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A Review: Stability of dye sensitized solar cell

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Abstract-Dye-sensitized solar cells (DSSCs) are a type of solar cell that uses a dye-sensitized semiconductor to capture sunlight and convert it into electrical energy. The stability of DSSCs is an important factor in determining their long-term performance and viability as a renewable energy technology. There are several factors that can affect the stability of DSSCs, including the stability of the dye, the stability of the electrolyte, and the stability of the electrodes. Dyes can degrade over time due to exposure to light and other environmental factors, leading to a decrease in the efficiency of the solar cell. Electrolytes can also degrade over time, leading to a decrease in the performance of the solar cell. In addition, the electrodes can oxidize or otherwise degrade over time, leading to a decrease in the efficiency of the solar cell. To improve the stability of DSSCs, researchers are exploring a range of approaches, including the development of more stable dyes and electrolytes, the use of more robust electrodes, and the incorporation of protective coatings and encapsulation layers to shield the solar cell from environmental factors. In addition, researchers are working to better understand the mechanisms of degradation in DSSCs so that they can be addressed more effectively in future designs.

Keywords- Dye solar cell, stability, performance parameters, solar cell, solar energy.

1. INTRODUCTION

DSSCs(dye-sensitized solar cells) are a type of thin-film photovoltaic device that converts sunlight into electricity .They were first invented in 1991 by Michael Gratzel and Brian O'Regan at the Ecole Polytechnique Federale de Lausanne in Switerland . DSSCs are also known as Gratzel cells, after their inventor.

DSSCs consist of a layer of dye-sensitized nanocrystalline titanium dioxide particles, which are coated with a thin layer of photosensitive dye. When light strikes the dye, it excites electrons in the dye molecules ,which are the transferred to the titanium dioxide particles .The electrons then flow through an external circuit to generate an electrical current .The dye is usually made from organic or inorganic materials, and can be selected to absorb different wavelengths of light, allowing for the creation of cells that are optimized for different solar spectra.

DSSCs have several advantages they also have high power conversion efficiency, with some cells reaching efficiencies of over 14%. However, DSSCs are still not widely used in commercial applications due to their lower stability and durability compared to silicon-based cells. Nonetheless, ongoing research continues to explore new materials and design strategies to improve the one of the key advantages of DSSCs is their low cost of production.

The materials used in DSSCs are cheaper and more abundant than those used in traditional silicon-based solar cells,making them a potentially attractive alternative for large-scale deployment. Additionally, DSSCs can be manufactured using relatively simple techniques, such as screen printing or spray-coating, which further reduces costs. Another advantages of DSSCs is their flexibi;ity. DSSCs can be made into flexible, lightweight and semi-transparent panels, which makes them suitable for a wide range of applications, including building-integrated photovoltaic, wearable electronics and portable chargers. This flexibility also makes them less vulnerable to damage from vibrations, shocks and other external stresses. DSSCs are also capable of generating electricity in low light conditions, such as on cloudy days or in shaded areas, this is because DSSCs can absorb light from a wide range of angles and wavelengths allowing them to capture a greater portion of the available solar spectrum. This means that DSSCs could potentially provide a more consistent and reliable source of renewable energy in areas with fluctuating levels of sunlight.

However, there are also several challenges associated with DSSCs. One of the main challenges is their relatively low stability and durability. DSSCs are sensitive to moisture, oxygen and UV radiation, which can degrade the performance of the cells over time. This limits their lifespan and makes them less suitable for long-term application.

Another challenge is the relatively low power conversion efficiency of DSSCs compared to traditional silicon-based solar cells. While some DSSCs have achieved efficiencies of over 14% , this is still lower than the efficiencies of some silicon-based cells, which can reach over 20%. Improving the efficiency of DSSCs is an active area of research , and there have been several promising developments in recent years, including the use of new materials and innovative design strategies. Overall, DSSCs have the potential to be a cost-effective and versatile alternative to traditional silicon-based solar cells, particularly for applications where flexibility and low light performance are important. However, further research is needed to address the challenges associated with stability, durability and efficiency, in order to make DSSCs a more practical and widely-used technology. Figure 1 shows the dye solar cell layout diagram.

