

# A Brief Study On The Responsibilities Of Electrolytes In Dye-Sensitized Solar Cells

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**ABSTRACT:-** The electrolyte acts as a conductor between photo - catalysts and the operational electrodes, making it an essential part of the direct solar water heating system. Its importance in DSSC is evident given since it is crucial for both the intracellular excitons between host electrode surface and the renewal of dye. Electrolyte is the main component of a decolorization solar cell and is what revitalises the dye after the oxidation of its components. A product's long-term reliability and conversion efficiency (PCE) are both heavily impacted by the electrolyte used in its construction. The efficiency of a DSSC device is determined by three factors: the coefficient of performance, the current ( $J_{sc}$ ), and the voltages ( $V_{oc}$ ) (ff). All control factors in DSSCs will be influenced by the electrolyte.

**KEYWORDS:-** Electrolytes, sensitized, solar cells etc

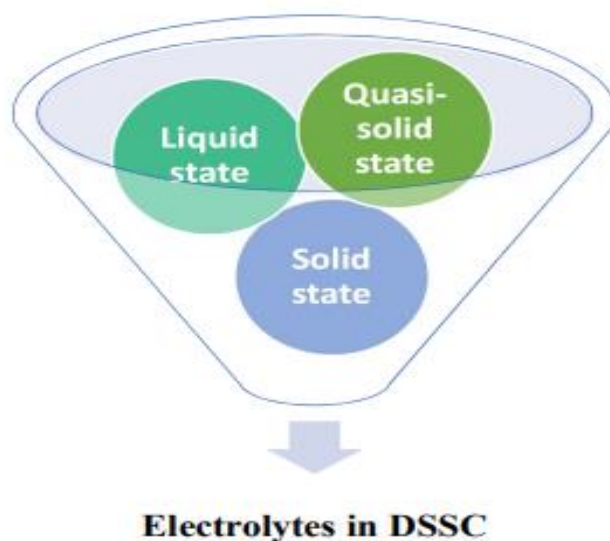
There are crucial characteristics that electrolytes must have in order to serve their purpose in DSSC. Here is a list of just a few of them:

- It is necessary for the electrolyte to be able to transport the charge from one electrode to the other. When the sensitizer begins injecting electrons into the conduction band of the semiconductor, the state of the semiconductor should swiftly return to its ground state.
- The electrolytes need to have a long-term stability, considering physical and chemical characteristics such as thermal, optical, and electrochemical stability in the interfacial contact, and they should not be engaged in the desorption and degradation of the sensitizer.
- The electrolytes need to provide the rapid scattering of conducting charge carriers and produce a good interfacial contact with the nano semiconductor and photocathode in order to be effective.
- In addition, the electrolytes shouldn't exhibit any notable absorption in the visible light spectrum. In spite

of the fact that the conventional redox pair of the electrolyte medium it provides for a good interaction between the triiodide ions and the injected electrons. Overall, it was a push that was directed at increasing the dark current. Because of this, the concentration of the redox pair has to be carefully adjusted.

- In DSSC, the solid, liquid, and quasi-solid forms of electrolytes are the most essential, and each of these three types may be further enhanced by the addition of a variety of additives called dopants.

Regenerating the photosensitizer by the use of electron donation from iodine as part of a redox pair is the obligatory labour that must be done by the electrolyte. Iodine is eventually reclaimed thanks to the triiodide reduction behaviour of the cathode, which is part of a larger cyclical process controlled by the load applied from the outside. owing to the fact that the electrolyte that contains iodide and iodine as a redox pair is the most typical of all. It is more stable, and it has a longer lifespan and is more durable [9]. When compared to other conventional solar cells like silicon solar cells, etc., various tasks involving DSSC that use liquid electrolyte are carried out. This is due to the fact that DSSC has a fairly better performance, is relatively inexpensive, and has a high efficiency. Iodide/triiodide ( $I^-/I_3^-$ ) redox couple in an organic solvent like acetonitrile is the standard and most preferred liquid electrolyte utilised so far, and it has achieved an efficiency of 11.1%. This makes it the most effective liquid electrolyte among all liquid electrolytes.



