MASTER

Atomic Layer Deposition of Metal Oxide Thin Films for Perovskite Solar Cells

Gidaszewski, Dawid

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by

Dawid Gidaszewski

MSC THESIS

Assessment committee

Member 1 (chair):	prof. dr. M. Creatore
Member 2:	prof. dr. R.A.J. Janssen
Member 3:	prof. dr. C.C.M. Rindt
Advisory member 1:	dr. N Phung
Advisory member 2:	dr. S.R. Ratnasingham

Graduation

Program:	Sustainable Energy Technology
Capacity group:	Plasma & Materials Processing
Supervisor:	prof.dr. M. Creatore
Date of defense:	06-09-2023
Student ID:	1759035
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Specialization:	Plasma & Materials Processing
Daily Supervisor(s):	dr. N. Phung; dr. S.R. Ratnasingham

Abstract

In order to combat rising global temperatures, the emission of greenhouse gasses, especially CO_2 needs to be mitigated by transitioning to renewable energy sources. Photovoltaics (PV) is a technology that enabled the start of this transition alongside wind technologies. However, the currently developed technologies are either reaching their maximum efficiency (Si-based PV) or extremely expensive (III-V elements-based PV), therefore new emerging technologies such as tandem solar cells and perovskite solar cells have gained much attention recently. Recombination junction is a crucial element of monolithic tandem solar cells, which combine both emerging technologies. To enable all-perovskite tandem solar cells with efficiency above 30%, an efficient solvent-barrier layer, and hole transport layer for narrow bandgap (NBG) sub-cell ought to be researched. Thermal atomic layer deposition (ALD) SnO_2 has been recently widely used as a buffer layer against indium tin oxide (ITO) sputtering and as a solvent-barrier layer in a recombination junction of tandem solar cells. However, in the literature, there is a lack of research in terms of key factors that define if a SnO_2 film is suitable to be implemented as a solvent-barrier layer. Regarding the hole transport layer for NBG perovskite sub-cell, organic PEDOT:PSS which is widely used to date, is desired to be replaced by metal oxides to avoid parasitic absorption and water-based solution processing.

In this thesis, the thermal ALD SnO_2 deposited at 100 °C was analyzed to derive processing parameters that determine the solvent-barrier properties of the SnO_2 film. Mass density, indirectly analyzed by refractive index investigation, and thickness were found to be the key factors determining the permeability of the layer to the solvent, that is H_2O. Even though the dosing and purging times were adjusted, such that the mass density was increased, this improvement was still not sufficient to provide protection against water tests mimicking the deposition of PEDOT:PSS for a 50 nm layer. The only instance in which the performance of the solar cell was only mildly affected after the water test, was a 75 nm layer of thermal SnO_2 of a standard deposition process, previously developed in our research group (PMP). This successful approach was later implemented into a monolithic all-perovskite solar cell, which achieved a power conversion efficiency of 22.4%. Furthermore, a new PE-ALD NiO process was developed by adopting the Ni-precursor Alanis^{TM} at 150 °C of processing temperature. The 8 nm film obtained through this process was later analyzed by ultraviolet photoelectron spectroscopy, proving that its energy levels are compatible with the NBG perovskite sub-cell, when MeO-2PACz is used on top of the layer. The additional usage of MeO-2PACz adjusts the energy levels and prevents the redox reactions between NiO and the perovskite absorber. What is more the PE-ALD process was found to be suitable also for depositions at 100 °C and lower, thus enabling its future implementation in the recombination junction on top of the ITO layer.