Efficiency and Structural Developments in Organic Solar Cells

Reported by Jonnathan Marin October 27, 2020

INTRODUCTION

As energy demands increase and limited energy sources deplete rapidly, the urgency for a clean and renewable energy source continues to increase. Since the discovery of the photovoltaic effect in 1839 by Edmond Becquerel[1a], solar cells have become a top candidate in the renewable energy race. Solar cells have improved tremendously since their earlier examples, most notably the efficiency of organic solar cells (OSCs). Initially sought because of their cheap, flexible, and simple nature, OSCs were eventually overlooked due to their very low efficiencies.[1b] However, in recent years, the efficiency of OSCs has increased dramatically, mainly due to structural modifications and novel techniques aimed to expand their light absorption properties, improvement of their stability, and optimization of their charge mobility.

LIGHT ABSORBTION ENHANCEMENT

Organic dye-sensitized solar cells (ODSSCs) serve as early examples of the benefits of organic materials in the field of photovoltaics. Easily tunned to absorb in the visible and IR spectrum,[1a] ODSSCs played a crucial role in enhancing the efficiency of inorganic materials.[2a] Particularly, porphyrins have shown great promise as light-harvesting materials.[2b] The Xie group has extensively studied the effects of a bulky substitution in their porphyrin based ODSSC (**Figure 1**), and through further derivatization has shown the effects of such substitutions in their efficiency.[2c] In addition, the Xie group further enhanced the efficiency of their optimal motif through a fascinating multi-dye covalent sensitization strategy.[2d] With great promise as ODSSCs, porphyrins are now also being used in organic solar cells (OSCs); one example includes a creative design motif by the Zhu group, in which bulky substitution of their porphyrin-based OSC also lead to higher efficiency.[2e]

Dye	V_{oc} (mV)	$J_{sc}\left(\frac{mA}{cm^2}\right)$	Fill factor	Efficiency
1	781±2	20.07±0.13	0.702±0.003	11.1±0.1

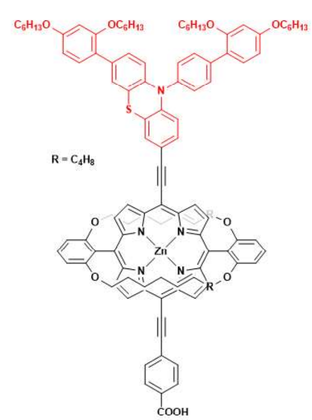

Figure 1: Substituted ODSSC

STABILITY

The extreme conditions that solar cells are exposed to for a prolonged period demands high thermal and photochemical stability from their components. Unfortunately, OSCs have shown a high sensitivity to both.[3a] In efforts to improve their stability, the Krebs group studied various donor:acceptor hetero junction polymer OSCs pairs and concluded on the most stable motifs (**Figure 2**).[3b] These

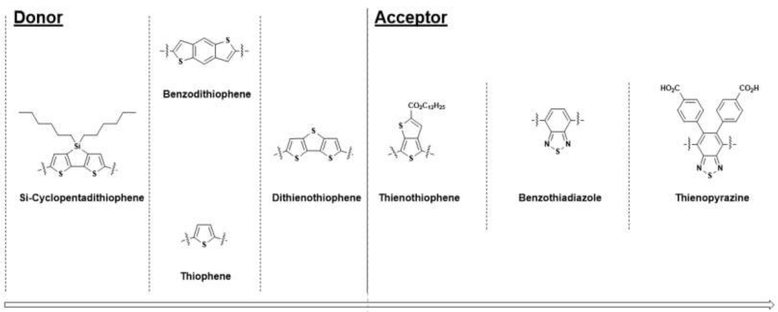

Figure 2: Stability Ranking of Donor and Acceptors

findings have been quickly translated and further studied in small molecule OSCs by different labs such as the Brabec group.[3c] The inherited stability of polymer, small molecule, and fullerene-based OSCs have also been explored and reported by the McGehhe group.[3d]

CHARGE MOBILITY

Charge mobility remains the most crucial and least understood factor in OSCs. Although many theories and studies highlight some crucial impacts of charge mobility in efficiency, a consensus towards the exact properties affecting these materials remains unsettle. Multiple reports by the Li group studying band gap tunning through small and extensive functional modifications shines a light on the impact of the electron dissociation properties responsible for loss in efficiency.[4a,b] Other unique approaches such as multiple acceptor OSCs mixtures by the Jianhui group has also shown to affect charge mobility resulting in improved OSCs efficiencies.[4c]

FINAL THOUGHTS

OSCs have improved dramatically over the last years. Work aimed to improve their light-harvesting properties and stability has been very fruitful and shows promise to optimizing these flaws in OSCs. Nonetheless much improvement is still needed before they can compete with non-organic based solar cells. Understanding of charge mobility remains unclear, different types of OSCs hold inherited problems to overcome, and the field itself suffers from various other challenges.

REFERENCES

1. **a)** Beddiaf Zaidi; Introductory Chapter: Introduction to Photovoltaic Effect, Solar Panel and Photovoltaic Materials; IntechOpen: London, **2018** **b)** Service, R. *et al. Science,* **2004**, 306(5704)

2. **a)** Grätzel, M. *et al. Nature,* **2001,** 414, 338 **b)** D'Souza, F. *et al Sol. RRL,* **2017**, 1:1600002 **c)** Xie, Y. *et al. J. Mater. Chem. A.,* **2019**,7; 20854-20860 **d)** Xie, Y. *et al. J. Am. Chem*. A. Soc., **2020**, 142, 11; 5154–5161 **e)** Zhu, X. *et al. ACS Applied Materials & Interfaces* **2020** 12 (37); 41506-41514

3. **a)** Zhan, X. *et al. Chem Soc Rev* **2016**, 45(9):2544-82 **b)** Krebs, F.C. *et al. J. Mater. Chem*., **2011**, 21; 4132-4141 **c)** Brabec, C. J. *et al. Adv. Energy Mater*., **2016**, 6: 1600515**. d)** McGehee, M. *et al. Chem. Mater*. **2015**, 27, 18, 6345–6353

4. **a)** Li, Y. *et al. Energy Environ. Sci*., **2020**,13; 2459-2466 **b)** Li, Y. *et al. J. Am. Chem. Soc*. **2020**, 142, 3; 1465–1474 **c)** Hou, J. *et al. Adv. Mater*. **2019**, 31; 1902302