E-MAP –
A Self Driving Lab for Solution Based Combinatorial Semiconductor Discovery

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1. Introduction

The Energy Materials Acceleration Platform (E-MAP) at the Karlsruhe Institute of Technology enables automated processing and characterization of energy materials for photovoltaics, light emission, optoelectronics, and other thin-film applications. It consists of three fully integrated process sections inside an inert-atmosphere glovebox cluster: (1) Synthesis of semiconductor inks using combinatorial microfluidics and pipetting. (2) Automated deposition of thin films via spin coating, which can be used to fabricate all common solution-processable thin-film devices (organic PV, organic LEDs, perovskite PV, perovskite-inspired semiconductors, etc.).[1] (3) Optoelectronic characterization techniques integrated as modular bays. Thanks to this strict modularity, the entire system remains open to expansion at any time - both to address new scientific questions and to enable use by other research groups.

2. Results

In this work we demonstrate in-situ und ex-situ characterization modules of the E-MAP to monitor solution processing of semiconductor inks of unknown viscosity and wetting behavior. We employ a deep-learning based computer-vision system to monitor robotic pipetting inside a fully automated spin coater system to measure the contact angle between liquid and substrate (Fig. 1). A hybrid pipeline combining deep semantic segmentation with classical geometric analysis enables the system to assess the wetting behavior in real time and stop the deposition of the semiconductor ink if the coating outcome is likely unfavorable. This feature is key in the exploration of novel compositional parameter spaces to limit the rate of failed sample fabrications.

After spin coating a robotic gantry system transfers the thin-film samples to the characterization section where we demonstrate automated charge carrier mobility measurements using metal-insulator-semiconductor charge extraction by linearly increasing voltage (MIS-CELIV).[2] Our novel approach of dynamic MIS-CELIV uses spring contact pins pressed atop the thin-film to locally inject and extract charge carriers to calculate hole and electron mobilities on arbitrary positions of the sample. These are essential gate criteria properties for materials discovery in many thin-film optoelectronic applications such as photovoltaics and organic light emitting diodes.

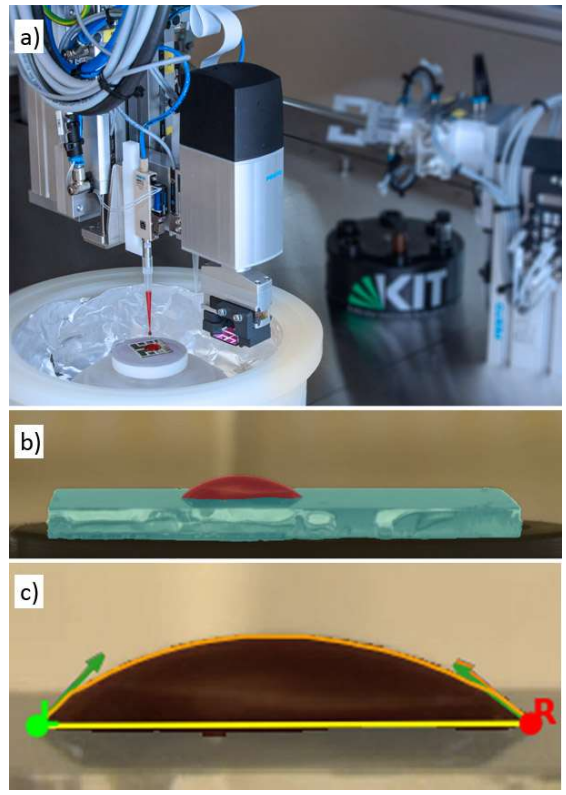

Fig. 1: a) One of the automated spin coater modules of the E-MAP. b) In situ contact angle measurement and c) deep semantic segmentation image of a substrate and droplet inside the spin coater module.

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References

[1] Rupam Datta, Kai Trombotto Herfert, Daniel M. Többens, Pirmin Tischler, Martin Peterlechner, Ben Breitung, Marcel Habrik, Jan Bruder, Uli Lemmer, Susan Schorr, Alexander Colsmann, Holger Röhm, *Photovoltaic properties of BiI3 with copper interstitials*, EES Solar, 2025, https://doi.org/10.1039/D5EL00108K

[2] Alexander Deniz Schulz, Steffen Andreas Otterbach, Henrik Tappert, David Elsing, Wolfgang Wenzel, Mariana Kozlowska, Stefan Bräse, Alexander Colsmann, Holger Röhm, *Doping Strategies for Tetrasubstituted Paracyclophane Hole Transport Layers in Perovskite Solar Cells*, Adv. Funct. Mater., 2024, 34, 47, 2402110, https://doi.org/10.1002/adfm.202402110