Atomic Layer Deposition for Photovoltaics

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Abstract

In the field of photovoltaics (PV), ultrathin film technology has become the key driver for enhancing the efficiency. Atomic layer deposition (ALD) has already truly made its mark within this field, both in R&D and in high-volume manufacturing. This success of "ALD4PV" can most likely be understood from a range of unique capabilities and merits offered by ALD; most notably the ability to prepare a wide range of high-quality materials with excellent thickness control, uniformity and conformality. Within this tutorial, an overview of ALD4PV will be presented, and exactly those typical ALD aspects that are important to the PV application will be highlighted.

The starting point for this tutorial will be the well-known (industrial) success story of ALD Al_2O_3 surface passivation layers for silicon (*c*-Si) solar cells. Since then, the field has gone beyond "just Al_2O_3 passivation": The wide range of ALD materials has resulted in novel passivation schemes with tailored properties, e.g. for passivating n^+ and/or p^+ *c*-Si. Also, the conformality of ALD enables the passivation of black silicon. ALD is also prominent in the upcoming field of passivating contacts: ALD (metal oxide) films are used to both passivate the surface and extract charge, or to serve as hydrogenation layers in poly-Si-based passivating contacts.

Thin-film absorber cells benefit from ALD as well. Here, the focus will be on perovskite (and tandem) cells. Key strengths of ALD here include the ability to prepare conformal, pin-hole free charge extraction layers on rough/mesoporous substrates and the ability to do interface engineering with ultrathin layers. Although often still challenging, the soft deposition conditions and relatively low temperature of ALD enable processing on top of fragile perovskite absorbers, with the most notable example being the ALD SnO_2 buffer layers being used in the record perovskite/c-Si tandem solar cells.

This tutorial will conclude with a vision for the prospects for ALD4PV, both with respect to research as well as industry.