Focused Electron Beam Induced Deposition of Nickel for nano-sensing applications

A. Perentes, G. Sinicco, G. Boero*, P. Hoffmann
Institute of Applied Optics
* Institute of Microelectronics and Microsystems
Swiss Federal Institute of Technology (EPFL), Station 17
CH – 1015 Lausanne

Focused Electron Beam Induced Deposition (FEBID) is one of the ultimate techniques for maskless rapid prototyping of nano-devices. FEBID of uncontaminated materials remains a challenge and would drastically increase the number of applications. The use of carbon free precursors [1] or addition of reactive gases (assisting the deposition) [2] resulted in the deposition of Au, SiO_2, Co, Rh and Pt of reasonable quality. Nickel, as one of the few magnetic elements and known catalyst for carbon nanotube growth, has not been studied extensively.
With the intention of producing a nanoscaled magnetic sensor [3], we studied the FEBID of conductive Nickel containing deposits from two different precursors: bis(methylcyclopentadienyl)nickel(II) $[Ni(C_5H_4CH_3)_2]$ and tetrakis(trifluorophosphine) nickel $[Ni(PF_3)_4]$. In addition, the effects of the simultaneous injection of reactive gases (oxygen and hydrogen) on the FEBID material chemical composition and electrical conductivity were studied and are reported (see figure 1) and discussed.

The highest deposited nickel content was obtained with the fluorinated precursor, resulting in a FEBID material chemical composition of Ni_4CO_2PF, compared to the $NiO_{0.5}C_{7.5}$ obtained by the decomposition of the carbon containing precursor. For both precursors, the injection of molecular oxygen in the SEM chamber during the FEBID process resulted in the incorporation of oxygen and production of nickel oxide in the deposited material, resulting in the following chemical compositions NiOCPF and $NiO_3C_{3.5}$, for the fluorinated and the carbon containing precursor respectively. Surprisingly, gaseous Hydrogen did not improve the nickel content of the FEBID materials.

The electrical conductivities of the obtained materials were determined (see table 1), and the Ni_4CO_2PF material presented the lowest resistivity of approximately 10^3 $\mu\Omega$cm (100 times larger than metallic nickel), which is reasonable for FEBID materials [1]. The nano-sensor is actually in production and its performance will be presented.

[1] Utke I et al., JVSTB 18 (6), pp. 3168, 2000
[2] Perentes A et al. Accepted for publication in CVD
[3] Boero G et al., APL 86 (4), 042503

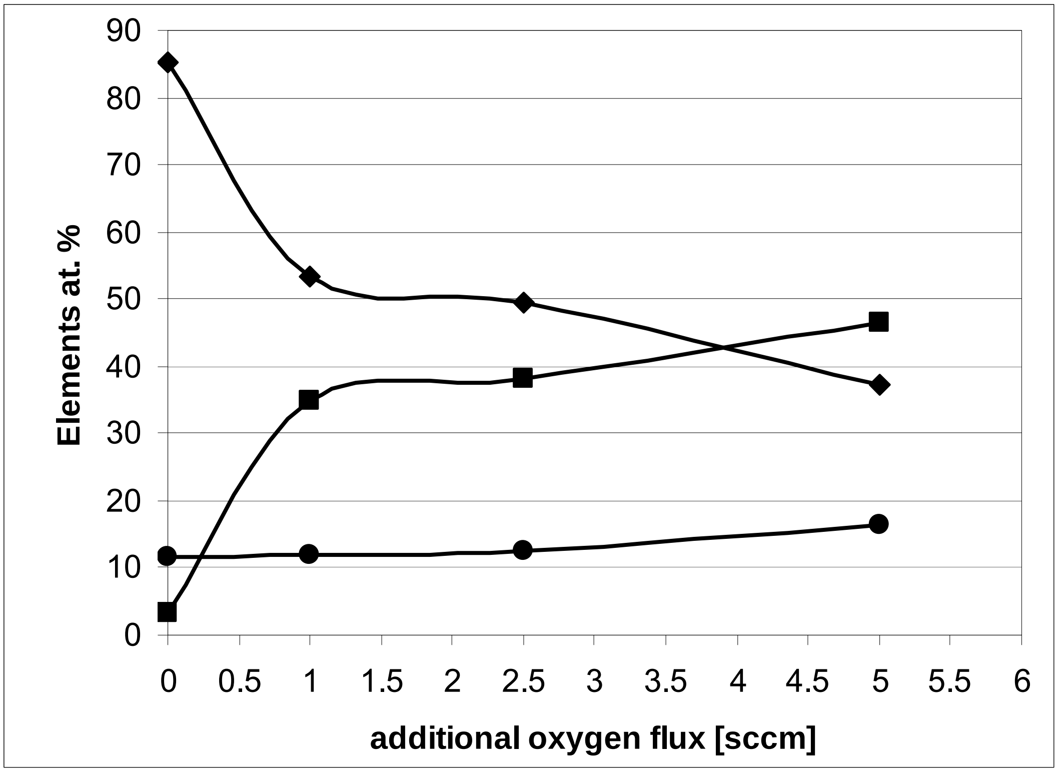

Figure 1: FEBID material chemical composition obtained from the carbon containing precursor, as function of the additional oxygen injected simultaneously. Carbon (lozenge symbols), Oxygen (square symbols) and Nickel (round symbols). Chemical composition obtained by electron dispersive x-Ray spectroscopy.

Precursor	Additional Oxygen	Deposited material	Electrical conductivity [μΩcm]
$Ni(C_5H_4CH_3)_2$	No	$NiO_{0.5}C_{7.5}$	$\approx 1.8 \cdot 10^6$
$Ni(C_5H_4CH_3)_2$	Yes	$NiO_3C_{3.5}$	$> 10^{10}$
$Ni(PF_3)_4$	No	Ni_4CO_2PF	$< 10^3$

Table 1: Electrical conductivities of the different deposited lines as function of their chemical composition