Recycling of costly and durable transparent conductive electrodes from degraded organic solar cells

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Organic solar cells (OSCs) exhibit a great potential for the manufacturing of low-cost next-generation energy technologies that can be easily integrated into existing infrastructures or wearable electronics. Their maximum lifetimes around 5 years may be sufficient for such modern electronic applications but their integration into commercial products could also result in large indium tin oxide (ITO) wastes discarded with OSCs that reached the end of their lifecycle (**Fig. 1**). Here, we investigate methods to recycle ITO/zinc oxide (ZnO) substrates from degraded OSCs. We compared recycling methods and the photovoltaic performances of OSCs prepared either with fresh ITO/ZnO substrates or with recycled ones (**Fig. 1**).

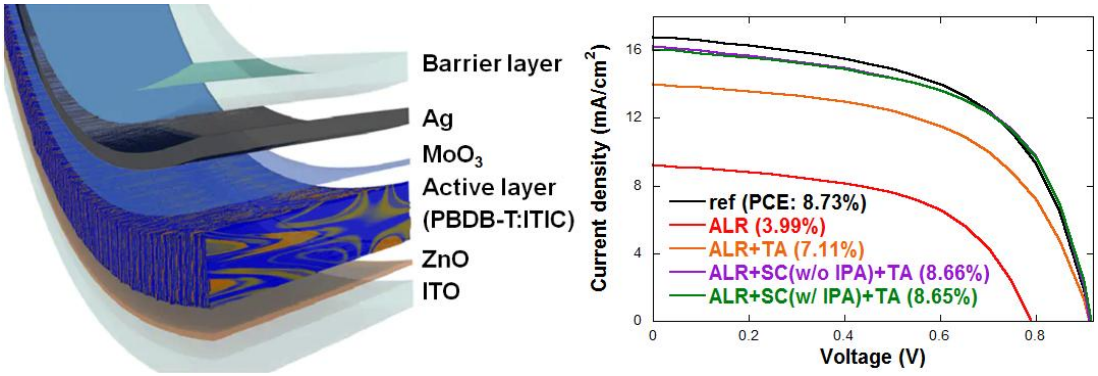

Fig. 1: (left) Schematic representation of the inverted OSC architecture and (right) current density-voltage curves of OSCs exposed to AM1.5G irradiation.

Complete active layer removal (ALR) was achieved by sonicating the OSCs in dichlorobenzene. However, as can be seen from the power conversion efficiencies (PCEs) presented between brackets in **Fig. 1** (right), ALR is not sufficient to produce photovoltaic performances on par with reference OSCs. Additional surface cleaning (SC) and thermal annealing (TA) are necessary to yield PCEs similar to those obtained for the reference OSCs (~8.7%).[1] SC is a commonly employed process in the electronics industry which is performed sequentially with acetone, water, surfactants and isopropanol (IPA). Comparing the individual impacts of the SC solvents, we found that the repetitive use of IPA is detrimental to the OSC performances as it gradually damages the ZnO layer. Avoiding IPA SC simplifies the recycling process and enables multiple recycling of ITO/ZnO substrates with only minor decreases in PCE. The PCE of OSCs recycled 10 times without IPA only drops to 7.9%, a value within 10% of the reference OSC performances. Our results thus open the path to simple recycling of costly and durable substrates from degraded OSCs to simultaneously reduce electronic wastes and promote circular economy.

[1] T. Takada *et al*. High Performance Organic Solar Cells Fabricated Using Recycled Transparent Conductive Substrates. *ACS Sustainable Chem. Eng. 8*, 5807-5814 (**2020**).