RESEARCH HIGHLIGHTS

Journal of Semiconductors
(2023) 44, 030201
doi: 10.1088/1674-4926/44/3/030201

Single-component organic solar cells

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Citation: S J Liang, W W Li, and L M Ding, Single-component organic solar cells[J]. *J. Semicond.*, 2023, 44(3), 030201. https://doi.org/10.1088/1674-4926/44/3/030201

Bulk-heterojunction organic solar cells (OSCs) with physically mixed electron donor and acceptor as photoactive layer have received broad attention due to the advantages of light weight, flexibility, solution-processed fabrication, etc.[1–11]. With the rapid development of non-fullerene acceptors, the power conversion efficiencies (PCEs) of OSCs already exceed 19%[12, 13]. However, the photoactive layer is thermodynamically unstable and tends to form self-aggregated structure, resulting in reduced thermal/light stability during long-term operation. This issue can be tackled *via* covalently linking donor and acceptor into one material as double-cable conjugated polymers to fabricate single-component organic solar cells (SCOSCs)[14–16]. In 2019, Brabec *et al.* reported that SCOSCs exhibited excellent thermal stability and photostability due to the built-in microstructure[17]. SCOSCs have some merits such as simplified fabrication and homogenous viscosity, which can be applied in large-area devices.

Double-cable conjugated polymers usually consist of conjugated backbone as electron donor and conjugated side units as electron acceptor. At the beginning, fullerene and its derivatives were used as side units. Janssen *et al.* and Zhang *et al.* reported double-cable polymers with fullerene side units in 2001 (Fig. 1, P1 and P2), which gave PCEs below 1% in SCOSCs[18, 19]. In the following decades, many advances were made in constructing fullerene-based double-cable polymers[20–23]. However, the narrow absorption spectra and the difficult modulation of electronic properties of fullerene derivatives severely limit their application.

Rylene diimides, e.g. naphthalene diimides (NDIs) and perylene bisimides (PBIs), were then used as side units since they showed high crystallinity, high electron mobilities and deep frontier orbital energy levels. Li *et al.* reported double-cable conjugated polymers containing diketopyrrolopyrrole backbone and PBI side units (P3), and the length of the linkers can be adjusted[24]. The polymers with longer alkyl spacer exhibited stronger π-stacking and pronounced nanophase separation, and a PCE of 2.74% was obtained. The PCE was further enhanced to 4.18% when using a linear conjugated backbone based on benzodithiophene (BDT) unit (P4)[25]. Another important task is to tune the nanophase separation of donor and acceptor segments to realize efficient charge transport and to reduce charge recombination. The crystalline cooperativity between them was the critical factor to affect the nanophase separation[26]. Extra thermal annealing on P5 thin film yielded a well-ordered lamellar structure, and a PCE of 6.32% was obtained with a FF of 0.65[27]. Recently, NDI units were also incorporated into double-cable conjugated polymers (P6), leading to a PCE of 8.4%[28].

Near-infrared electron acceptors were also used to construct double-cable conjugated polymers. A non-fused electron acceptor with thienopyrrolodione core was used to make P7[29]. The polymer has an asymmetric configuration to balance the crystallinity of conjugated backbone and side units, presenting broad absorption at 300–850 nm, and yielding a PCE over 10% with excellent thermal/light stability.

Now the PCEs for double-cable conjugated polymers already go from below 1% to above 10%. Further enhancement can be realized *via* new materials design and device optimization. It could be a promising approach to use Y-series acceptors[30] as the side units. These materials will present breakthroughs in the near future.

Acknowledgements

This research was supported by Beijing Natural Science Foundation (JQ21006), National Natural Science Foundation of China (52073016, 92163128, 51973031, 51933001), the Fundamental Research Funds for the Central Universities (buctrc201828, XK1802-2), and the Open Funds for State Key Laboratory of Organic–Inorganic Composites (oic-202201006). L. Ding thanks the National Key Research and Development Program of China (2022YFB3803300), the open research fund of Songshan Lake Materials Laboratory (2021SLABFK02), and the National Natural Science Foundation of China (21961160720).

