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SOLID-STATE ELECTROLYTES FOR DYE-SENSITIZED SOLAR CELLS

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ABSTRACT

A dye-sensitized solar cell (DSSC) is a low-cost solar cell belonging to the group of thin film solar cells. It is based on a semiconductor formed between a photo-sensitized anode and an electrolyte, a photoelectrochemical system. First version of a dye solar cell, also known as the Grätzel cell, was invented by Michael Gratzel. In a traditional solar cell, it is made from two doped crystals, one doped with n-type impurities (n type semiconductor), which add additional free conduction band electrons, and the other doped with p-type impurities (p type semiconductor), which add additional electron holes. When placed in contact, some of the electrons in the n-type portion flow into the p-type to "fill in" the missing electrons, also known as electron holes. Eventually enough electrons will flow across the boundary to equalize the Fermi levels of the two materials. The result is a region at the interface, the p- n junction, where charge carriers are depleted and/or accumulated on each side of the interface. In silicon, this transfer of electrons produces a potential barrier of about 0.6 to 0.7 V. Dye-sensitized solar cells (DSSCs) have aroused intense interest over the past decade owing to their low cost and simple preparation procedures. Much effort has been de-voted to the study of electrolytes that enable light-to-electrical power conversion for DSSC applications. This review focuses on recent progress in the field of liquid, solid-state, and quasi-solid-state electrolytes for DSSCs.

KEYWORDS : dye-sensitized solar cell , liquid electrolytes, solid-state, and quasi-solid-state electrolytes.

DSSC

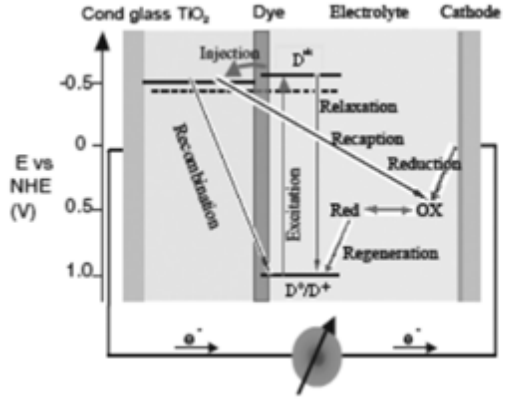
The dye-sensitized solar cells (DSC) provides a technically and economically credible alternative concept to present day p–n junction photovoltaic devices. In contrast to the conventional systems where the semiconductor assume both the task of light absorption and charge carrier transport the two functions are separated here. Light is absorbed by a sensitizer, which is anchored to the surface of a wide band semiconductor. Charge separation takes place at the interface via photo-induced electron injection from the dye into the conduction band of the solid. Carriers are transported in the conduction band of the semiconductor to the charge collector. The use of sensitizers having a broad absorption band in conjunction with oxide films of nanocrstalline morphology permits to harvest a large fraction of sunlight. Nearly quantitative conversion of incident photon into electric current is achieved over a large spectral range extending from the UV to the near IR region. Overall solar (standard AM 1.5) to current conversion efficiencies (IPCE) over 10% have been reached. There are good prospects to produce these cells at lower cost than conventional devices. Here we present the current state of the field, discuss new concepts of the dye-sensitized nanocrystalline solar cell (DSC) including heterojunction variants and analyze the perspectives for the future developmentofthe technology

How DSSC Works

When placed in the sun, photons of the sunlight can excite electrons on the p-type side of the semiconductor, a process known as photoexcitation. In silicon, sunlight can provide enough energy to push an electron out of the lower-energy valence band into the higher- energy conduction band . As the name implies, electrons in the conduction band are free to move about the silicon. When a load is placed across the cell as a whole, these electrons will flow out of the p-type side into the n-type side, lose energy while moving through the external circuit, and then flow back into the p-type material where they can once again re- combine with the valence-band hole they left behind. In this way, sunlight creates an electrical current

