Focused Electron Beam Induced Deposition (FEBID) is a versatile direct write tool for the fabrication of functional (3D) nanostructures. FEBID uses gaseous precursor which adsorb and diffuse on the surface where they get locally decomposed by a finely focused electron beam. Although many different application concepts have been demonstrated, final applicability depends strongly on predictable morphologies and defined deposit chemistries. Both demands require locally constant precursor coverage which leads to constant ratios between available precursor molecules and potentially dissociation electrons species which is denoted as working regime. What seems to be straightforward turns out to be very complicated when dimensions approaches the nanoscale where local working regimes are influenced by a number of variables like directional gas flux effects, deposit related barriers hindering ideal diffusion or geometrical shadowing effects, comprehensively discussed in this contribution. As starting point it will be demonstrated how patterning directions relates to the directional gas flux, caused by the geometrical arrangement of the gas injection system. It is found that volume growth rates (VGR) can vary by more than 50 % for different patterning orientations which significantly complicates the predictable deposit volumes (Fig. 2). Furthermore, it is shown how the chemistry changes along with the VGR which has strong implications on final functionalities. To demonstrate these effects in a comprehensive way, a new patterning strategy is introduced which visualize morphological and chemical effects within one deposit. Based on these experiments a model is derived which fully explains the observations taking directional adsorption, surface diffusion and local replenishment effects into account as well. The experiments are complemented by finite difference simulations and numeric calculations in well agreement and support the proposed dynamic model of laterally varying working regimes. In order to investigate the tunability of the regime situation, the accessible process parameters during deposition are systematically varied. It is demonstrated how constant working regimes can be established (Fig. 1) which provide both, predictable morphologies and laterally constant chemistries as indispensably required for potential applications. In summary the study demonstrates the nanoscale implications of molecular gas and surface dynamics on final deposit volumes and chemistries. Furthermore, it is also shown how stable conditions can be achieved by a careful setup of the deposition process which is essential for further steps toward industry related FEBID application.

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Fig. 1: 3D AFM height images of FEBID structures fabricated with spiral out patterning strategy and constant electron doses. Unbalanced process parameters (1 ms dwell times) lead to disruption of the morphology (a) in contrast to balanced conditions b) (100 µs dwell times) as effect of indicated directional gas flux component.

unbalanced conditions  

balanced conditions

Fig. 2: lateral variations of segment heights (red) and chemistry by means of C / Pt ratios (blue) for a disrupted deposit (Fig. 1a). Each patterning point has been patterned only once which demonstrates the strong implications of the directional gas flux effects.