Materials scientists from the Soochow University in China have fabricated all-polymer solar cells (all-PSCs) with 11.2% high efficiency.

Among various strategies to develop the high efficiency conjugated donor polymers, the substitution of fluorine atoms on the conjugated polymer backbone has attracted considerable attention recently, due to the simultaneous lowering of the highest occupied molecular orbital (HOMO) without sacrificing the bandgap, enhanced molecular ordering, high extinction coefficient, and the ability to tune the blend morphology to reduce the charge carrier recombination.

As reported in their previous work, PM6 has a large bandgap of 1.80 eV, a deep HOMO level of -5.50 eV, high crystallinity and a dominant face on molecular packing. The characteristics indicate that PM6 should be a promising wide bandgap donor polymer for all-PSCs with a narrow bandgap polymer acceptor.

In this work, the team developed all-PSCs based on a fluorinated wide-bandgap p-type conjugated polymer PM6 as the donor, and a narrow bandgap n-type conjugated polymer PZ1 as the acceptor. In addition to the complementary absorption and matching energy level, the optimized blend films possess high crystallinity, predominantly face-on stacking, and a suitable phase separated morphology. With this active layer, the devices exhibited a high Voc of 0.96 V, a superior Jsc of 17.1 mA cm^{-2}, a fine fill factor (FF) of 68.2%, and thus an excellent power conversion efficiency (PCE) of 11.2%, which is the highest value reported to date for single-junction all-PSCs. Furthermore, the devices showed good storage stability. After 80 days of storage in the N_2-filled glovebox, the PCE still remained over 90% of the original value. Large-area devices (1.1 cm^2) also demonstrated an outstanding performance with a PCE of 9.2 %, among the highest values for the reported large-area all-PSCs. These results indicate that the PM6:PZ1 blend is a promising candidate for scale-up production of large-area high-performance all-PSCs.

All-PSCs with a ITO/PEDOT:PSS/PM6:PZ1/ZnO/Al configuration, were prepared using toluene as the solvent. The photovoltaic properties of devices were optimized by changing the D/A weight ratios and introducing solvent additives. The details are shown the table as below.

D/A [w/w]	CN [%v/v]	V_{oc} [V]	J_{sc}[a] [mA/cm^2]	FF [%]	PCE [PCE_{ave}[b]] [%]
2.25:1	w/o	0.97	11.2(11.0)	38.8	4.2(4.2)
2:1	w/o	0.98	12.0(11.8)	39.2	4.6(4.5)
	w/o	0.98	12.4(12.3)	39.7	4.8(4.7)
1.75:1	2	0.95	16.4(15.4)	66.4	10.4(10.2)
	3	0.96	17.1(16.4)	68.2	11.2(10.6)
	4	0.95	15.4(14.9)	67.6	9.9(9.8)
1.5:1	w/o	0.98	11.7(11.3)	39.1	4.5(4.3)

[a] The integral J_{sc} in parentheses from the EQE curves. [b] The average PCE in parentheses from more than 10 devices.

(Cited from the research)

The variation of D/A weight ratios from 2.25:1 to 1.5:1 has little effect on the performance of the devices. And the device with an optional D/A ratio (1.75:1, w/w) shows a PCE of 4.8% with a high Voc of 0.98 V, a moderate Jsc of 12.4 mA cm^{-2}, and a low FF of 39.7%.

Moreover, the team measured the density-voltage (J-V) curves of the PCEs based on the PM6:PTZ1 (1.75:1, w/w) blend without additive and with chloronaphthalene (CN) (3%, v/v) additive treatment. The corresponding photovoltaic parameters of the devices are summarized in the table as below.

Compared with the device based in the as-cast blend film, the device processed with CN showed significantly higher Jsc (15.4-17.1 mA cm^{-2}) and FF(66.4-68.2%), but a slightly lower Voc (~0.95 V). Hence, the PCE was dramatically enhanced. The device with 3% CN additive treatment showed a maximum PCE of 11.2% with a Voc of 0.96 V, a Jsc of 17.1 mA cm^{-2}, and an FF of 68.2%.

