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Mini Review

Applications of Polymers in Energy Conversion and Storage Fields: A Review

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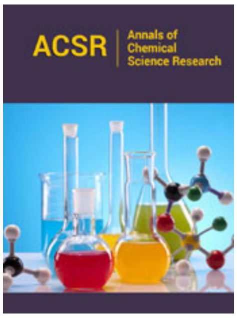

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Introduction

The rapid development of photovoltaics, which directly convert solar energy to electricity, has been achieved by both academia and industry and regarded as one of the most clean and renewable energy resources for the next generations. Although inorganic solar cells presently provide higher efficiencies, the high cost and energy-consuming production process limit their wide application. Therefore, extensive studies have investigated new inexpensive organic photovoltaic systems. Recently, polymers have been studied widely in this promising area owing to their versatile and adjustable physical and chemical properties, among which organic solar cells (OSCs) and perovskite solar cells (PSCs) have attracted considerable attention due to their advantages of low cost, lightweight, and flexibility. Especially in the photocatalysis area, polymers can be used to modify photo-corrosive semiconductors to improve the efficiency and stability of solar hydrogen production. Therefore, based on the important roles that polymers play in high-efficiency solar cells and solar hydrogen generation, we herein provide a mini review on the major applications of polymers in energy conversion and storage fields.

Applications of Polymers on Organic Solar Cells

As a promising renewable energy technology, the OSCs have attracted considerable attention due to their excellent features such as lightweight, mechanical flexibility and low-cost methods for fabrication [1]. With the innovative design and efficient application of new polymer materials, which are used as the photo-active layer or buffer layer in OSCs, the power conversion efficiencies (PCEs) of the latest single-junction devices have gradually enhanced to more than 16% [2]. Specifically, the synthesis and employment of poly(3-hexylthiophene) (P3HT) successfully improved the device efficiency from less than 1% in the poly (phenylene vinylene) (PPV) system to 4%-5% [3,4]. Then, the polymers based on the benzodithiophene and thieno [3,4-b] thiophene (PTB7) was further synthesized and applied to OSCs and the corresponding device efficiency was enhanced to 7.4% [5]. Recently, a novel copolymer PM6 was used as a donor material to fabricate the device with a PCE of 16.54% [2], which will stimulate the design of new polymer materials with high efficiency. A series of D-A1-D-A2 random polymers, such as PTPDBTO-T, PTPDBTO-TT, PTPDBTO-3T, and P2FBT-x, have been synthesized and applied to fabricate the thick active layer device with relatively stable efficiency by our team (Figure 1) [6,7].

Applications of Polymers on Perovskite Solar Cells

In PSCs, the polymers are extensively used to facilitate the nucleation process which can regulate the crystallization of perovskite films and improve the device optoelectronic property and chemical stability [8]. Due to the high carrier mobilities and tunable bandgap of polymers, they can also be employed as hole/electron transporting materials (HTMs/ETMs) and interface layer to enhance the carrier separation efficiency and reduce the recombination by improving the surface of perovskite film. Many researchers including our group have deeply studied the application of polymers as the HTMs in PSCs by designing and synthesizing the novel polymer materials (Figure 1). The conventional HTM, poly(3,4 ethylene-dioxythiophene): poly(styrenesulfonic acid) (PEDOT:PSS) slowly faded out of interest owing to its low work-function nature which limits the potential open circuit voltage of devices and great acidity which results in relatively poor stability [9]. In order to solve these issues, some neutral and hydrophobic polymer HTMs with deep highest occupied molecular orbital levels, such as poly[N,N′-bis(4-butylphenyl)-N,N′-bis(phenyl)benzidine] (poly-TPD) [10] and poly(bis(4-phenyl)(2,4,6-trimethylphenyl)amine) (PTAA) [11], have been successfully exploited, and they are playing the leading role in the pursuit of high PCE (yielding PCEs of 15.3% and 19.4% respectively) and high stability. These studies reveal that the application of polymers can provide valuable guidelines for improving the efficiency of PSCs.

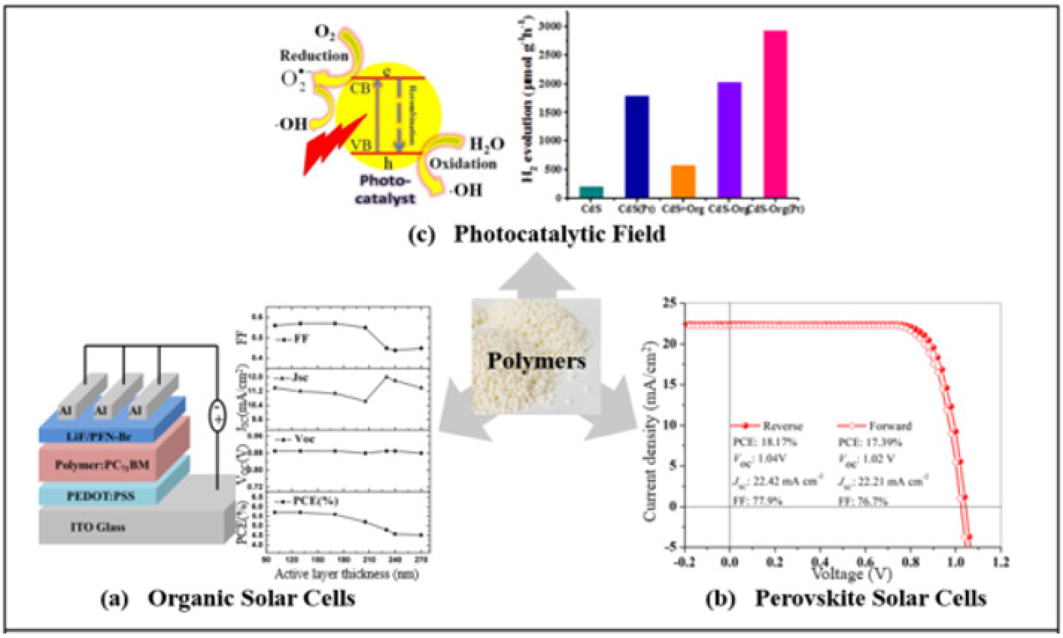

Figure 1: Applications of polymers in energy conversion and storage field.

