Hybrid interfaces in scalable organic photovoltaics

Morten Madsen
University of Southern Denmark, Mads Clausen Institute
madsen@mci.sdu.dk

The power conversion efficiency of organic photovoltaics (OPV) has recently crossed the 20% milestone, placing an even larger focus on degradation processes and device stability. Here, recent results on oxide-organic as well as 2D MXene-organic interfaces in scalable OPV will be presented. Transition metal oxides have been demonstrated as an important class of materials for OPV devices, where they serve as charge carrier selective interlayers for efficient electron and hole extraction. However, interlayer related instabilities have been reported as a degradation route for high performing non-fullerene acceptor OPV devices, making a thorough understanding of such interfaces important for the further development of OPV technology. Recent progress made within sputtered oxide charge extraction and transport interlayers for OPV devices will be presented. Supported by a variety of surface science characterization techniques, the effect of e.g. oxide composition, microstructure and defect states on the performance of sputtered oxide interlayers in organic photovoltaic devices will be discussed, demonstrating also how to tune such interlayers for more stable interfaces and thus reach prolonged OPV device lifetimes [1,2]. In addition, results on the use of 2D MXene to tune interfaces between active layers and transport layers in OPV will be presented [3], demonstrating how 2D MXene can be used to passivate interface defect states, and from that improve efficiency and in particular device stability. Finally, routes for Roll-to-Roll (R2R) up-scaling and manufacturing of OPV will be presented. This includes development of the hybrid interfaces using industrial-compatible Sheet-to-Sheet (S2S) and R2R techniques, and the scale up from cells to modules using various device configurations. This part also includes examples on development of scalable transparent tandem solar modules reaching power conversion efficiencies of above 12% for an average visible transmittance of 30%, developed in the EU project CITYSOLAR.

1. Mariam Ahmad, Hervé Cruguel, Mehrad Ahmadpour, Noemi Vannucchi, Nahed Mohammad Samie, Céline Leuillet, Alexander Generalov, Zheshen Li, Morten Madsen and Nadine Witkowski, "Uncovering the electronic state interplay at metal oxide electron transport layer/non-fullerene acceptor interfaces in stable organic photovoltaic devices" *ACS Appl. Mater. Interfaces*, 15, 55065 (2023)
2. M. Ahmadpour, M. Ahmad, M. Prete, J. L. Hansen, D. I. Miakota, W. Greenbank, Y. J. Zheng, M. Top, T. Ebel, H.-G. Rubahn, V. Turkovic, S. Canulescu, N. Witkowski, and M. Madsen "Tuning surface defect states in sputtered titanium oxide electron transport layers for enhanced stability of organic photovoltaics" *ACS Appl. Mater. Interfaces*, 16, 16580 (2024)
3. U. K. Aryal, H. Pazniak, T. Kumari, M. Weber, F. O. L. Johansson, N. Vanucchi, N. Witkowski, V. Turkovic, A. Di Carlo, M. Madsen, "2D MXene Based Electron Transport Layers for Non-Halogenated Solvent Processed Stable Organic Solar Cells", *ACS Appl. Energy. Mater*. 6, 4549 (2023)