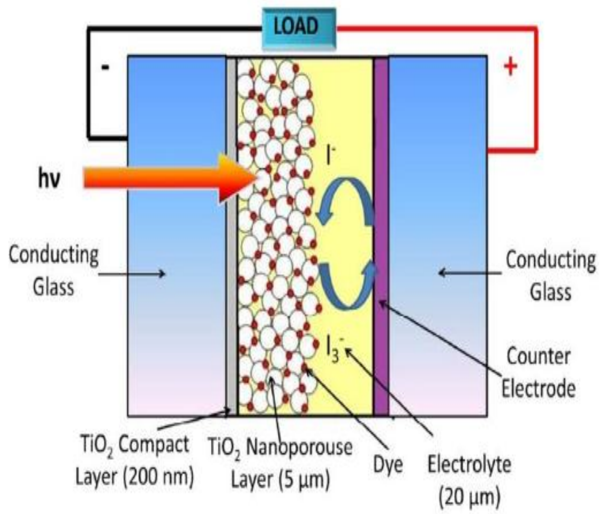

Fig.1. Dye solar cell [3]

2. Historical review of DSSCs

Dang Lam Tuan Cuong et al.(2022) observed the performance of titanium dioxide / reduced Graphene oxide (TiO_2/rGO –TG) nanoparticles was synthesized by ultra sound assisted mechanical mixing method . This method showed that the sample with 1.0wt % rGO under the ultrasonic power of 720W , which possessed the PCE of 6.37% in the 500 hours illumination test under the 300W metal halide lamp and 100 hours drying at 85^{o}C, enhance the performance due to the addition of suitable amount of rGO increased the electron density in the conduction band ,helped to increase the value of current density and efficiency.This examine indicated the addition of rGO enhance the properties of high thermal conductivity and mechanical strength could effect the UV radiation and high temperature.This synthesized can potentially be applied of high performed and stabilized DSSCs widely[1].

Kaiyuan Yang et al.(2022) improved the stability of DSSCs by the copper complex (CuL), where L is the tetradentate ligand 6,6-bis(pyridine-2-methoxy) methyl-2,2- pyridine, was used as a redox couple. CuL has give better stability because ligand reaction not change under presence of a high concentration of 4-tert-butylpyridine, although ligand exchange reactions occur seldom with copper complexes containing bidentate ligands. The stability test under solar enery of 800h at room temperature and 25% relative humidity,after 800h the device retains the initial power efficiency of 2.56%.short-circuit current density of 14.4 mA cm^2 and a photoelectric conversion efficiency of 9.1%,both Voc and Jsc of the device are improved, resulting in a 10.0% PCE for the device and maintained an initial efficiency of 96% after 800 h. Designing a tetradentate ligand was to enhance the stability ,the electrochemical stability and ligand exchange stability of the target complex are measured. The cyclic voltammetry measurement results for many cycles change from Cu(II) to Cu(I).
The reason is that the tetra dentate ligand has strong coordinating ability, and the oxygen atom is close to the copper center, which has a certain protective effect on the central copper atom and blocks the contact between TBP and the copper ion [2].