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Received 19 DECEMBER 2022.

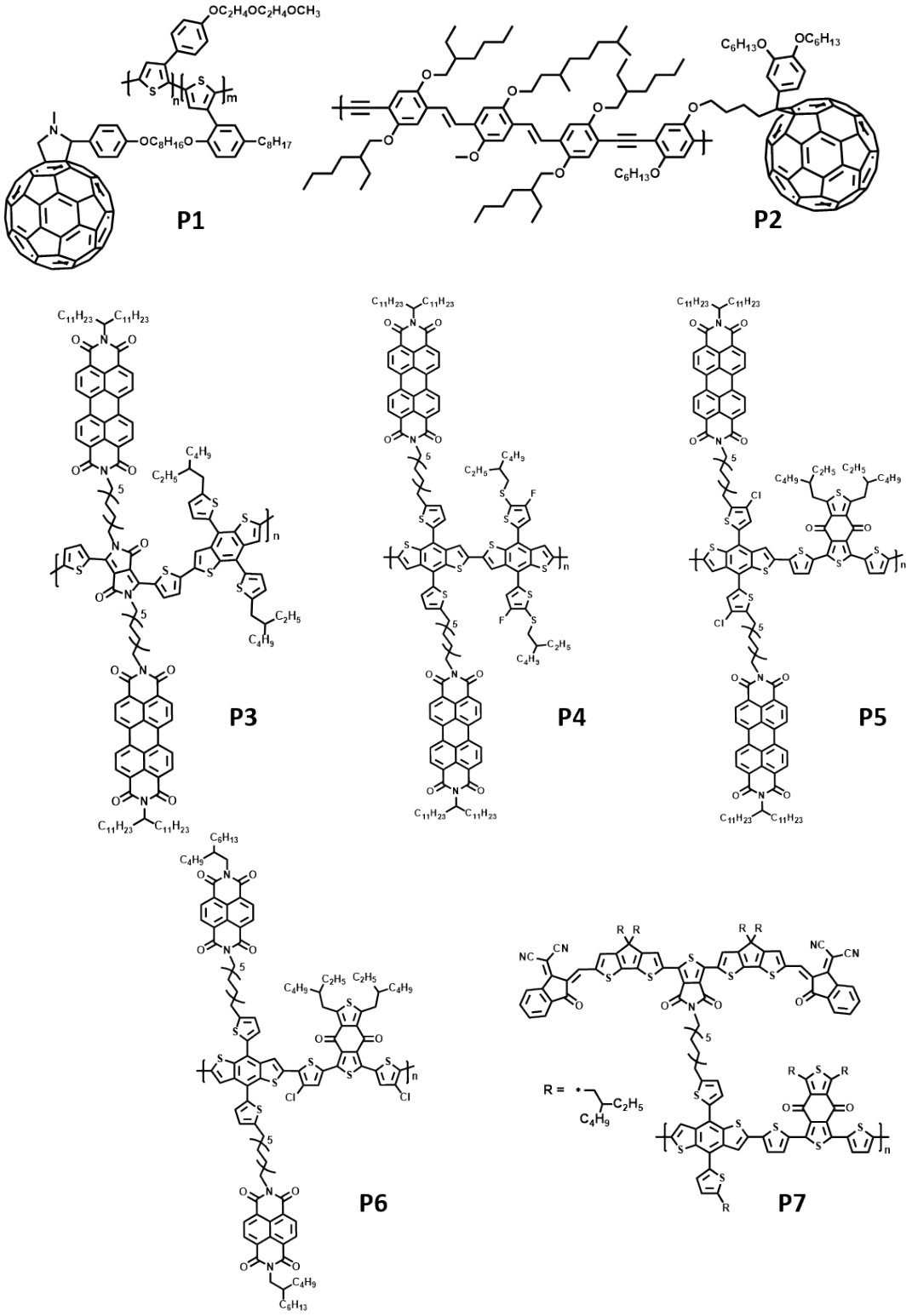

Fig. 1. Chemical structures for representative double-cable conjugated polymers.

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