Experimental evaluation of gas-flux distribution with gas injection systems for focused beam induced deposition

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Focused electron beam and focused ion beam induced processing have gained interest as powerful methods for three-dimensional maskless fabrication at nanometer scale. A number of complex structured device prototypes could be created and characterized in the last decade [1]. The principle of this technique is based on the locally confined decomposition of a precursor molecule with a focused particle beam. Conventionally the precursor is delivered through a nozzle based gas injection system (GIS). Despite of recently published detailed results on monte-carlo simulation for gas-flux distributions [2] the influence on the focused beam induced deposition method is still inexplicit. The typically used gas injection systems are often inefficiently constructed and applied due to little knowledge of the influence of the gas-flux distribution on the deposition process. The precursor adsorption, desorption and diffusion on the substrate surface is discussed to be decisive for the growth rate of the depositions. Therefore a better knowledge of the precursor density at the region of interest for deposition is crucial for further successful development of this method.

In this presentation we illustrate an experimental approach to ascertain the gas-flux distribution. A scanning electron microscope LEO 1530 VP was equipped with a separately pumped residual gas analyzer (RGA). The gas was injected into the system vacuum chamber through a custom tailored GIS. A second nozzle covered with a thin orifice was vertically mounted at the specimen position on the x,y,z,r-stage of the microscope (Fig. 1). This nozzle was directly connected to the RGA and was used to extract the part of the gas-flux which directly hits the aperture. The extractor nozzle position relative to the injector nozzle was controlled via LabView program. Through the GIS nozzle a constant flow of the inert and nonpolar gas argon controlled with a mass flow controller was injected into the system vacuum chamber. By acquiring the stage position and the corresponding partial pressure of argon a detailed distribution of the gas-flux impinging on the surface could be recorded (Fig. 2). With this new experimental setup the gas-flux distribution could be measured directly at the position of the specimen with a very high resolution (Fig. 3). Surface reactions and surface diffusion do not affect the measurement since only directly impinging molecules will be detected with the RGA. Furthermore this method enables the determination of gas-flux distributions for all different nozzle designs and for different flow conditions.

In order to investigate the relevance of the knowledge of the gas-flux distribution for the focused beam induced processes a deposition experiment with iron-pentacarbonyl as precursor was performed. For this experiment the injection nozzle was mounted on the x,y,z,r-stage of the SEM under the same angle as in the gas-flux distribution measurement. With FEBID an array of cubic structures was deposited on equidistant positions. The volume of each individual deposition was determined by AFM measurements. With the evaluated data a position dependent correlation between deposition rate and available precursor could be found. The RGA system was calibrated for the argon flow with a precursor type independent capacitive pressure gauge attached to the supply line. With the comparison of the RGA signal of the calibration curve and the measured values from the gas-flux distribution it is possible to approximate the number of molecules per second impinging the surface at very specific position of interest for deposition. This quantitative analysis will provide the desired input parameters for simulation of the deposition process. The limits in interpretation of the data will be discussed.

[1] Utke, I., Hoffmann, P., Melngailis, J., Gas-assisted focused electron beam and ion beam processing and fabrication, 2008 *Journal of Vacuum Science and Technology B: Microelectronics and Nanometer Structures* 26 (4), pp. 1197-1276
[2] Friedli, V., Utke, I. Optimized molecule supply from nozzle-based gas injection systems for focused electron- and ion-beam induced deposition and etching: simulation and experiment, 2009, *Journal of Physics D: Applied Physics* 42 (12), art. no. 125305

Fig.1. GIS injection nozzle and vertically mounted extractor nozzle in the system vacuum chamber of the scanning electron microscope

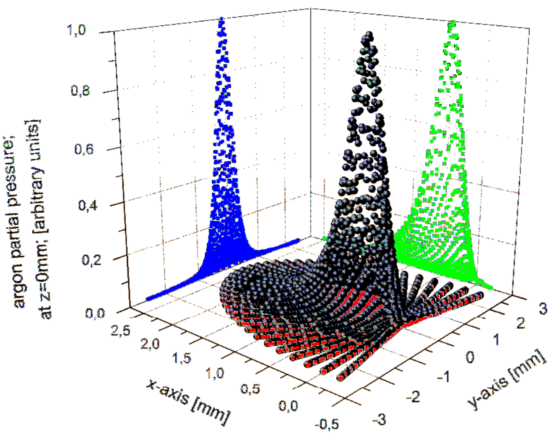

Fig.2. Recorded gas-flux distribution. Each dot is a position dependent measurement of the argon partial pressure, normalized to the maximum.

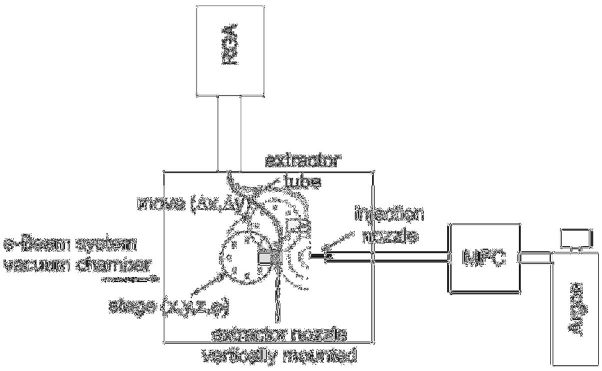

Fig.3. Experimental setup