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# Degradation Mechanisms in Organic Solar Cells: The Role of Interfaces

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## Abstract

In recent years the performances of organic solar cells have improved considerably, reaching power conversion efficiencies higher than 10%. However, long-term stability of these devices is still to be achieved. In order to improve the lifetime of these devices, a good understanding of the different degradation mechanisms is needed. Degradation pathways are complex and diverse: they can be induced by numerous stimuli (heat, light, presence of O<sub>2</sub> and H<sub>2</sub>O...) which can affect different regions of the device (active materials, interfaces, morphology, etc...). In this work, we attempt to isolate the contribution of each different degradation mechanism by applying different kinds of stresses to the devices (thermal ageing, photo-ageing) and, in particular, focusing on the interfaces in the devices.

The robustness under thermal and photo-ageing of the top interface in inverted architectures was first investigated. In particular, the influence of the hole transport layers (MoO<sub>3</sub>, WO<sub>3</sub> and PEDOT:PSS) and the top electrode (Ag and Al) on the stability of the device was studied. Under thermal stress, the combination of MoO<sub>3</sub> as HTL and silver as electrode was shown to be especially unstable due to a rapid loss of open-circuit voltage (V<sub>oc</sub>) while WO<sub>3</sub> and aluminum proved to be very robust. In depth analysis (XPS, RBS) showed that interdiffusion was occurring in MoO<sub>3</sub>/Ag devices. We suspect that this phenomenon affects the Fermi level of the MoO<sub>3</sub> and/or increases the recombination rate at the interface with the organic active layer.<sup>1</sup>

The robustness of the bottom interface was also investigated, especially in terms of resistance to photo-degradation. Different kinds of electron transport layers (ZnO or TiO<sub>x</sub>) and active layers (P3HT:PC60BM and PCDTBT:PC70BM) were submitted to photo-ageing with or without UV. As expected, the UV component of the light (300-400 nm) is detrimental for the device for both ETL and both active layers. This loss of performance is mainly due to a loss of V<sub>oc</sub>, which can be attributed to an increase of the recombination rate at the interface. While the loss of V<sub>oc</sub> is always observed, the degradation kinetics are different in the four cases, and depend not only on the active layer used, but also on the ETL chosen. In particular, the use of ZnO as ETL seemed to slow down this degradation process. These findings indicate that TiO<sub>x</sub> reacts faster with the active layer to form recombination centers, even in the absence of oxygen.

Thanks to these different studies, we have managed to identify degradation mechanisms

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specific to some organic solar cell architectures. Specifically, the combination of MoO<sub>3</sub>/Ag seems to be very unstable with thermal ageing. The UV component of the light, while always detrimental for the device, seems to react faster with the active layer when TiO<sub>x</sub> is used as ETL. Knowing this, specific solutions can be designed to improve the stability of organic solar cells against thermal and/or photo-ageing.

(1) Greenbank, W.; Hirsch, L.; Wantz, G.; Chambon, S. Interfacial thermal degradation in inverted organic solar cells *Appl. Phys. Lett.* **2015**, 107 (26), 263301.