Automated synthesis of Al-doped ZnO nanoparticles: an online UV-Vis spectroscopy approach

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Innovative techniques for fabricating and seamlessly integrating customized nanomaterials into complex optoelectronic semiconductor systems, such as organic light-emitting diodes and thin-film solar cells, are of significance in the ongoing energy transition. With a surging demand for these technologies and a concurrent scarcity of rare earth materials in semiconductors, aluminum-doped zinc oxide (AZO) nanoparticles have emerged as an economically viable, eco-friendly substitute for indium tin oxide (ITO). [1-2] Our research leverages the versatile sol-gel synthesis method to create homogeneous AZO nanoparticles, allowing precise control over size and morphology through key parameter adjustments, including temperature. These variations impact the transparency and conductivity of solar cells, positioning our research as pivotal in renewable energy (see Fig. 1). To achieve precise control in a batch reactor, we employ a process controller, a model-based soft sensor, and online UV-Vis spectroscopy. This system continuously measures the real-time mass concentration of AZO, providing input for the model-based soft sensor. Leveraging population balance equations (PBE), the soft sensor offers real-time particle size distribution (PSD) data, with model parameters identified through offline Small-Angle X-ray Scattering (SAXS) and Dynamic Light Scattering (DLS) measurements.

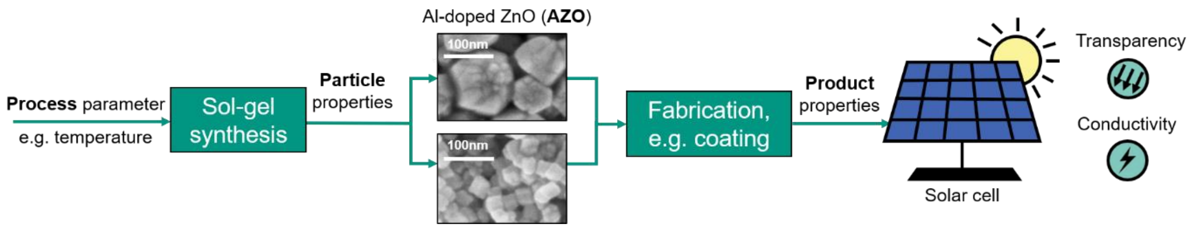

Figure 1. The process temperature is a key control parameter to influence the AZO sizes, as well as the transparency and conductivity of solar cells.

At the upcoming DECHEMA annual meeting 2025 within the sub-theme PMT, we will present our findings on AZO sol-gel synthesis, elucidate the population balance model parametrized by SAXS and DLS, showcase online UV-Vis measurements, and detail an innovative approach for automated AZO production. Our work advances the synthesis of nanomaterials for emerging technologies, promising precise control over AZO particle and product properties.

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References:

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[2] Ellmer, K., Klein, A., Rech, B. (Ed.), Transparent Conductive Zinc Oxide: Basics and Applications in Thin Film Solar Cells, Springer Science & Business Media, Berlin/Heidelberg 2008.