V) of the cell sensitized with the velvet red rose dye is higher than that of the cell sensitized with the ivy rose dye (Voc=0.3V).

3. Experimental Method-Process

3.1. Materials

All materials were used in the experiments without the need for extra purification. In experiments; Titanium IV isopropoxide (TTIP, ≥97.0%, Sigma-Aldrich), ethyl alcohol (≥99.5%, Sigma-Aldrich), urea (Chemsolid), terpineol (Sigma-Aldrich), ethyl cellulose (Sigma-Aldrich), FTO (Florine doped tin oxide) conductive glass (RS < 15 Ω/Sq Sigma), counter electrode (Platinum: Solaronix), redox electrolyte solution (Solaronix) used.

3.2. Production of TiO_2 nanoparticles

In this study, the sol-gel method was used for the production of TiO_2 nanoparticles. 6 ml of TTIP was dissolved in 5 ml of isopropanol. 75 ml of distilled water and 2.5 ml of citric acid were added to this mixture and vigorously stirred at 80 °C for 4 h. After 4 h, the viscous solution formed was centrifuged and the precipitate formed was washed several times with pure and then sintered at 450 °C for 2 h. The white particles formed were crushed in an agate mortar and turned into powder.

3.3. Extraction of plant dyes

Velvet red rose and ivy rose leaves were washed several times with distilled water and dried in a vacuum oven in the dark for one day. The dried leaves were pulverized in a high-speed grinder. 5 g of each dye extract was taken and placed in soxhlet cartridges containing 100 ml of alcohol separately. It was waited until the systems siphoned 5 times, then waited for it to cool down. The cooled extracted dyes were stored in a dark environment at 4 °C until used in the experiments. The beaten rose leaves and the soxhlet system is shown in Fig. 2.

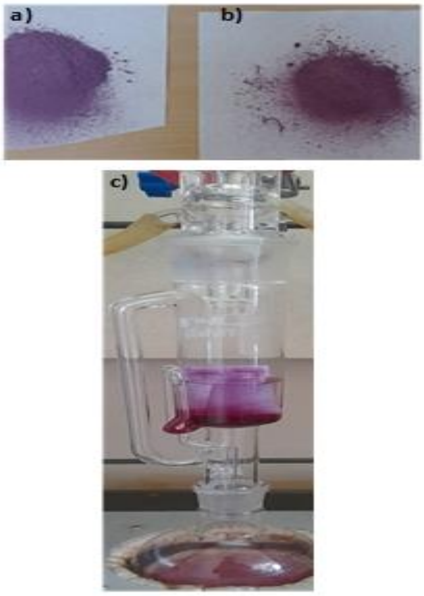

Figure 2. a) Ivy rose extract, b) Velvet red rose extract, c) Production of dyes with the Soxhlet system

3.4. Production of DSSCs

For TiO_2 paste making, 1.5 g TiO_2, some ethyl cellulose, and a few drops of terpineol were mixed in an agate mortar to obtain the appropriate paste consistency. TiO_2 paste was coated with the doctor blade method [12] on the conductive surface of the FTO glasses, which were previously cleaned with alcohol and pure water. It was sintered at 450 °C for 45 min to form the photoanode layer. Photoanodes taken from the muffle furnace were immersed in the dye for 24 h after cooling. A few drops of electrolyte solution were dropped on the dye-sensitized photoanodes and closed with a Pt counter electrode. Then the measurement process was started. The photoanodes produced are given in Fig. 3.

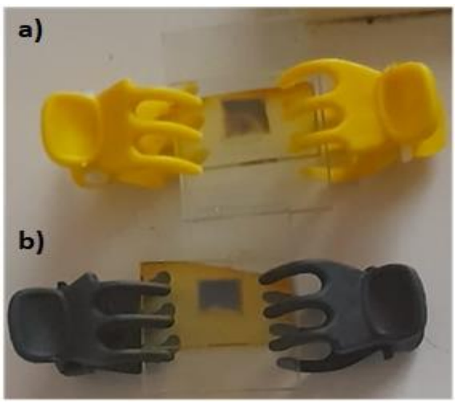

Figure 3. DSSCs a) sensitized with ivy rose dye, b) sensitized with velvet red rose dye

3.5. Characterization

X-ray diffraction (XRD) analyses were performed with Rigaku ManiFlex-600, Scanning electron microscope (SEM) images with Zeiss sigma 300, and UV measurements with UV-3600-Shimadzu-Japan. Electrochemical impedance spectroscopy (EIS) measurements were taken with the Fytronix Impedance Analysis System and I-V measurements were taken with the Fytronix Solar Simulator LSS 9000 I-V Characterization System.

4. Findings and Discussions

The structural analysis of TiO_2 particles produced by the sol-gel method is shown in Fig. 4. The crystal planes corresponding to the 2θ angles in the given Fig. 4 show that TiO_2 is in anatase structure [13]. For high-performance DSSCs, the anatase phase of TiO_2 is very important.

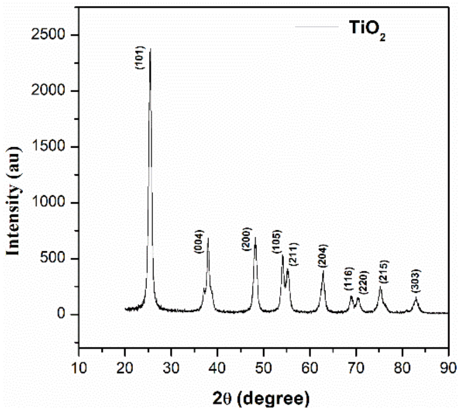

Figure 4. XRD diffraction pattern of produced TiO_2

SEM images in Fig. 5 show the presence of spherical particles. The tight contact between these particles improves electron transport on the photoanode surface [14]. In addition, the presence of tightly packed nanospheres allows better dye absorption on the surface. On the other hand, the presence of such a morphological feature may facilitate charge transport at the interface.

