Routes for enhancing long-term stability and mechanical properties of organic solar cells

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Organic photovoltaic devices (OPV) are nowadays among the most promising alternative energy sources thanks to record efficiencies extending beyond 18%, low production costs, low environmental impact and completely new integration possibilities due to free-form design. However, their great potential is shadowed by their relatively low stability when exposed to combined light, oxygen and heat. Furthermore, to utilize them in truly flexible or even stretchable applications, their otherwise intriguing mechanical properties needs to be further improved.

This PhD thesis focuses on degradation and stability of OPV devices, and it presents in this respect results on promising stabilization routes for two OPV constitutive layers, namely the active layer and the interlayer. The first main finding in reporting on the successful utilization of two naturally occurring additives such as Beta-carotene and Astaxanthin as stabilizing components in the active layer of fullerene-based OPV devices. Furthermore, the synthetization of a new additive molecule covalently bonding the antioxidant Astaxanthin and the silicone oil PDMS was shown to successfully stabilize the PTB7:[70]PCBM system, improving the accumulated power generation and at the same time reporting improved mechanical properties of the active layer. Both of the presented routes presents clear stabilization improvements beyond state-of-the-art, and it is the first demonstration of synergistic improvement of the photochemical stability and mechanical properties of OPV using additives. The study on the active layer was paired with a study on the influence of interlayers on the long-term stability of non fullere OPV devices. Sputtered TiOx was found to be an equally performing and more stable, ETL layer compared with the one based on ZnO nanoparticles.

Perovskite-based solar cells (PSC) have in the past few years been reporting record-high efficiencies exceeding 25%, however multiple degradation processes and device instabilities are limiting their commercialization. The last part of the PhD thesis is reporting the effects of electrical bias on the degradation and, in particular, dynamics of recovery mechanisms of PSC solar cells when degraded to different stages of their initial efficiency. For the first time, a relation between the PSC degradation mechanisms, ion migration and the utilized interlayers, is reported.

Overall, this thesis gives insights into degradation and especially stabilization of new emerging organic and perovskite solar cells and show new routes for stabilization of both active layers and interlayers, leading to device lifetime improvements.