Focused Electron Beam Induced Surface Activation: A Novel Lithographic Method to Fabricate Nanostructures

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Focused electron beams with sizes in the nanometer regime appear as ideal tools to fabricate or manipulate nanostructures. Indeed focused electron beam induced processing (FEBIP) was intensively explored and developed in the last decade. An important maskless fabrication technique in this regard is the electron beam induced deposition (EBID), which was the starting point of our investigations. In EBID a focused electron beam is used to locally decompose adsorbed precursor molecules, with the resulting non-volatile dissociation products forming a deposit[1, 2]. With our specific "surface science approach" it was possible to overcome hitherto existing limitations concerning the purity of such EBID deposits, i.e., we produced clean Fe nanostructures from $Fe(CO)_5$ on Si(001) [3] and Rh(110) [4] under UHV conditions. Our recent results presented here considerably expand the FEBIP concept: if a focused electron beam is used to locally irradiate a 300 nm thin commercial SiO_x layer [5] or an ultra thin (few nm) SiO_x layer on Si(100) without offering any precursor gas, the exposed areas can later be ''developed'' by dosing $Fe(CO)_5$ at room temperature. The resulting formation of pure Fe deposits is attributed to the decomposition of $Fe(CO)_5$ at surface areas, which are "activated" by electron preirradiation and is enhanced by autocatalytic growth of iron in the presence of $Fe(CO)_5$ [4, 5] (Fig. 1, 2). The catalytic activation could be identified as being due to local electron induced desorption of oxygen and SiO is proposed as the active species. The described novel two step process is referred to as focused electron beam induced activation (FEBIA). Very recently our findings were generalized by the verification that FEBIA also works on other substrates like TiO_2 and (oxidized) ultrathin Si_3N_4 membranes (Fig. 2 f). In comparison to the original EBID protocol, the FEBIA process has the particular advantage that effects caused by scattered electrons can be effectively minimized and thus smaller and better defined structures can be targeted. From a more general point of view, the here reported local chemical modification of a substrate might be the starting point for a whole new way to fabricate nanostructures.

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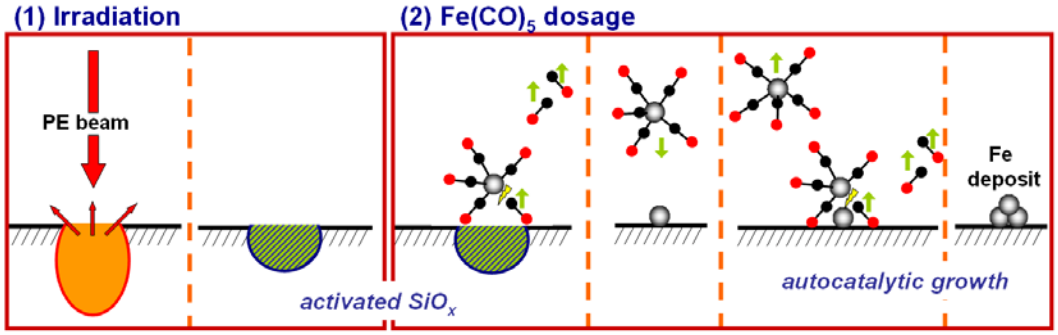

Figure 1: *Scheme of the FEBIA Process:* (1) Local activation of the SiO_x substrate by irradiation with an electron beam. (2) Formation of clean iron deposits upon dosage of the precursor $Fe(CO)_5$. First the precursor molecule is catalytically decomposed at the activated/predefined position and continues to grow autocatalytically as long as the precursor is supplied.

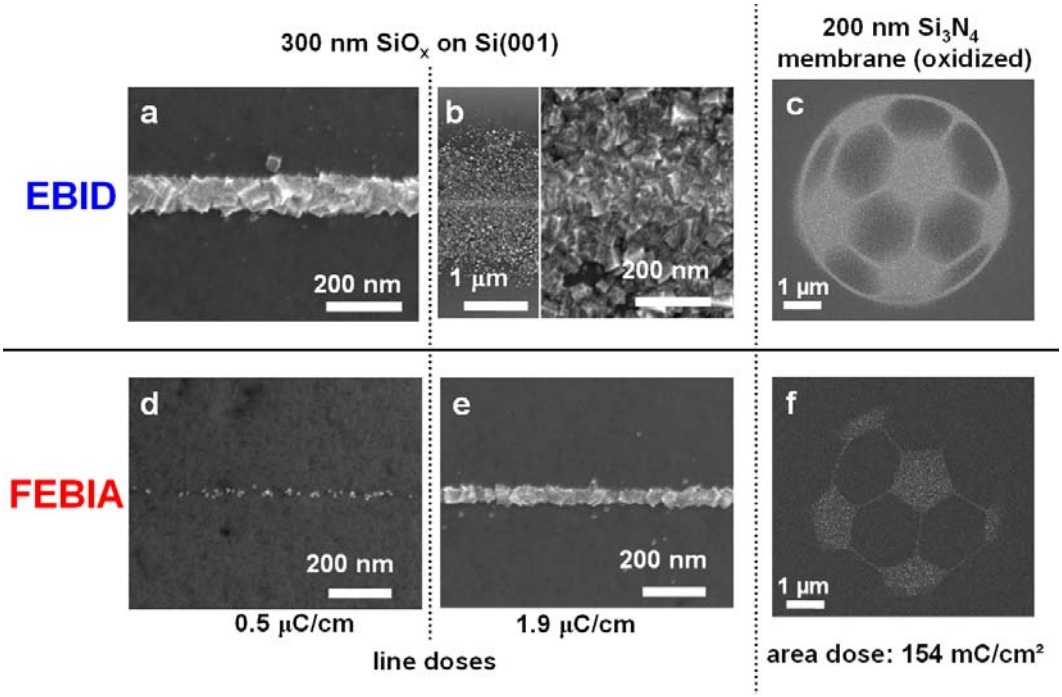

Figure 2: *Comparison of EBID and FEBIP:*SEM micrographs of different clean iron deposits via EBID (upper row) and FEBIA (bottom row) with the precursor $Fe(CO)_5$ on two different substrates. Dosage time of $Fe(CO)_5$ with a background pressure of 3 10^{-7} mbar after electron irradiation was 157 minutes for the "football" in Figure 2 (c) and 270 minutes for all other structures shown here. The electron doses applied are identical in each column as indicated.