Controlling Chemistry, Structure and Volume Growth Rate via Process Parameters of Electron Beam Induced Deposition

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Ion beam induced deposition (IBID) of conducting (W, Pt, …) or insulating (TEOS, …) materials from a gaseous pre-cursor has become an essential part of focused ion beam related processes such as transmission electron microscope (TEM) related lamella preparation, device modification or the fabrication of 3D nanostructures. The use of IBID on critical samples such as nanoscale devices or soft matter specimens, however, can cause significant problems due to sputter contributions, unwanted ion implantation or considerable thermal stress. A way to reduce such side effects to a minimum is the use of electron beam induced deposition (EBID) instead of IBID which attracts more and more attention. Compared to IBID, however, electron assisted deposition processes show two major drawbacks: *i)* a low deposition rate which makes EBID time consuming and partly inefficient for high-throughput applications; and *ii)* a much higher carbon content of the deposits which influences the intended functionality. To compensate for these drawbacks and push EBID processes towards its intrinsic limits it is necessary to improve the fundamental understanding of the growth processes which is part of this study. In particular, the influence of EBID process parameters on chemical composition, structural details and volume growth rates is experimentally investigated.

As a starting point, the temporal evolution of the volume growth rate for free standing Pt nano-rods is studied, which gives insight in the formation process, and reveals the strong dependency on the precursor diffusion. These pre-investigations allow then for the selection of a defined precursor regime which is the basis for all further comparisons. In the following the influence of electron energy, beam current, dwell time, refresh time, and beam defocus on the final deposits is investigated by electron energy loss spectroscopy, high-resolution TEM, scanning electron microscopy and electrostatic force microscopy. The investigations show clearly how the preparation parameters can be tuned to maximize the volume growth rate and how strong the carbon content of the deposits is changed. Figure 1 shows a TEM image revealing a varying carbon content along the nano-rod by changing the process parameters during deposition. The correlation with the volume growth rates reveals that minimum carbon contents are achieved neither at maximum nor at minimum deposition rates but somewhere in between. Figure 2 shows the volume growth rate (squares) and Pt / C ratios (triangles) in dependence on the refresh time between subsequent electron pulses.

Beside the practical aspect of this work a comprehensive model is presented which explains the observations and indicates furthermore the importance of the pre-cursor dynamics on the surface.

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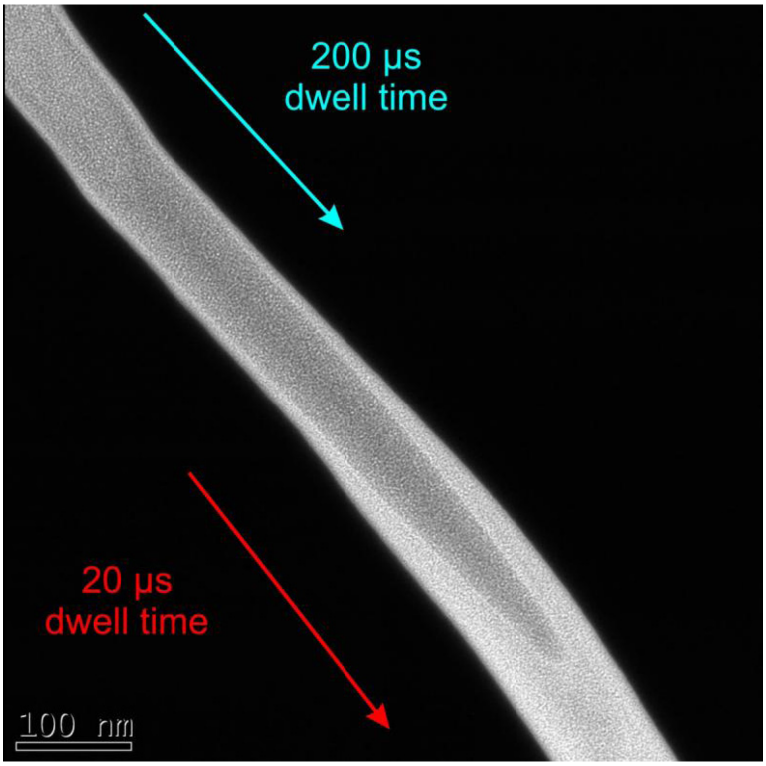

Figure 1. TEM image of a Pt nano-rod with varying dwell times during deposition. The 200 µs part (darker areas) shows a higher Pt content compared to shorter dwell times of 20 µs.

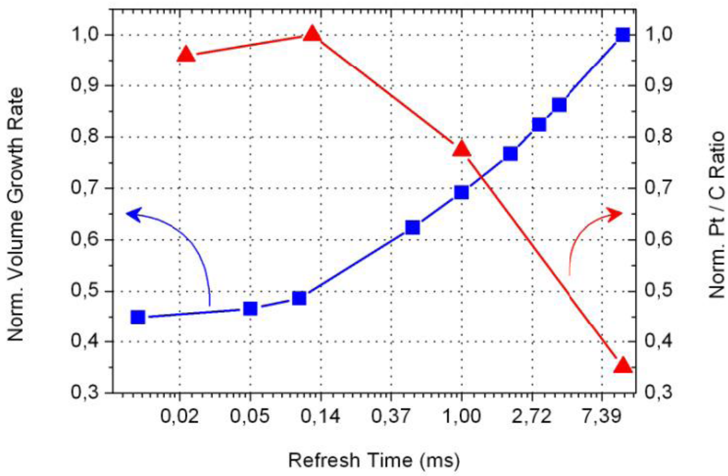

Figure 2. Comparison of volume growth rates (squares) and Pt / C ratios (triangles) in dependence on the refresh time during deposition. It can be seen that an increasing volume growth rate entails a higher carbon content.

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