**Figure :- Different types of electrolytes in DSSC**

## **IMPORTANCE AND CHARACTERISTICS OF ELECTROLYTES IN DSSC**

The use of electrolytes in DSSC makes for one of the most interesting aspects of this technology. Studies that

are repetitive in nature have been examined at some point throughout the course of the preceding decade due to the high potential and PCE of the acute importance of their findings. A considerable amount of mixing took place between the cation species and the co-additives in the electrolyte. The purpose of this is to increase both the voltage and the lifetime of the electrons. It has also been shown that the cations in the photosensitizer will not be able to encourage the recombination behaviour of the electrons in titanium dioxide [10]. This was demonstrated using the electrolyte. Tertiary butyl pyridine (TBP) is one of the additives that is often added to the electrolytes. This substance is responsible for inducing the negative shift of the TiO<sub>2</sub> conduction band. It is vital to have a solid understanding of the power of the components in the electrolyte that scheduled the life duration of the electrons in order to produce a hole conducting layer and boundary at the working electrode in order to produce highly efficient solar cells. The additions and cations have the capacity to influence the electron diffusion, charge traps, conductive band potential of the semiconductor, and the electron life span [11].

### **Selectivity**

The selectivity of the electrolyte should be based on the electrolyte's non-leakage, durability, non-degradability, uniform surface, and good fortune of the electrodes, which will enhance the efficiency with which it converts energy. Overall, it should function as a medium that is highly excited about the transfer of charge, and it should have a fast recombination life in the context of the whole cell setup.

### **Stability**

The strength of DSSC lies in the electrolyte's capacity to remain stable throughout time. In the event that it is more stable, the outcomes of the electrolyte and its durability will be effective. The capacity of an electrolyte to withstand changes in temperature and humidity are its most important characteristics. It should be able to duplicate the consonant readings and function efficiently for undisputed hours. The stability of DSSC is determined only by the I-V curve's capacity to hold its shape for a certain number of days when subjected to constant illumination from a light source.

### **Storage**

The criterion for storage have to include how effectively and reliably the DSSC configuration works. In DSSC, there are many different elements, such as the capacity to be kind to the environment, inexpensive electrolyte, and so on.

### **Retention Factor**

The major aspects that contribute to DSSC's exceptional capacity for retention are the material's long-lasting nature as well as its speed. The mechanical strength of the electrolyte contributes to the increase in open circuit voltage (Voc) and short circuit current (Jsc) that occurs when power is reduced.

## PROGRESS ON DSSC

These solar panels get their power from the sun, and their primary function is to recreate the process of photosynthesis that takes place on plants throughout the cooking process. During the process of photosynthesis, solar energy is stored and used to create starch in the presence of water and carbon dioxide. The photosensitizer molecule that green plants use to capture light energy is called chlorophyll. Pioneering researchers have implemented a technique known as photosensitization in solar cells, which are thereafter referred to as dye-sensitized solar cells. In the first stages of photography, the idea of photosensitization was applied to colour photography. They had built the solar cells using thin-film technology and named them Dye-sensitized solar cells. Photosensitization was employed for the first time in 1991 by Origan and Graze Co-workers. The construction of the photo-galvanic cell consists of a dark dye in a solution that is allowed to get photo-excited and chromophores that have been reduced. At that precise moment, an oxidised form of a redox species in solution will donate an electron and bring back the dye molecules to their initial state. During the phase known as the solution, two metallic electrodes are submerged in a solution and then linked to one another through an external circuit. This causes a redox reaction to take place. Both efficiency and stability have been inadequately reached by these photogalvanic cells. This photoelectrochemical cell will take in photons and then convert electrons via the use of chemical processes that will take place within the p-n junction. Over the course of the previous three decades, researchers have made significant strides in the areas of cost-effectiveness, environmental friendliness, stability, and ease of manufacture [7]. Despite the fact that several research have led to findings that enable DSSCs to be used as conventional solar cells. The fabrication of hybrid cells composed of organic and inorganic materials with the purpose of creating power conversion efficiency for light collecting devices that may be used both outdoors and inside. The uncomplicated one Fabrication of DSSCs in an open-air environment using inexpensive materials opened the door to various options to concentrate on the applications of DSSCs.

