Direct-write Deposition of Pure Gold Nanostructures – New Possibilities and New Challenges

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In this review we report on the focused electron beam deposition of practically pure gold nanostructures by in-situ purification during the deposition and post-deposition purification of carbon-contaminated gold.
Beam-induced deposition with a focused electron beam is currently experiencing increasing attention, as it is a maskless direct-write method. With its capability to fabricate true 3-dimensional structures in the nanometer-regime FEBID stands out among other direct-write methods. Only recently [1] the direct-write synthesis of free-standing 3D nanostructures has been demonstrated by FEBID.
Especially the FEBID of pure gold nanostructures is heavily desired, as gold assumes a special status due to its optical dielectric function [2]. Gold nanostructures are often used as model systems to study electronic excitations resulting from interaction with light. Gold is often used in optoelectronic and nano-optical devices, and plasmonic structures [3].
Up to now it has been an unsolved difficulty to deposit pure gold by FEBID. Only with a carbon-free gold precursor suffering from a low stability the FEBID of pure gold has been achieved. In practice almost exclusively metalorganic gold precursors such as $(CH_3)_3Au(tfac)$ are used. Post-deposition cleaning of noble metals has already been successfully shown for Pt [5], but also for FEBID Au from metalorganic precursors purification approaches have been developed [6].
In this work we present and compare different purification procedures for FEBID gold. A Zeiss Leo 1530 VP with an 3 kV electron beam (4 nA) was used to deposit gold nanostructures from $(CH_3)_3Au(tfac)$. While pristine deposits show a gold content in the 30 at% range, the gold content can be increased by electron-induced annealing or by plasma ashing after deposition. By using an additional oxidative booster (Fig. 1) we have achieved the deposition of pure gold structures in-situ during FEBIP. The purity was found to depend on the flux of the oxidative booster (Fig. 2). The effect of different process parameters on the gold purity will be presented. A line EDX-spectrum trough the cross-section of the deposit proves, that the high gold purity is not only achieved on the top surface layer but the entire deposit over its entire thickness consists of high-purity gold.
We will shine some light on this direct-write deposition mechanism and draw conclusions for other precursor systems. Finally, we will discuss potential applications in nanophotonics and biosensing.

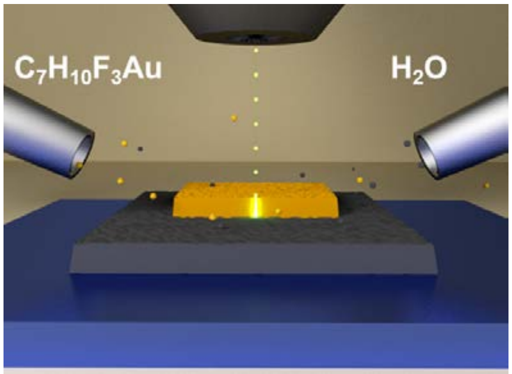

Fig. 1 Principle of oxidative assisted FEBID of Au nanostructures

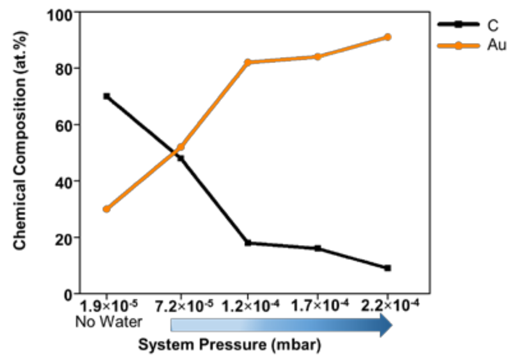

Fig. 2. Effect of the concentration of the oxidative booster on the purity of the deposit

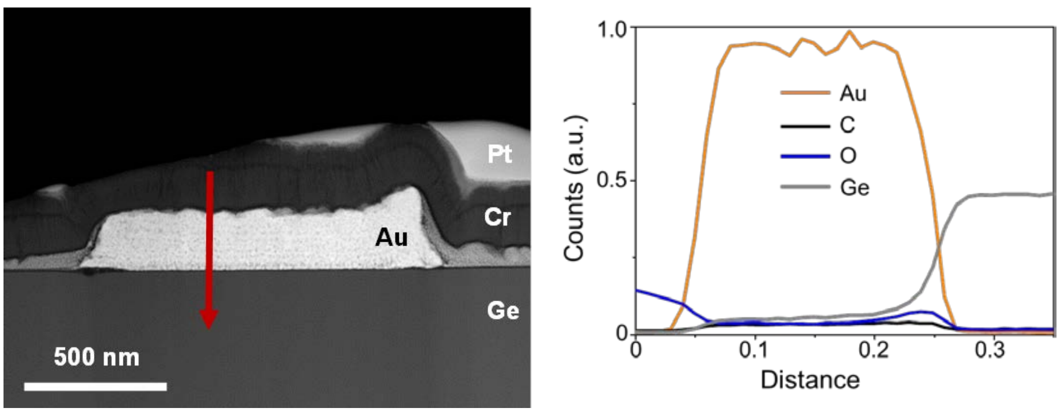

Fig. 3. Image of the cross-section through a FEBID-Au deposit and an EDX line scan depicting a homogenous high gold purity over the entire thickness of the deposit.

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