Optimization of the recycling process for the recovery and reuse of transparent electrode substrates from degraded organic solar cells

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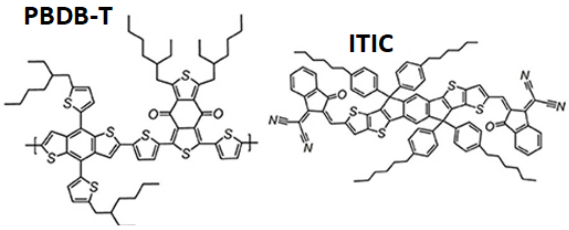
Organic solar cells (OSCs) are often referred to as low-cost photovoltaic technology but they suffer from two major drawbacks: (1) their relatively short lifetime; (2) the use of costly indium tin oxide (ITO) electrode substrates. Here, we explore the possibility to recover ITO/zinc oxide (ZnO) cathodes from degraded OSCs based on PBDBT:ITIC active layers (molecular structures in **Fig. 1**)[1)] for fresh OSC fabrication. In particular, we use UV-Vis absorption and scanning electron microscopy to correlate various solvent treatments with the device performances of recycled ITO/ZnO substrates.



Cathode type	Jsc (mA/cm²)	Voc (V)	FF (%)	PCE (%)
Fresh ITO/ZnO	16.8	0.91	56.9	8.73
DCB cleaning	14.0	0.91	55.7	7.11
Full cleaning (w/ IPA)	16.1	0.92	58.7	8.65
Full cleaning (w/o IPA)	16.3	0.91	58.4	8.66

Fig. 1. Molecular structures of active molecules and photovoltaic performances of OSCs prepared with fresh ITO/ZnO or recycled ones

We demonstrate that cleaning with a good solvent for the active layer such as dichlorobenzene (DCB) is not sufficient to produce power conversion efficiencies (PCEs) on par with OSCs employing fresh ITO/ZnO substrates (**Fig.1**). On the other hand, an additional cleaning with acetone, surfactant, water and isopropanol (IPA) leads to OSCs with PCEs corresponding to 99% of the value obtained in reference OSCs. Our results indicate that repetitive cleaning with IPA gradually removes the ZnO layer from the ITO surface thus leading to a 40% drop in PCE for substrates recycled 10 times. However, IPA does not seem to be essential for substrate cleaning and substrates recycled 10 times without IPA produce a PCE of 7.93%. This value corresponds to 91% of the PCE of the PCE of reference OSCs.

Our results thus confirm that an optimized solvent treatment sequence can be used to efficiently remove the active layer and surface contaminations from degraded OSCs and enables the repetitive reuse of costly ITO/ZnO substrates. With the imminent mass production of OSCs, such recycling process could become crucial to ensure conservation of resources and promote circular economy while reducing the cost of OSCs.

Reference

1) W. Zhao *et al.* Adv. Mater., 28, 4734-4739 (2016)