## COMPONENTS OF DSSCS

- These n-type DSSCs are a photo-electrochemical device that operates in a configuration that resembles a sandwich. It is made up of a photo-anode, a photo-sensitizer, electrolyte, and a counter electrode, and it also

has a conducting current collector that is coupled to an external circuit.

- The Working electrode is a collection of nanostructured semiconductors that are adhered on a conductive substrate that is formed of fluorine-doped tin oxide that is placed on top of a glass plate.
- The photo-sensitizers are molecules that have the capacity to collect light and have a tendency to accept photons that are generated from a light source.
- The electrolyte is a mixture of (i) redox couples, (ii) additives, and (iii) solvents, and its primary function is to shuttle back the oxidised sensitizer molecules.
- The counter electrode is a substance that should have an electrocatalyst on top of a conductive substrate constructed of fluorine-doped tin oxide atop a glass plate. This material is known as the counter electrode material.

### **Transparent conductive substrate**

A transparent conductive substrate is a kind of substance that can gather electrons created by the device and also conduct or transport them (TCO). The many types of TCOs that are available include carbon cloth, metallic plate, metallic foam, fluorine-doped tin oxide on a glass plate, indium-doped tin oxide on a glass plate, and so on.

### **Photo-anode**

The semiconducting material that serves as the photo-electrode is seeded with the material, which has remarkable charge transport and the aptitude to decrease charge recombination. On a TCO substrate, these semiconductor materials have the ability to absorb dye molecules. Materials such as TiO<sub>2</sub>, ZnO, SiO<sub>2</sub>, CeO<sub>2</sub>, WO<sub>3</sub>, and Nb<sub>2</sub>O<sub>5</sub> are examples of those that are often utilised for photo-electrodes [8]. In DSSCs, the rutile form of titanium has typically been employed as a semiconductor material and also serves as a photo-electrode. This has been the case in most cases. TiO<sub>2</sub> crystals with an anatase structure nevertheless have a band gap in energy of around 3.2 eV. The recombination of photo-excited dye molecules produced a route that led to an exceptionally high level of transformational competence. When light is shone on the nanostructured TiO<sub>2</sub>, an electron is transferred from the ground state to the excited state of a dye molecule. The dye molecule is subsequently injected into the conduction band of the nanostructured TiO<sub>2</sub>. In n-Type double-sided semiconductor light-emitting diode solar cells, the dye-sensitized TiO<sub>2</sub> semiconductor layer that is overlaid on a conducting glass plate serves collectively

as the photo-anode or photo-electrode. It is expected that these semiconducting materials would have a high photoactivity. When employing NiO for the photo-electrode material, the p-type DSSC device also operates in a reverse mechanism, so instead of electron mobility, it generates hole mobility. This is possible because of how the device works. A molecule is referred to be a sensitizer if it has the ability to absorb photons from various light sources and then cause it to pump electrons into the conduction band of a semi-conductor. In addition to this, it is expected that it will acquire an electron from the redox pair that is offered in the electrolyte. examples include metal-based complex dyes and metal-free organic dyes [9, 10, 11].