Applications of Polymers on Photocatalytic Field

The polymers have been further applied in the field of photocatalysis, promoting the development of visible-light responsive photocatalysts which is indispensable for effective utilization of sunlight [12]. Inorganic semiconductor CdS has become a hotspot for photocatalytic hydrogen production due to its narrow bandgap and appropriate band structure position, but there are problems of rapid recombination of photogenerated carriers and severe photo-corrosion. Some studies have shown that the polymers can be used to modify the inorganic semiconductors with photo corrosive properties to form hetero structured photocatalysts, improving the efficiency and stability of solar hydrogen generation [13]. Inspired by this, we did the following work: the region asymmetric conjugated polymer PR1F [14] was successfully used to modify the surface of inorganic semiconductor CdS by coordination bond Cd-S, and photocatalytic hydrogen production activity of the organic-inorganic composite CdS/PR1F is nearly 14 times higher than that of CdS without modification (Figure 1). But this discover has not yet been published in a journal. We hope our work could provide a new idea for the improvement of photocatalytic hydrogen production efficiency.

Conclusion

In summary, the polymers can not only be used as new high-performance multi-functional solar materials to influence device's efficiency and stability in the organic photovoltaic fields, but also be used to modify photocatalysts to improve the efficiency of solar hydrogen production in the photocatalysis area. Consequently, the applications of polymers are significant for improving the energy conversion and storage fields, and the polymers will play a major role in the future.

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References

1. Zhang S, Qin Y, Zhu J, Hou J (2018) Over 14% efficiency in polymer solar cells enabled by a chlorinated polymer donor. Adv Mater 30(20): 1800868.

2. Liu S, Yuan J, Deng W, Luo M, Xie Y, et al. (2020) High-efficiency organic solar cells with low non-radiative recombination loss and low energetic disorder. Nature Photonics 14(5): 300-305.

3. Yang H, Shin TJ, Yang L, Cho K, Bao Z, et al. (2005) Effect of mesoscale crystalline structure on the field-effect mobility of regioregular Poly (3-hexyl thiophene) in thin-film transistors. Advanced Functional Materials 15(4): 671-676.

4. Ma W, Yang C, Gong X, Lee K, Heeger AJ (2005) Thermally stable, efficient polymer solar cells with nanoscale control of the interpenetrating network morphology. Advanced Functional Materials 15(10): 1617-1622.

5. Liang Y, Xu Z, Xia J, Tsai ST, Wu Y, et al. (2010) For the bright future-bulk heterojunction polymer solar cells with power conversion efficiency of 7.4%. Advanced Materials 22(20): E135-E138.

6. Li Z, Wang X, Ren J, Gan G, Liu C, et al. (2018) Fabrication of benzothiadiazole–benzodithiophene-based random copolymers for efficient thick-film polymer solar cells via a solvent vapor annealing approach. Journal of Materials Chemistry C 6(16): 4555-4564.

7. Ren J, Li Z, Zhang Z, Wang X, Zeng X, et al. (2018) Thickness insensitive polymer solar cells employing D-A1-D-A2 random terpolymers based on different thiophene units as electron-donor. Organic Electronics 62: 56-64.

8. Hou W, Xiao Y, Han G, Lin JY (2019) The applications of polymers in solar cells: A review. Polymers 11(1): 143.

9. Meng L, You J, Guo TF, Yang Y (2016) Recent advances in the inverted planar structure of perovskite solar cells. Acc Chem Res 49(1): 155-165.

10. Zhao D, Sexton M, Park HY, Baure G, Nino J, et al. (2015) High-efficiency solution-processed planar perovskite solar cells with a polymer hole transport layer. Advanced Energy Materials 5(6): 1401855.

11. Shao Y, Yuan Y, Huang J (2016) Correlation of energy disorder and open-circuit voltage in hybrid perovskite solar cells. Nature Energy 1(1): 15001.

12. Shi R, Ye HF, Liang F, Wang Z, Li K, et al. (2018) Interstitial P-doped CdS with long-lived photogenerated electrons for photocatalytic water splitting without sacrificial agents. Adv Mater 30(6): 1705941.

13. Nanda K, Swain S, Satpati B, Besra L, Mishra B, et al. (2015) Enhanced photocatalytic activity and charge carrier dynamics of hetero-structured organic-inorganic nano-photocatalysts. ACS Appl Mater Interfaces 7(15): 7970-7978.

14. Liu C, Gan G, Li Z, Sun N, Li X, et al. (2019) Region asymmetric polymers based on fluorinated benzothiadiazole-benzodithiophene for polymer solar cells with high open-circuit voltage. New Journal of Chemistry 43(9): 3801-3809.