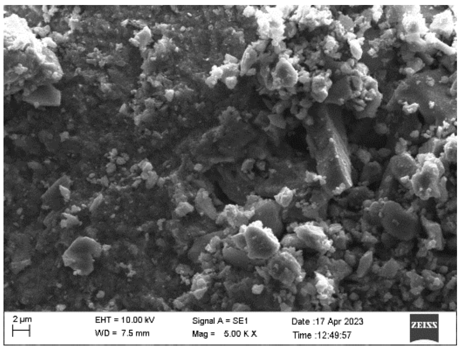

Figure 5. SEM image of TiO_2 particles.

Fig. 6 reflects the UV analysis of natural dyes extracted from two different rose varieties. The dyes obtained from both rose varieties exhibited absorption in a wide wavelength range at 300-700 nm. The dye of the velvet red rose has an extra absorption peak in the wavelength range of 500-600 nm. This absorption behavior can be explained by the higher cell performance of the velvet red rose (η=0.12).

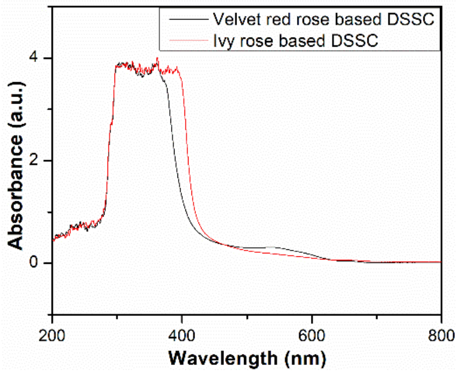

Figure 6. Absorption curves of extracted dyes

The photovoltaic parameters of the produced DSSCs are given in Fig. 7 and summarized in Table 1. When Table 1 was examined, it was seen that the cell sensitized with velvet red rose dye had higher power conversion efficiency than the cell sensitized with ivy rose dye. This can be explained by the high interaction of carbonyl and hydroxyl groups with the TiO_2 surface and stronger absorption in the visible region in the velvet red rose dye [15].

Table 1. Photovoltaic parameters of the produced cells

Sample	J_{sc} (mA/cm^2)	V_{oc} (V)	FF	η (%)
Velvet red rose-based DSSC	0.55	0.5	0.46	0.12
Ivy rose-based DSSC	0.70	0.3	0.35	0.07

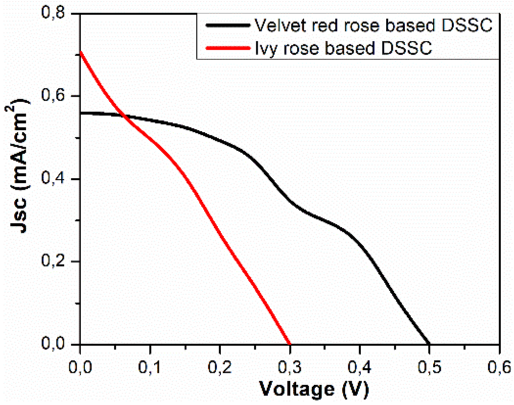

Figure 7. I-V curves of produced DSSCs

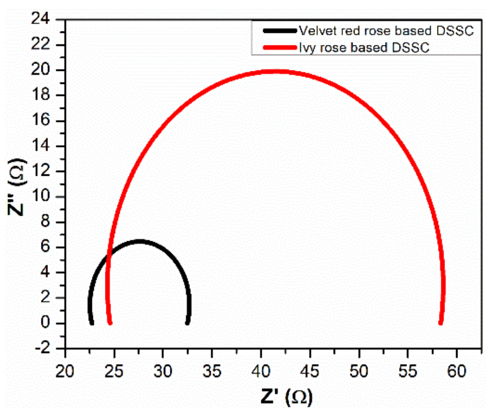

Figure 8. Nyquist curves of DSSCs sensitized with different dyes

EIS analyzes are used to comment on the resistance parameters of a DSSC. Thanks to this analysis, comments can be made about cell performance and resistance parameters. The Nyquist curves in Fig. 8 show two semicircles. As the diameter of the semicircles increases, the impedance value of the DSSC increases and the cell efficiencies decrease [16]. The cell sensitized with ivy rose dye has a larger impedance value because it has a larger semicircular diameter. This could be explained by the lower cell performance of the cell sensitized with the ivy rose dye.

5. Conclusion and Recommendations

XRD analyses confirmed the crystal structure of anatase TiO_2. SEM images showed tight contact between the spherical particles, which facilitated electron transfer. UV analyses showed that dyes sensitized with velvet red rose dye exhibited stronger absorption in the visible region. This was explained by the high cell performance of DSSC sensitized with velvet red rose dye. I-V measurements showed that DSSc sensitized with velvet red rose dye exhibited higher power conversion efficiency. This was attributed to the high interaction of the carbonyl and hydroxyl groups found in the red velvet rose dye with the TiO_2 surface. EIS analyses showed that the cell sensitized with ivy rose dye had a greater impedance value. This was explained by the poor cell performance of DSSC sensitized with ivy rose dye.

6. Credit Authorship Contribution Statement

Fehmi Aslan: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing - review & editing.

7. Ethics Committee Approval and Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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