

## Openbaar eindrapport TKI+ Urban Energy Project

### Atomic Layer Deposition for Perovskite Solar cells (ALD4PSC)

September 2019

#### Target of the project and project partners

ALD4PSC had the goal of paving the way for atomic layer deposition (ALD) to deliver high quality metal oxides serving as charge transport layers, while also improving the environmental stability of the PSC device. Fundamental understanding of the metal oxide/perovskite interface was developed to provide efficient and selective charge transport. The achieved results have been highly relevant for ECN part of TNO, GreatCell Solar as industrial resident of Solliance and the Dutch ALD equipment manufacturer Meyer Burger B.V.

#### Project results

TU/e has developed a plasma-assisted ALD process of NiO serving as a hole transport layer (HTL) in a p-i-n perovskite structure and a thermal ALD process of SnO<sub>x</sub> serving as electron transport layer (ETL). The performance of the ALD NiO HTL was improved by post-deposition annealing which, amongst other affects, reduced the resistance of the NiO and thus the series resistance of the cells. 17% champion power conversion efficiency was achieved in these cells. When investigating ALD SnO<sub>x</sub> ELTs deposited directly on top of perovskite, we found that although the bulk of perovskite was unchanged, the cells performed poorly due to interface chemical reactions with the perovskite. With a PCBM interlayer between the perovskite and ALD SnO<sub>x</sub>, efficiencies comparable to the reference were achieved. The ALD SnO<sub>x</sub> process was chosen for transfer to sALD, to both the rotary and S2S reactors of TNO. The barrier properties of the ALD SnO<sub>x</sub> layer, which increased the solar stability, were a key motivation. The SnO<sub>x</sub> layers grown by ALD and sALD had similar material properties but the sALD layer lost some efficiency on upscaling so needs further optimization. Solar cells with (s)ALD SnO<sub>x</sub> layers passed 1000 hour MPPT and thermal stress tests, and 100cm<sup>2</sup> module with over 14% active area PCE was achieved.

#### Contributions to targets of TKI Urban Energy

The project results are a showcase for the introduction of ALD processing of novel electron and hole transport layers, highly relevant for the market position of Dutch ALD equipment manufacturers.

#### Publications related to the project

1. Dibyashree Koushik, Marko Jošt, Algirdas Dučinskas, Claire Burgess, Valerio Zardetto, Christ Weijtens, Marcel A. Verheijen, Wilhelmus M.M. Kessels, Steve Albrecht, and Mariadriana Creatore; *Plasma-Assisted Atomic Layer Deposition of Nickel Oxide as Hole Transport Layer for Hybrid Perovskite Solar Cells*; Journal of Materials Chemistry C, accepted for publication.
2. Interface Studies of Metal Oxides Grown Directly on Hybrid Perovskite by Atomic Layer Deposition, to be submitted (2019)

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