

3D nanoprinting with electrons: shape, composition and in-situ process analysis

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One of the most promising techniques for manufacturing three-dimensional nanostructures is focused electron beam induced deposition (FEBID) [1]. This method facilitates the focused beam of electrons from a standard scanning electron microscope (SEM) to locally dissociate molecules of a precursor physisorbed to the substrate. Some atoms of dissociated precursor chemisorb to the substrate creating nanoscale-sized deposit, while the other parts desorb and are removed from the vacuum chamber [1]. Although FEBID has been successfully applied to create nanostructures with very interesting magnetic, plasmonic or superconducting properties [1], more research is required to fully understand all surface processes happening during FEBID. In this contribution we present three complementary approaches to achieve this goal.

We will start with f3ast, the algorithm to translate a standard CAD file into a stream file understandable by the SEM to precisely control the path of the electron beam and thus to precisely control the shape of deposited structures [2]. We will discuss the continuum model, which laid foundation to f3ast and current limitations of the 3D printing process and proposed solutions.

Secondly, we will present the extension of the FEBID continuum model, which accounts for co-deposition of ligands alongside metal atoms during growth of the deposit [3]. The basics of this model and its possible application to predict shape and composition of the FEBID deposits will be discussed.

Finally, we will discuss focused electron beam induced mass spectrometry (FEBiMS) [4], its foundations and limitations and its applicability to understand surface phenomena observed during FEBID. Results of FEBiMS will be confronted with results of standard gas and condensed phase measurements.

We will show, how by combining several methods together with modeling can lead FEBID further as a method of 3D printing of functional nanostructures.

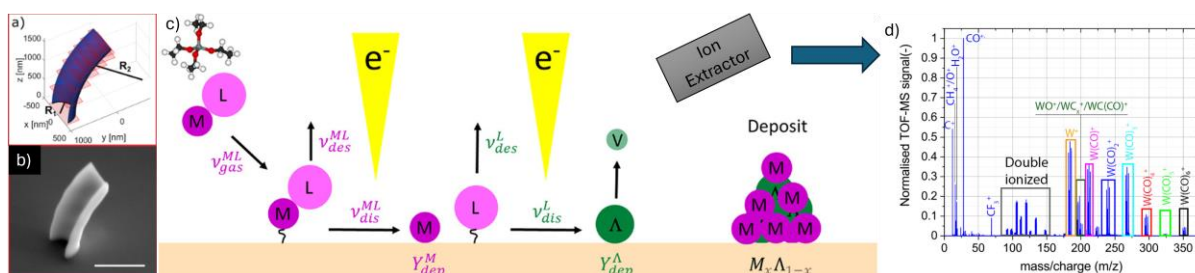


Figure 1. a) CAD model of a structure sliced by f3ast, which was later deposited using created stream file; b) SEM image of the structure deposited from the file presented in a); c) schematic representation of the modeling co-deposition process using extended continuum model; d) mass spectrum of the volatile fragments recorded during FEBID process. Figure adapted from [2], [3], [4] from left to right.

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