

Unraveling Electron-Induced Dissociation and Molecule-Surface Kinetics for 3D Nano-printing of Photonic Quantum Elements

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Focused electron beam induced deposition (FEBID) is a direct-writing technique that allows flexible high-fidelity printing of 3D nanostructures at sub-50 nm resolution. The free electrons used for printing can also serve as reducing agents in electron beam enhanced surface reactions such as electron-enhanced atomic layer deposition (e-ALD) and chemical vapor deposition (e-CVD) [1]. The “ebeast” project aims to study and optimize their impact in FEBID to realize pure-metal deposition, ultimately enabling direct fabrication of nano-optical components for photonic quantum applications.

The kinetics of FEBID can be empirically understood using continuum modeling, in particular with respect to the ligand co-deposition [2]. The ligand co-deposition model breaks down the molecule-surface kinetics of FEBID into different processes, including precursor (ML) adsorption and desorption, detached ligand (L) desorption and electron induced dissociations of ML and L (see Figure 1). Until now, FEBID is likely to operate in undesirable conditions for most precursors, causing the typically observed significant co-deposition of ligand material. Experimental results for elevated substrate temperature in combination with a low electron flux point towards a substantial contribution from the low desorption rate of the cleaved ligand fragments to the overall contamination of the deposit [3]. The obtained high metal contents under these specific FEBID conditions are the driving force to address this lack of knowledge in the adsorption types and characteristic rates of different processes for the specific molecule and its ligands.

The planned ebeast project aims to decouple the elementary processes and probe them in separately in complementary experimental settings. At Empa, e-ALD and e-CVD experiments are conducted to provide insights into the adsorption and desorption characteristics of molecules including their mean residence times. At FBH, FEBID is studied with continuous precursor supply and pulsed electron exposure with varying electron fluxes to resolve the diffusion and desorption dynamics and their time scales. All experiments are performed on same molecules and ligands to ensure cross-validation and safe parameter extraction. The gained experimental insights together with continuum modeling the molecule kinetics as well as Monte Carlo simulations for the electron dynamics will be integrated into a predictive 3D continuum rate model that governs both shape and composition.

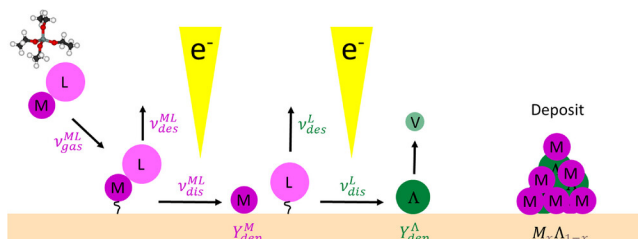


Figure 1. Schematic representation of the multi-step ligand co-deposition model [2].

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References

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