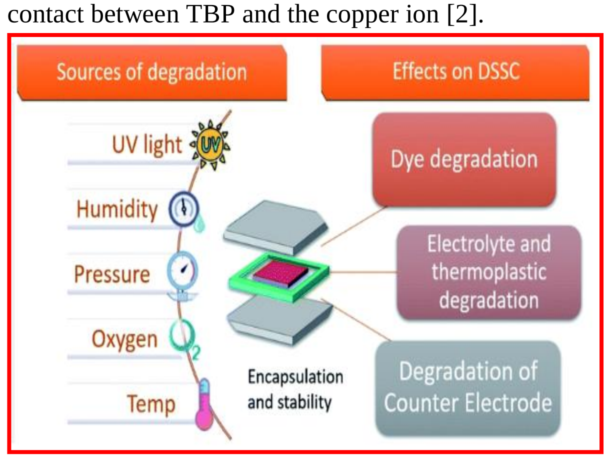

Fig.2. Factors affecting stability of DSSC

Kamaraj Santhosh et al.(2021) determined organic dyes coupled with poly-ethylene glycol-Hydroxy ethyl cellulose Quassi solid-state electrolyte polymers blended iodine redox as electrolyte for increase the stability of DSSCs . This synthesized optical and electrochemical properties were determined using UV Visible spectrometry and cyclic voltammetry techniques . That study was analysed on DSSSCs device with organic dyes such as carboxylic acid and cyanoacrylic acid coupled with the QSSE all these dyes were examine under electrochemical impedance spectrum after examine , observed cyanoacrylic acid ($C_{41}H_{33}N_5O_2S_2$) sensitized was good ionic conductivity (1.13 x 0.001 S/cm) , high chemical capacitance (17.01uF) , high recombination resistance (53.97 ohm) and lower charge transfer resistance (2.35 ohm) due to the presence of a strong electron and also enhance the PCE of 6.24% and short circuit current (Jsc) of 16.39 $mAcm^{-2}$. cyanoacrylic acid improve the efficiency and stability of DSSCs[3].

Mahyar Mohammadnezhad et al.(2020) demonstrated the preparation of nano composite layers made up of Gold Nanoparticles (AuNPs) and Multiwall carbon nano tubes (MWNCT) to improve the performance of DSSCs. These nanocrystalline fabricated TiO_2 films act as photoanode in DSSCs. This preparation were achieved a Power Conversion Efficiency (PCE) of 6.61% due to the light absorption of the photo anode by AuNPs and MWCNTs. Thus, These composite device show ~54% higher PCE and J_{sc} as compared to control device. Just because of reducing TiO_2 film thickness (5.31micrometer), while retaining the UV absorption and charge carrier generation. This demonstration tested ten days continuous illumination and the result retaining 92% of the initial PCE value [4].

Mohammad Mazloum-Ardakan et al.(2019) observed DSSCs parameters such as current density, open circuit voltage and efficiency improvement by using an azobenzene carboxylic acid with N719 dye. which is attributed to reduced dye aggregation, higher electron injection and increased Voc. This corresponded to the improved electron density in the TiO_2 conduction band of the photo anode and reduced charge recombination revealed through electrochemical impedance spectroscopy measurement [5].

Surasak Santhaveesuka et al.(2018) fabricated nanocomposite TiO_2 thin film particles with sol-gel method used to DSSCs,to improving the long –term stability, The performance of DSSCs with solid state electrolyte by adding potassium iodide(KI) and iodine(I_2) into solid state electrolyte. Consisting propylene carbonate (PC), ethylene carbonate (EC) and 1- methyl-3-propylimidazodium iodide (MPI) and poly (styrene – co – acrylonitril) (P(S-A)) gelated with solid state electrolyte.solid state electrolyte is more stable than liquid electrolyte,because potassium iodide salt partially dissolved in liquid electrolyte however completely dissolved in solid state electrolyte .This state showed that the power conversion efficiency of light energy into electrical energy of 2.56% under irradiation of $80mWcm^{-2}$,v_{oc} is 0.609,J_{sc} is $6.32mAcm^{-2}$.This work test under 45 days,observation show that solid state electrolyte is better than liquid electrolyte[6].

Saad Sarwara et al.(2017) improved long-term stability at a high temperature by incorporating Zeolite molecular sieve in ionic liquid based electrolytes. The current density of devices with 5 wt% of ZSM-nano additive gradually decreased from 13.02 to 9.66 $mAcm^{-2}$ up to 300 hours and remained stable 9 $mAcm^{-2}$ even up to 1200 hours. In contrast, DSSCs without Nano-ZSM additive showed the initial increase of Jsc followed by a continuous decrease. Thus, the initial increase of short-circuit photocurrent density of DSSCs without Nano-ZSM additive can be ascribed to the trace amount of water present in devices because all manufacturing process of devices was done under ambient conditions. However, long-period storage of devices at a high temperature eventually decreases Jsc mostly owing to desorption of dye molecules from TiO_2 surface or exchange of thiocyanate ligand of dyes with water. The initial decrease of Jsc of devices with ZSM nano can be ascribed to the water molecules desorbed from ZSM-nano at high temperature and then the thermodynamic equilibrium of the interaction between trace water and ZSM-nano reached which resulted in the stabilized value of Jsc increases by 17% on average relative to that of device without any additive, mainly owing to its light scattering effect. Moreover, the devices containing Zeolite molecular sieve show remarkable enhancement of the thermal stability at 60 C for a period of 1200 hours under dark condition with a marginal variation of performance. On the contrary, the performance of devices without additives is continuously deteriorated during this period because of adverse effects of trace waters present in electrolytes, which can lead to dye molecules' detachment or degradation. This research study will pave a new way to fabricate thermally stable dyesensitized solar cells with high efficiency. The initial decrease of Jsc of devices with ZS-Mnano can be ascribed to the water molecules desorbed from ZSM-nano at high temperature and then the thermodynamic equilibrium of the interaction between trace water and ZSM-nano reached which resulted in the stabilized value of J_{sc}[7].

