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doi: 10.1007/s40843-016-5143-0
Sci China Mater 2016, 59(10): 785–786

SPECIAL ISSUE: Excitonic Solar Cells (II)

Preface to the SPECIAL ISSUE: Excitonic Solar Cells (II)

Among all the excitonic solar cells (ESCs) including dye-sensitized solar cells (DSSCs), quantum solar cells (QDSCs), perovskites solar cells (PSCs), and organic photovoltaics (OPVs), PSCs attracted enormous research attention in the past 7 years and attained the highest power conversion efficiency (PCE) of over 20% with the biggest progress, from 3.8% to over 22.1% in 7 years. However, one can easily realize the fact that such a rapid progress achieved in PSCs was made possible is largely based on the fundamental knowledge, experimental skills, and characterization facilities obtained and accumulated through the multi-decade long endeavor in the study of other excitonic solar cells. Even though PSCs have attracted much research human resource and funding, the study on other excitonic solar cells has never stopped, and such persistent efforts have continued to shed more lights and advance our understanding of the fundamentals and engineering details in materials, device structures, light absorption, and charge transfer processes. Such a fundamental understanding has a universal impact on all excitonic solar cells and beyond. *SCIENCE CHINA Materials* organizes the special issue "Excitonic solar cells" to show the recent development and remaining challenges in this exciting field. The special issue (I) focused on the recent development and research works of PSCs. The special issue (II) is devoted on the continued research efforts with recent understanding and process in other excitonic solar cells including DSSCs, QDSCs and OPVs.

For DSSCs, the key to the breakthrough in 1991 was the use of mesoporous TiO_2 electrodes, invented by O'Regan and Grätzel, which had a high internal surface area to support the sensitizer monolayer. These devices had a PCE of 7.1%. Recently, the highest PCE of 14.3% was obtained. DSSCs are composed of mesoporous nanocrystalline TiO_2 films (photoanodes) modified with photosensitizing dyes as working electrodes, redox electrolytes and counter electrodes. PCE still is an important parameter to measure the performance of DSSCs, but the severe charge recombination that occurs at the photoanode hinders the future improvement of PCE. One of the key goals for achieving high efficiency is to reduce the energy loss caused by the unwanted charge recombination at various interfaces. Wei *et al*. presented a comprehensive discussion on the surface modifications of different photoanodes that have been adopted in literature not only for reducing recombination but also for enhancing light harvesting.

Each part of DSSCs heavily influences the performance of the devices. In addition to photoanodes, the dye and electrolyte are key components of DSSCs, which are closely related to the photo-current generation and transport. The optimal organic sensitizer for solar cell applications should possess a broad absorption spectrum in order to produce large photocurrent response. Yang *et al*. prepared two monomer type dithiafulvene based sensitizers for improving the light-harvesting ability. The PCE of the device is up to 5.26%. To date, the high efficiency DSSCs have been achieved by using liquid electrolytes. But, in the case of liquid electrolytes based DSSCs, sealing problems and long-term durability substantially hinder the practical application of the devices. The quasi-solid-state electrolytes are usually prepared by solidifying the liquid electrolytes using low molecular mass organo gelators, polymer gelators and nanoparticles, which show good performance and long stability. Dai *et al*. designed a novel gel electrolyte using crosslinked gel network by self-assembly for DSSCs.

QDSCs can be regarded as a derivative of DSSCs. The organic dyes of QDSCs are replaced by semiconductor quantum dots (QDs) as sensitizers. By using a QD, it is possible to utilize hot electrons to generate multiple electron–hole pairs per photon through the impact ionization effect. It is well known that the morphology, size, and structure of photoanode materials play an important role in the sensitizer loading amount, light scattering, as well as electron transport and recombination properties, which determine the overall photovoltaic performance of QDSCs to a great extent. Kuang *et al*. designed a hierarchical ZnO nanorod-on-nanosheet arrays photoanode for efficient CdSe QDSCs with PCE of 4.26%. For photoanodes, surface defects and grain boundaries of nanocrystals allow high surface charge recombination, which limits the performance of QDSCs. Tian *et al*. introduced an ultrathin layer of the surface of the photoanodes by atomic layer deposition (ALD). The solar cell based on CdS/CdSe QDs with ALD treatment exhibited a PCE of 5.07% that was much higher than that of the cells without modification (4.03%). Sun designed a bulk heterojunction QDSC employing PbS quantum dot capped with ZnS by successive ionic layer adsorption and reaction process.

OPVs have attracted wide attention owing to their valuable potentials, such as lightweight, flexibility and possibility of large area fabrication, etc. Recently, a series of studies showed that PCE of OPVs can be greatly improved by utilizing novel highly efficient donor (D) and acceptor (A) materials, and optimization of interface structure regulation and design of the device structure. Zhang and Zheng *et al*. develop a new two-step dissolution to prepare P3HT:$PC_{61}BM$ and PTB7:$PC_{71}BM$ solar cells. This two-step dissolution treatment paves a path to optimize the performance of polymer solar cells

Recently, some ferroelectric materials also exhibit anomalous photovoltaic properties, which have been used in photovoltaics. The devices based on ferroelectric materials yield a V_{oc} that is much higher than the band gap of the corresponding active material owing to a strong internal electric field and the series circuit formed by the material's ferroelectric domains. The efficiency of these devices has been suggested to surpass the limit of the S–Q theory. Here, Xiao *et al*. reviewed the foundations and recent progress in ferroelectric materials for photovoltaic applications.

As the development of PSCs reached a plateau, the study on other excitonic solar cells appears to have a revitalization with regained momentum and significant progress, albeit less drastic than that in PSCs, for example, QDSCs have reached a high power conversion efficiency of 11.2%. The lessons we have learned from PSCs would definitely benefit the research on other excitonic solar cells.

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