### **Counter electrode**

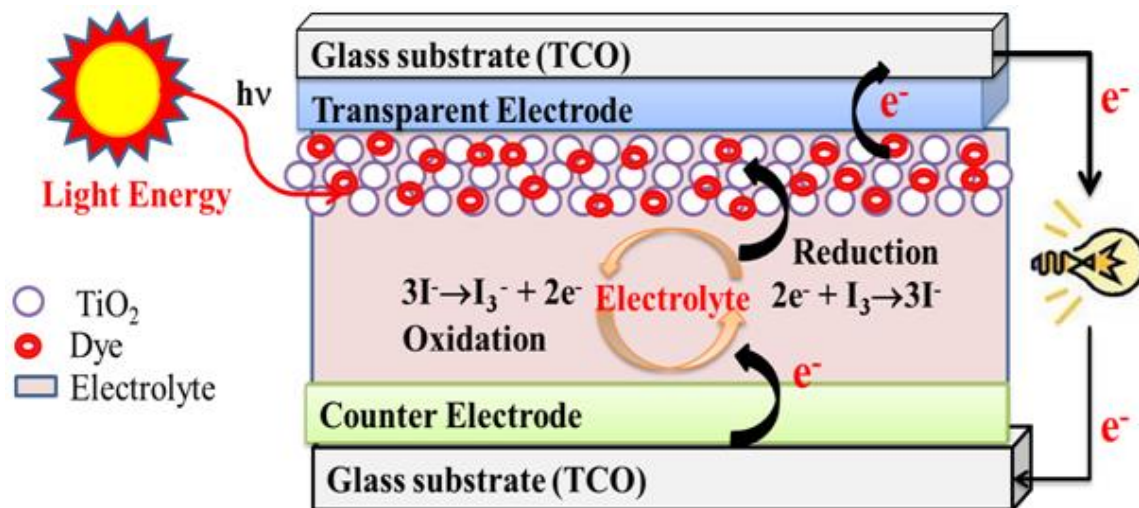
These electrodes are an essential component of DSSCs since they not only allow electrons but also catalyse the process of regenerating oxidised redox pairs. These electrodes have a coating of conventional TCO plates, which operate as an electrocatalyst and increase the reaction's conductivity. Electrocatalysts and counter electrodes made of noble materials, such as platinum, find widespread usage in commercial applications. The alteration of these electrodes has been the subject of a significant amount of study in recent years. Some of the materials, such as those based on carbon, as well as mixed transition metal oxide, are being tested out as potential electrocatalysts [12].

### **Electrolyte**

In general, the electrolyte is responsible for accounting for the electron fluxes that occur between the electrodes. In DSSCs, the regeneration of dye requires the development of a few specific properties. Redox couples, additives, and solvents are the components that make up these electrolytes. It is possible for a significant amount of leakage to occur in this liquid electrolyte. Transition metal complex mediators are being changed such that they are non-corrosive, have a low absorption of visible light, and have a fine-tuneable redox potential, all of which have affected the improvement of volatile organic compound levels. Conducting polymer substrates are employed, and they may be further differentiated into solid-state electrolyte and quasi-solid-state electrolyte in order to increase the stability as well as address other difficulties. These redox pairs are responsible for charge mobility across the electrodes as well as the regeneration of oxidised sensitizer molecules via the donation of electrons. Iodide and tri-iodide, as well as  $\text{Co}^{2+}/3+$ ,  $\text{Cu}^{1+}/2+$ , and other ions, are examples of frequent redox mediators. [13, 14, 15]

### **WORKING PRINCIPLE OF DSSC**

A transparent conductive substrate that has a finely sintered mesoporous TiO<sub>2</sub> coating that has been sensitised using a sensitizer molecule makes up the photo-anode. This photo-anode is layered on top of a counter electrode with full electrolyte sandwiched in between the components that make up the electrodes. This particular cell configuration is illuminated by the light source.



**Figure :- Schematic diagram of the device structure**

As soon as they are exposed to light radiation, these dye molecules begin to take up the photons of energy from the light sources, which causes them to get excited, which in turn generates photo-excited electrons. In the mesoporous TiO<sub>2</sub> surface, these electrons are injected into the low-level conduction band. These currents of electrons are directed via an external circuit so that they may arrive to the counter electrode component. The substance that has a highly electro-catalytic behaviour and is deposited on a conductive substrate is employed as a counter electrode. Examples of such materials include platinum, carbon-based compounds, metallic substrates, metal composites, and so on.