Federico Bella et al.(2015) observed the photoanode used TiO_2/rGO nanopartical in DSSCs,which increase the electron density in the conduction band of the material,the sample of rGO around 1.0wt%.This is also enhance the value of current density Jsc and efficiency.The addition of rGo,show the better stability of photoanode in DSSCs.The TiO_2/rGo was successfully test by the ultra assisted mechanical mixing method ,which possessed the efficiency of 6.37%.In the 500h illumination test under the 300 watt metal halide lamp and 100h drying at 85^{o}C.This fabrication shows the high performed and stability in DSSCs[8].

3. Performance of parameters of DSSCs

The performance of dye-sensitized solar cells (DSSCs) can be evaluated by several parameters, which include:

(i) Efficiency

Efficiency is the most important performance parameter of DSSCs. It is the ratio of the electrical power output of the cell to the incident light power. The efficiency of DSSCs can range from 5% to 14%, depending on the materials and fabrication processes used.

(ii) Short-circuit current density (Jsc)

Jsc is the maximum current density that the cell can produce when there is no external load connected to the cell. It is a measure of the current generation capacity of the cell. The Jsc of DSSCs can range from 5 mA/cm2 to 20 mA/cm^2.

(iii) Open-circuit voltage (Voc)

Voc is the voltage generated by the cell when there is no external load connected to the cell. It is a measure of the maximum voltage that the cell can produce. The Voc of DSSCs can range from 0.6 V to 1 V.

iv) Fill factor (FF)

FF is a measure of how efficiently the cell can convert the incident light into electrical power. It is the ratio of the maximum power output of the cell to the product of Jsc and Voc. The FF of DSSCs can range from 0.5 to 0.8.

(v) Stability

Stability is an important parameter for any solar cell technology. The stability of DSSCs can be affected by factors such as the choice of materials, the fabrication process, and the operating conditions. Ongoing research is focused on improving the stability of DSSCs and increasing their lifespan.

Overall, the performance parameters of DSSCs are constantly being improved through ongoing research and development. Improvements in efficiency, Jsc, Voc, FF, and stability will be critical for the widespread adoption of DSSCs in commercial and residential applications.

4. Conclusion and recommendation

Dye-sensitized solar cells (DSSCs) are a promising type of solar cell that convert sunlight into electricity using a semiconductor material coated with a light-absorbing dye. DSSCs have several advantages over traditional silicon solar cells, including lower cost, flexibility, and the ability to produce electricity in low light conditions. However, DSSCs also have some limitations, including lower efficiency compared to silicon solar cells, and the need for frequent replacement of the dye, which can degrade over time. Despite these challenges, researchers continue to explore ways to improve the efficiency and durability of DSSCs, and there is ongoing interest in their potential for use in a range of applications, from portable electronics to building-integrated solar systems. In conclusion, DSSCs represent a promising technology for harnessing the power of the sun, and ongoing research and development efforts are aimed at overcoming their current limitations and improving their performance and viability as a renewable energy source.

DSSCs are a promising technology that has the potential to offer several advantages over traditional silicon solar cells, such as lower cost, flexibility, and the ability to generate electricity in low light conditions. However, DSSCs also have some limitations, such as lower efficiency and shorter lifespan. If you are considering investing in or adopting DSSCs, it is important to weigh the advantages and limitations of this technology against your specific needs and goals. You should also consider the current state of research and development, as ongoing efforts to improve the efficiency and lifespan of DSSCs could have a significant impact on their viability as a renewable energy source. In general, if you are looking for a renewable energy solution that is cost-effective and flexible, and does not require high efficiency, DSSCs could be a good option to consider. However, if you require high efficiency and long lifespan, or if you are looking for a proven technology with a track record of reliability, traditional silicon solar cells may be a better choice. Ultimately, the decision to adopt DSSCs or any other renewable energy technology should be based on a thorough analysis of your specific needs, resources, and goals.

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