STRUCTURE AND OPERATIONAL PRINCIPLES OF DYE-SENSITIZED SOLAR CELLS

DSSCs include a substrate of fluorine-doped SnO_2 conducting glass (FTO), a porous nanocrystalline semiconductor oxide (the most employed is TiO_2) film sensitized by a dye (typically bipyridine ruthenium complexes) for absorbing visible light, a redox electrolyte (usually anorganic solvent containing a redox system, such as iodide/triiodide couple) layer for deoxidizing oxi-dized dye, and a platinized cathode to collect electrons and catalyze the redox couple regeneration re-action .The light-to-electricity conversion in a DSSC is based on the injection of electron from thephotoexcited state of the sensitized dye into the conduction band of TiO_2. The dye is regenerated byelectron donation from iodide in the electrolyte. The iodide is restored, in turn, by the reduction of tri-iodide at the cathode, with the circuit being completed via electron migration through the external load.The voltage generated under illumination corresponds to the difference between the Fermi level of theelectron in the TiO2and the redox potential of the electrolyte. Overall, the device generates electricpower from light without suffering any permanent chemical transformation.



LIQUID ELECTROLYTES

The first DSSC was reported in 1991 by M. Grätzel using organic liquid electrolyte containing LiI/I2, which obtained an overall light-to-electricity conversion efficiency of about 7.1 % under irradi-ation of AM 1.5, 100 mWcm–2. Later, many kinds of liquid electrolytes containing iodide/triiodideredox couple and high dielectric constant organic solvents such as acetonitrile (AcN), ethylene carbon-ate (EC), 3-methoxypropionitrile (MePN), propylenecarbonate (PC), γ-butyrolactone (GBL), and N-methylpyrrolidone (NMP) were investigated, and some DSSCs with high photovoltaic performance

were obtained [6,19–22]. Research during the past decade shows that each component of liquid elec-trolyte such as solvent, redox couple, and additive plays a different role in the photovoltaic performance of DSSCs.

SOLID-STATE ELECTROLYTES

STRUCTURE AND OPERATIONAL PRINCIPLE OF SOLID-STATE DSSCS

There are two kinds of solid-state DSSCs, one uses hole transport materials (HTMs) as medium, the other uses a solid-state electrolyte containing iodide/triiodide redox couple as medium. The structure and operational principle for the latter is similar to that of the DSSC using a liquid-state electrolyte con-taining iodide/triiodide redox couple as medium in Fig. 1. A schematic presentation of the struc-ture of solid-state DSSC using an HTM as medium is given in Fig. 4. At the heart of the system is amesoporous TiO_2 film, which is placed in contact with a solid-state hole conductor. Attached to the sur-face of the nanocrystalline TiO_2 film is a monolayer of a charge-transfer dye. Photoexcitation of the dyeresults in the injection of an electron into the conduction band of the TiO_2. The original state of the dye is subsequently restored by electron donation from the hole conductor. The hole conductor is regener-ated in turn at the counterelectrode, and the circuit is completed via electron migration through the ex-ternal load . In this DSSC, the reactions of excitation eq. 1, injection eq. 2, and recombination dark reaction eq. 6 still exist, the reaction eqs. 3–5 would be different.

HOLE TRANSPORT MATERIALS (HTMS)

Familiar large-band gap HTMs such as SiC and GaN are not suitably used in DSSCs since the high-tem-perature deposition process for these materials will certainly degrade the sensitized dyes on the surface of nanocrystalline TiO2. Researchers found [63–66] that a kind of inorganic HTM based on cop-per compounds such as CuI, CuBr, or CuSCN could be used in fabricating DSSCs. These copper-based materials can be cast from solution or vacuum deposition to form a complete hole-transporting layer,and CuI and CuSCN share good conductivity in excess of 10–2 S/cm, which facilitates their hole-con-ducting ability. For example [67], the DSSC based on CuI HTM obtained as high as 2.4 % light-to-elec-tricity conversion efficiency under irradiation of AM 1.5, 100 mWÑcm–2. However, its stability is quite poor, even worse than the traditional organic photovoltaic cell, which is also a common problem exist-ing in DSSCs based on this kind of inorganic HTMs. Therefore, researchers put their vision into organic HTMs.

CONCLUSIONS

In this paper, we study the process of DSSC and its working principle. What is electrolyte and characteristic of liquid and solid state electrolyte and introduce the recent progress, including our group results, on liquid, solid-state, and quasi-solid-state electrolytes for DSSCs.

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