At this stage, the photo-electrode and the cathode are partitioned from one another by a substance known as an electrolyte. These types of electrolytes may be broken down further into two categories, liquid-based electrolytes and quasi-solid-state or solid-state electrolytes, depending on the composition of the substance. In this case, redox couples are formed as R/R<sup>+</sup> (for example, iodide/tri-iodide, Co<sup>2+/3+</sup>, Cu<sup>1+/2+</sup>, etc.) that undergo oxidation-reduction reactions within those redox pairs. These reactions serve to regenerate the oxidised dye molecules and work in a continuous cycle, generating from the electron received from the counter electrode. The performance of the device is governed only by the amount of photons that are absorbed by it [16]. This cyclic process creates a continual flow of electrons in the circuit, which is referred to as electricity.

## MECHANISM OF SOLAR CELLS

These DSSCs are works in the mechanism to generate solar-to-electric energy. Employing the following step use of  $TiO_2/Dye/ I^-/I_3^- /Pt$  The device work upon light illumination

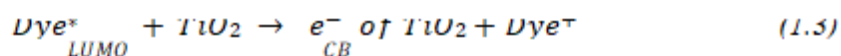
- 1) Absorption of photons by sensitizer molecules



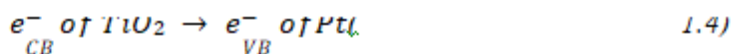
- 2) Photoexcitation of sensitizer molecules to their excited state



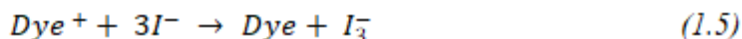
- 3) Electron Injection into CB of  $TiO_2$  Surface



- 4) Electron transportation from photo-anode to the cathode



- 5) Regeneration of oxidized sensitizer molecules by a reduced redox couple



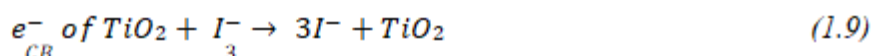
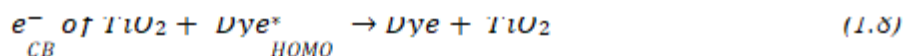
- 6) Regeneration, Recombination of the oxidized redox couple



- 7) Revolution of excited state to the ground state of sensitizer molecules.



The unavoidable reactions that affect the performance of DSSCs like backelectron transfer and dark reaction are explained below respectively



The difference in  $I^-/I_3^-$  and other redox couples like  $Co^{2+/3+}$  and  $Cu^{1+/2+}$  In place of  $I^-$  of the reduced state of redox pair and  $I_3^-$  place oxidized state of redox pair is used.



The usage of DSSCs comes with a number of significant benefits, the most notable of which are their low cost, ease of production, and combination of abundant and consistent raw materials. They provide a variety of limited properties, some of which include semi-transparency, the possibility of a multi-color spectrum, flexibility, and a low weight. A straightforward fabrication process has been carried out in the open air. The efficiency of the performance in low light circumstances is additionally inexpensive. In addition, the construction of the gadget may be printed on any surface that is flexible. They are able to function even when there is a limited amount of light and may be combined with any rigid type.

## **PHOTO-SENSITIZER OR DYE**

The sensitizer is what gathers the light from the source, and it plays an essential part in the operation of DSSCs. The second distinguishing feature of the sensitizer molecule is that it must be able to absorb light in the UV-visible spectrum and that it must have an acceptable redox potential [17, 18]. There have been several reports of sensitizers, based on the structural qualities held by industrial molecules, that have improved the effectiveness of the process. Sensitizers that are natural, those that are based on metals, and those that do not include metals

These pigments taken from plants have a high capacity for absorbing sunlight, and as a result, they are distributed throughout the plant in a manner that makes it possible for the molecules to become sensitised in a natural way. Chlorophyll, carotenoid, flavonoid, anthocyanin, and other similar compounds are all examples of natural sensitizers. There aren't many other naturally occurring sensitizers, but the ones that are there don't have any attraction to the strengths of the mordants that are needed to increase the sensitizer's likeness to the fibres. Tannic acid, alum, and salts of elements such as Al, Cr, Cu, Fe, K, Na, and Sn are the most prevalent types of mordants.

