Application of atomic layer deposition method in perovskite solar cells

Malgorzata Kot, Dieter Schmeißer

BTU Cottbus–Senftenberg, Konrad-Wachsmann-Allee 17, 03046 Cottbus, Germany

Hybrid perovskites like methylammonium lead triiodide (CH$_3$NH$_3$PbI$_3$) represent a new paradigm for photovoltaics, which have the potential to overcome the performance limits of current solar cell technologies and achieve low cost and high versatility. However, they are prone to degradation in presence of moisture and oxygen within a couple of hours or days.[1,2] Enhancing the stability of the perovskite materials and devices against environmental degradation[3,4] is of a great importance.

Atomic layer deposition (ALD) method has recently gained increased attention in the perovskite solar cell community.[3,5-7] Conformal, dense and pinhole-free films can be achieved by ALD at very low temperatures (400°C – down to room temperature).[8-10] An optimal ultra-thin ALD-processed Al$_2$O$_3$ buffer layer is capable to suppress carrier recombination and improve device efficiency.[6] Al$_2$O$_3$ as an encapsulating layer would increase moisture resistance of perovskite films and thus retard water-induced degradation.[7] The lowest temperature reported so far to prepare Al$_2$O$_3$ on the perovskite solar cell using ALD method is equal to 70°C.[7] However, long-time annealing of the perovskite films even at this low temperature accelerates their degradation.[11, 12] Therefore, room temperature (RT) ALD technique is highly desirable for Al$_2$O$_3$-based protection.

In this work, we study the ALD growth of Al$_2$O$_3$ on CH$_3$NH$_3$PbI$_3$ perovskite at room temperature using trimethylammonium (TMA) and water vapor as metal and oxygen precursors. High energy resolution synchrotron-based X-ray photoelectron spectroscopy (XPS) and atomic force microscopy studies indicate that RT-ALD-Al$_2$O$_3$ film grows on the perovskite surface, first in a layer by layer form, and then forming 3D islands. Depth profiling XPS study has shown that the ALD precursors are chemically active only at the perovskite film surface and the film bulk is not affected. Moreover, a stability test of the perovskite film upon air exposure has shown that an ultrathin RT-ALD-Al$_2$O$_3$ layer significantly enhances its lifetime. Solar cells with a fresh CH$_3$NH$_3$PbI$_3$ perovskite film have shown power conversion efficiency (PCE) of 15.4%, while the one with 50 days aged perovskite film only 6.1%. However, when the aged perovskite was covered with RT-ALD-Al$_2$O$_3$ the PCE value was clearly enhanced.[13] This finding opens new possibilities to increase the stability of the perovskite solar cells where the low temperature processing is mandatory to protect the perovskite film against degradation.

References


Acknowledgements

Authors would like to acknowledge the support during the XPS measurements of Dr. Chittaranjan Das and Mr Guido Beuckert from BTU, for the perovskite preparation to Dr. Konrad Wojciechowski and for the electrical characterization to Dr. Zhiping Wang, both from University of Oxford. This work was partially supported by DFG (SCHM 745/31-1).

*E-mail: malgorzata.sowinska@b-tu.de