Removing halos around IBID deposits with a broad ion beam

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Electron and ion beam beam induced deposition (E/IBID) are two flexible fabrication techniques for making unique three-dimensional objects with features sizes down to 10 nm on substrates. The technique is based on the local decomposition of adsorbed precursor molecules with a focused electron or ion beam (FEB or FIB). Movements of the focused particle beam determine the shape of the growing object. In general, not the primary beam particles, but secondary electrons (SEs) cause precursor decomposition. These SEs are generated by the primary beam when it traverses the FEB/FIB vacuum chamber and, after impact, the substrate. The precursor decomposition rate is highest at the point of impact of the focused beam on the surface of the substrate. However, the generated secondary electrons travel some distance away from the impact point and can, hence, decompose precursor molecules at other places as well. Moreover, some primary beam particles are scattered by gas molecules in the vacuum chamber and reach the substrate elsewhere. Consequently, during E/IBID delocalized deposition takes place around the actual object, up to a distance of 100 μm, see Fig. 1. The delocalized ghost deposition causes a thin halo around the deposited object. If *e.g.* metal leads are made by E/IBID, the halo can cause leakage currents.

Surfaces of materials can be cleaned by bombardment with a broad beam of low-energy ions. Recently, Mulders *et al.* developed a so-called Beam Induced Polishing and Sputtering (BIPS) system for use in scanning electron microscopes (SEM) [1]. Through a hollow needle, argon gas is delivered into the vacuum chamber, close to the beam impact point on the substrate. At the end opening of the needle, there is a slot, via which one can direct the FEB into the argon flow. Consequently, argon atoms are being ionized. A voltage difference between the needle and the substrate of typically 200 V accelerates the ions towards to substrate and, hence, the impacting 200 eV Ar^+ ions polish the substrate's surface by ion sputtering.

In this study we investigate the capability of a BIPS system to remove IBID halos. PtC stripes and rings (Fig. 2a) were made via decomposition of $CH_3C_PPt(CH_3)_3$. Next, the amounts of Pt and C between the stripes and in the center of the rings were measured by EDX before and after sputter polishing, see Fig. 2b. Also two PtC contacts were made on insulating SiO_2 at separations of tens of micrometers. The electrical conduction through the halo between the contacts was measured as a function of the polishing (Ga^+) ion dose. In addition, the shape changes of IBID objects during polishing with either a Ga or an Ar beam have been studied, see Fig. 3.

It is concluded that halos can be removed effectively by broad beam sputtering, but that the actual IBID structures get easily damaged in the process. In order to minimize damage, the polishing dose needs to be kept as low as possible.

[1] D. van Leuken, Master Thesis, Eindhoven University of Technology, 2017.

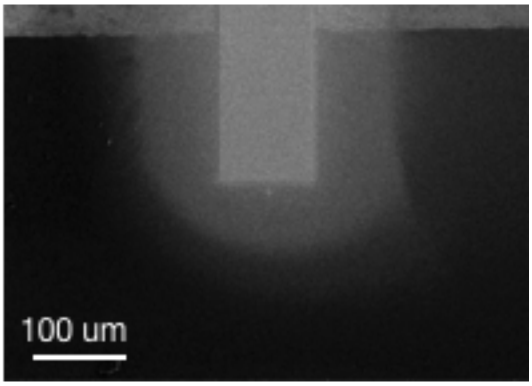

Figure 1. Pt IBID contact with a halo. (Top view SIM image.)

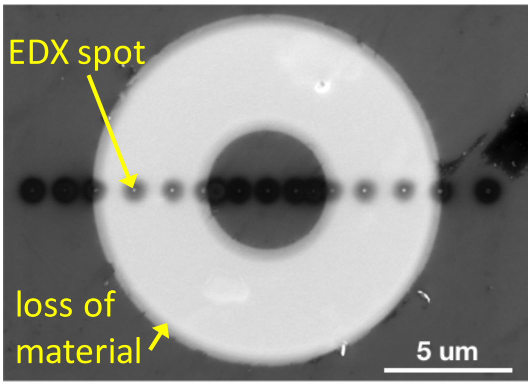

Figure 2a. PtC IBID ring, after 200 eV Ar^+ polishing in BIPS and subsequent EDX line analysis. The originally sharp edges were damaged by the Ar^+ bombardment; they became blunt. The dark spots are the sites of the EDX analysis.

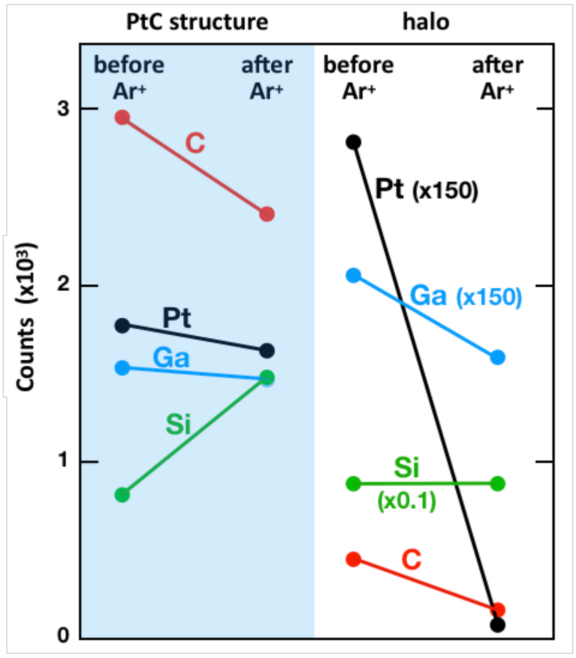

Figure 2b. The changes in EDX signals for Pt, Ga, Si and C by Ar polishing. The left half refers to the PtC deposit, the right half to the halo.

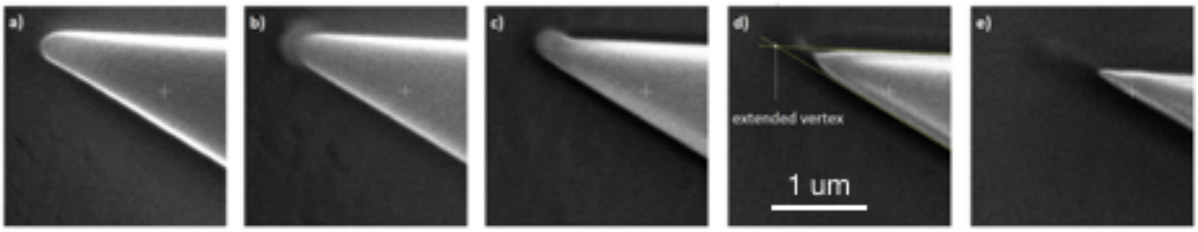

Figure 3. Top view SIM images of the disappearance of a sharp 200-nm high IBID structure by exposure to a broad Ga^{+} beam. From a) to e), the ion dose increases from 0 to 240 pC/um^2.