When it comes to DSSCs, using a metal-based sensitizer has shown to be an incredible success, attaining better conversion efficiency in particular. Ru (II) metal has an octahedral geometrical arrangement, takes a wide variety of particular ligands, and has high controllable oxidation states, in addition to having good solubility. These features may be altered in accordance with the requirements. Dyes based on ruthenium metal are often utilised in DSSCs. Some examples of these dyes are black dye, N719, and N3. Recent breakthroughs in sensitising materials have resulted in the dye being replaced with inorganic nanoparticles in the form of quantum dots, leading to the creation of a new kind of solar cell known as quantum dot-sensitized solar cells [19].

In order to improve the performance of DSSCs, it is necessary to modify the wide spectrum range and find a suitable molecular energy level orbital. Because of this need, the researcher focused their attention on organic molecules. For a metal-free sensor, it is best to use organic molecules that have strong electron delocalization

and the capacity to both give and absorb electrons. In the field of material science, the narrative of the  $\pi$ -conjugated organic systems is one of the most illustrious. Push-pull systems are a kind of organic  $\pi$ -conjugated system that are characterised by the presence of both an electron-donating group (D) and an electron-withdrawing group (A). The functionalization of the organic small molecule will result in the development of many important characteristics, including a greater molar extinction coefficient ( $\epsilon$ ), a low molecular mass, robust charge transfer within the molecules, molecular polarizability, and structural tune-ability. These interactions between D–A molecules collect significant intermolecular charge transfer (ICT), and when you change the individual D–A moiety components, the levels of energy and absorption change as a result. They are extremely designed in a simple style, and they are also quite flexible in synthetic methods. It may be possible to shift the wavelength of absorption by making structural adjustments to the molecule. These systems have done a great deal in the realm of photo-induced charge separation. Through the change of the D–A moiety, which alters the molecular orbital level and kinetic properties [20, 21, 22], the D–A system played the energetic role in the performance of the device. This was accomplished by frolicking.

The highest occupied molecular orbitals (HOMO) and the lowest unoccupied molecular orbitals (LUMO) together with the band-gap of the dye have been shown to be the most important factors in determining the performance of the DSSC. Donor-bridge acceptors (DA) structure organic is used in the process of designing flexible and appropriate metal-free sensitizers [23, 24]. Because electrons are shared between D and A structures, it can be determined that the electron-donating component and the electron-deficient component are linked together by means of a  $\pi$ -conjugated group. These sensitizers are made by attaching a moiety that acts as an anchor to the molecule so that it may bind to the photoelectrode [25]. Strong absorption at an appropriate energy level with photo-anode will make it possible to conduct an electron injection procedure that is effective [26, 27, 28]. The facilitation of charge transfer may be attributed to the tuning of the molecular energy levels (HOMO-LUMO) of the sensitizer molecule by use of an adaptable donor and acceptor unit [29]. Acceptor moiety is necessary for charge transfer and electron injection on the surfaces of semi-conductors [30, 31]. An efficient and effective internal charge transfer between the sensitizer molecules is produced as a result of the D-A arrangement, which calls for the combination of supplemental donating and accepting moieties. The redshift in UV absorption that takes place will result in an improvement in  $V_{oc}$  [32]. At this time, these organic sensitizers were synthesised by following a known methodology, and the molecular arrangements are being altered in order to increase the blocking action. As a result, we suggested using these organic compounds as a means of reducing the amount of charge recombination. We had come up with a novel form of push-pull molecules and constructed them in such a way that they were nicely organised as 2D—D-A and 2D—D—A molecules.

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