

Drying of Nanolayers for Perovskite Solar Cells – Phase Equilibria and Solvent Diffusion

Tobias Börnhorst^{1,2,5}, Simon Ternes^{1,2,4}, Ulrich W. Paetzold^{3,4}, Bryce S. Richards^{3,4}, Philip Scharfer^{1,2,5}, and Wilhelm Schabel^{1,2,5}

¹*Institute of Thermal Process Engineering (TVT), Thin Film Technology (TFT),*

²*Material Research Center for Energy Systems (MZE),*

³*Institute of Microstructure Technology (IMT),*

⁴*Light Technology Institute (LTI), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany*

⁵*Innovation Lab (iL), Heidelberg, Germany*

ISCST-20180917PM-B-DF5

Presented at the 19th International Coating Science and Technology Symposium
September 16-19, 2018, Long Beach, CA, USA[†].

Extended Abstract

For production of nanolayers for optoelectronic devices, liquid coating and subsequent drying is the method favored from an economic point of view when it comes to mass production. For fabrication of organometal halide perovskite solar cells, a precursor solution is coated in which the perovskite crystals are formed while the solvent is removed. In this context, the thermodynamic equilibrium, phase transitions and solvent diffusion kinetics are of great interest since the process determines the morphology and therefore the resulting power conversion efficiency of the solar cell.

While reports of deviating properties between the micrometer and nanometer scale film drying can be found in literature for polymers [1], thermodynamic and kinetic phenomena in perovskite nanolayers are still to be investigated.

In this talk, experimental methods are shown to analyze the drying and diffusive mass transport. The focus is on the individual phases of perovskite formation from the precursor solution. The kinetics of the gas-side controlled drying phase is measured by laser interferometry, while the film diffusion at low solvent loads is characterized by high-precision gravimetric sorption measurements.

The interferometrically measured drying curves of perovskite precursor solutions showed that after the first, gas-side controlled drying section, the drying process is significantly limited by the diffusion of the solvent in the film (see Figure 1).

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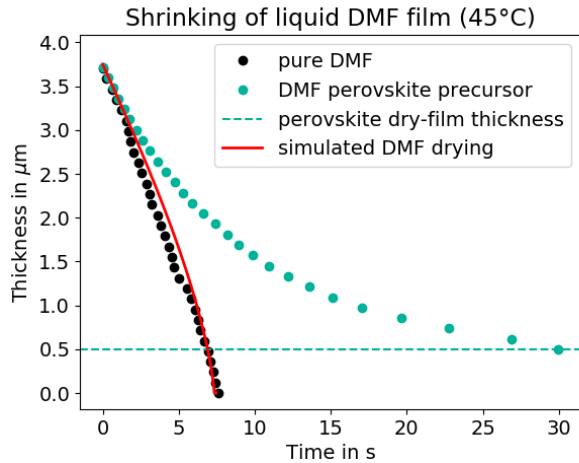


Figure 1: Measurement of film shrinking during drying of a pure solvent film (black) and a perovskite precursor solution film (green) at the same drying conditions.

Since the crystals form in this phase of drying, this is particularly decisive for the morphology of the resulting layer. The measuring method for the layer thickness progression via laser interferometry reaches its limits especially for the late phase of drying, since a (semi-)transparent layer of several hundred nanometers thickness is required. Especially the resulting perovskite crystals make an examination at the end of the drying impossible.

Therefore, gravimetric sorption measurements will be used to investigate the drying process which is controlled by film diffusion. A perovskite layer is produced via spin coating and dried afterwards. This is then exposed to a defined solvent vapor pressure in the sorption apparatus, while its mass is recorded by means of a high-precision sorption balance. This way, the sorption equilibrium and the sorption kinetics can be determined so that the drying process can be simulated with the data obtained.

Sorption measurements with dimethylformamide show that the kinetics are not determined exclusively by diffusion. Possible explanations of the measured phenomena are transformation processes of the crystal structures, which are triggered by the solvent and in turn change the thermodynamic equilibrium. This is consistent with reports from literature according to which intermediate complexes of DMF and perovskite precursor materials exist [2,3].

The aim of the further research work is to understand and control the individual complexes and their formation mechanisms in order to optimize the morphology of the final perovskite layer with regard to the power conversion efficiency of the solar cell.

The authors acknowledge financial support of the BMBF via the joint project POESIE (13N13692).

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[3] L. Zuo; S. Dong; N. Marco; Y. Hsieh; S. Bae; P. Sun; Y. Yang (2016): Morphology Evolution of High Efficiency Perovskite Solar Cells via Vapor Induced Intermediate Phases. In: *Journal of the American Chemical Society* 138 (48), S. 15710–15716.