Investigation of morphological changes in platinum nano-structures created by focused electron-beam-induced deposition

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Electron-beam-induced deposition[1] (EBID) allows the rapid fabrication of three-dimensional nano-devices and metallic wiring of nano-structures within a scanning electron microscope (SEM). The deposited material depends on the precursor chosen; the decomposition of the gaseous precursor is caused by the interaction of an electron beam with a solid substrate. Typical applications of EBID include contacting carbon nano-tubes[2], growing tips for field emission[3] and for magnetic force microscopy[4].

Deposited structures often contain undesirable contaminants such as carbon or oxygen as a result of species present in the precursor or from deposition conditions. We have observed that additionally, exposure to air results in platinum nano-structures deposited from methylcyclopentadienyl-platinum-trimethyl undergoing an ageing process, deteriorating the resistivity. This has not been reported in the literature to date. In our 55-day study, the structures' resistivities have changed from 2×10^5 μΩ.cm to 1.8×10^8 μΩ.cm. We describe how to prevent this oxidation process.

To mitigate the inclusion of carbon in deposits, a new carbon-free precursor, tetrakis trifluorophosphine platinum can be used, and the first reports have recently appeared in the literature[5]. We present the first transmission electron microscope images of nano-structures deposited from this material; clustering of phosphor is observed. The size and amount of these clusters depend on the thickness of the structure.

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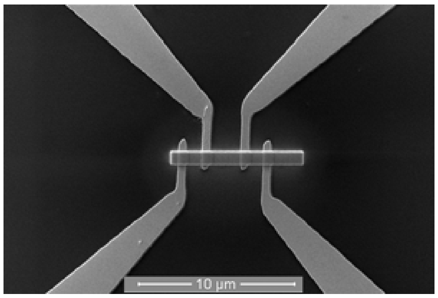

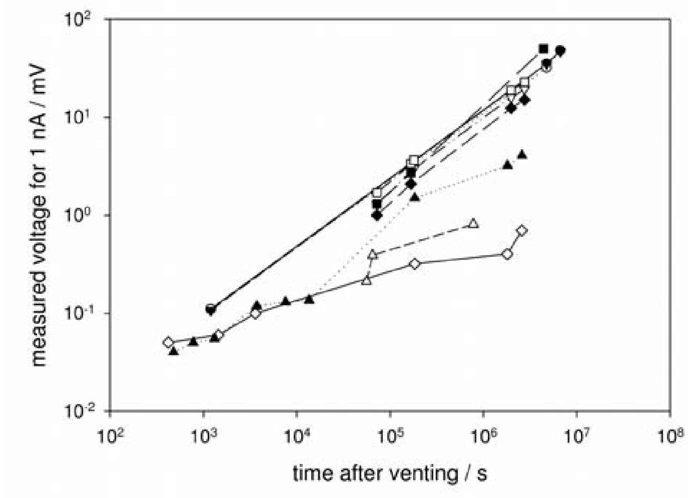

Figure 1: (left) SEM image of typical EBID-deposited structure across four gold electrodes on Si_3N_4 for four-point-probe resistivity characterization. (right) The measured voltage drop across the EBID-deposited structure for 1 nA (hence a measure of resistivity) is shown as a function of time after the structures are exposed to air.

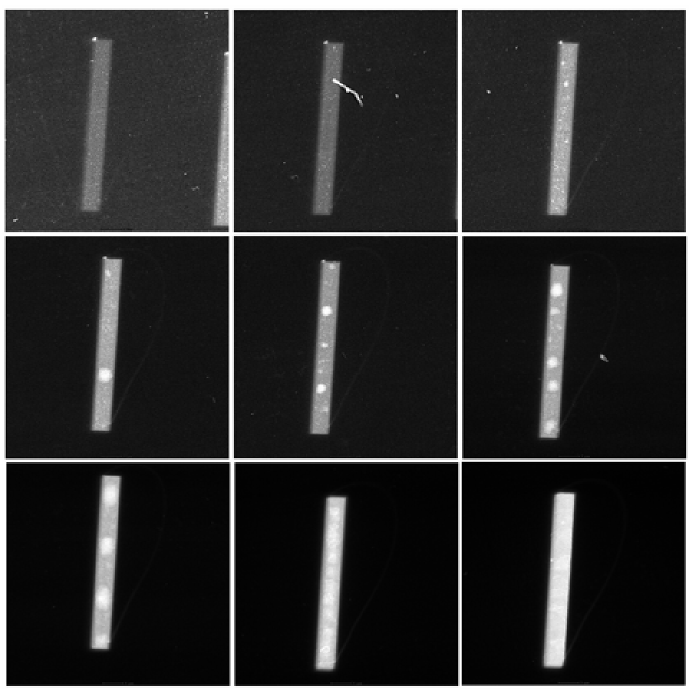

Figure 2: STEM-HAADF images of nine different deposits, with increasing thickness (deposition time). The presence of whiter areas can be seen whose number and size increase with deposit thickness. Electron energy loss spectroscopy mapping reveals these clusters are predominantly phosphor.