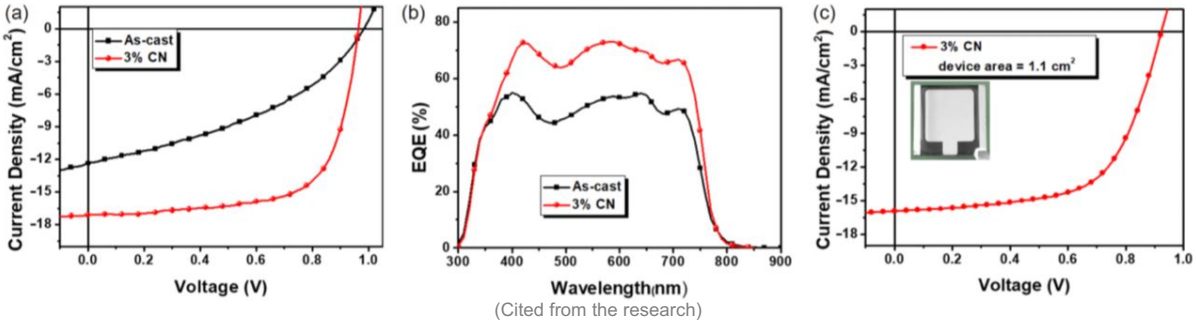
Table 1 The device performances of the all-PSCs based on **PM6**:**PZ1** (1.75:1, *w*/*w*) under the illumination of AM 1.5G, 100 mW cm^{-2}

Conditions	Area (cm^2)	V_{oc} (V)	J_{sc} [a] (mA cm^{-2})	FF (%)	PCE [b] (%)
As-cast	0.2	0.98	12.4(12.3)	39.7	4.8(4.7)
3% CN	0.2	0.96	17.1(16.4)	68.2	11.2(10.6)
3% CN	1.1	0.92	16.0(15.2)	61.9	9.2(9.1)

a) The calculated J_{sc} values in brackets from the EQE curves; b) the average PCE values in brackets from 10 devices.

(Cited from the research)

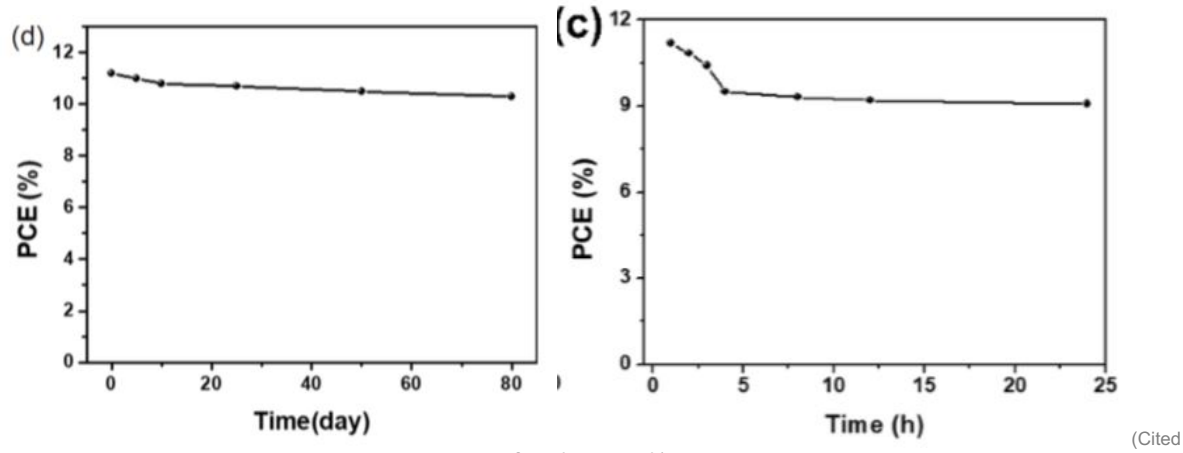
This PCE is the highest value reported to date for a binary, single layer all-PSC. The device based on PM6:PZ1 showed a higher Voc (0.96 V), an enhanced Jsc (17.1 mA cm^{-2}), due to the synergistic optimization of molecular energy levels and the blend morphology with the fluorination of polymer donor.



(Cited from the research)

Great long-term storage stability

To probe the stability of PM6:PZ1-based all-PSCs, the storage stability and thermal stability of the devices were measured. After 80 d of storage in N2-filled glovebox, the all-PSCs still demonstrated outstanding performance with PCEs up to 10.3%. Then, the devices were annealed at 80°C for 24 h, which still showed a PCE of 9.1%. Consequently, the all-PSCs based on PM6:PZ1 have great potential for scale-up fabrication.



(Cited from the research)

The research “11.2% Efficiency all-polymer solar cells with high open-circuit voltage” , which was published in Science. China Chemistry, was led by Prof. Yongfang Li, and implemented by Prof. Maojie Zhang from Soochow University.

Reference:

11.2% Efficiency all-polymer solar cells with high open-circuit voltage.

Yuan Meng, Jingnan Wu, Xia Guo, Wenyan Su, Lei Zhu, Jin Fang, Zhi-Guo Zhang, Feng Liu, Maojie Zhang, Thomas P. Russell, Yongfang Li