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Micromolding of NiFe and Ni thick films for 3D integration of MEMS

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3D integration of microsystems requiring stacking of patterns involves the control of adhesion, stress and thickness uniformity. CMP is generally used for planarization, but this method induces itself stress and surface oxidation, which is particularly critical for magnetic materials. In addition, thick films can only be deposited using electrodeposition and many process steps can lead to a lack of adhesion of the film on the seed layer. The present work reports a method for obtaining uniformly thick magnetic films dedicated to the fabrication of magnetic microsensors and actuators.
Ni and NiFe films have been deposited on a Cu/Ti seed layer sputtered on SiO_2/Si (for NiFe) and glass (for Ni). The molds were realized using AZ4562 photoresist. The electrodeposition is made with a sulfate-chloride bath where samples are put in vertical position. The deposition rate, composition and magnetic properties have been characterized as a function of the current density using optical and mechanical profilometry, EDS characterization and AGFM measurement. A particular attention has been paid to thickness uniformity, stress and adhesion on the seed layer. Non-uniformities in thickness have been characterized at different scales: pattern and wafer.

Pattern which dimensions is 1 mm x 1 mm have been realized. The deposition rate and composition are presented in Fig 1 and 2. The values are reproducible with former works using the same bath but a different configuration of cathodes [1].

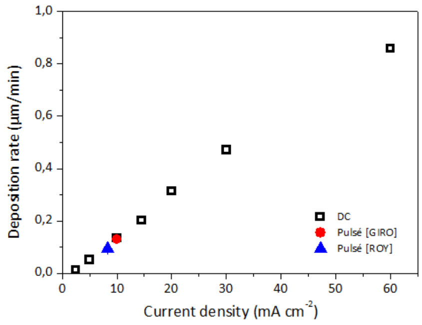

Fig 1: Pulsed and continuous (DC) current deposition rate

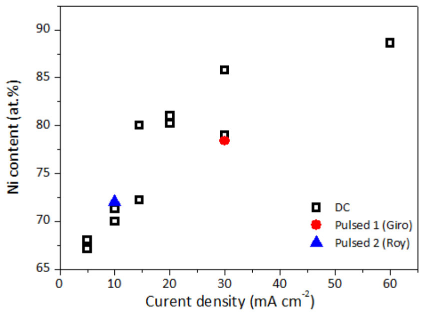

Fig 2: Pulsed and DC film composition

The deposition over a pattern is asymmetrical while DC current is used. This phenomenon has been reduced by using a positive/negative pulsed current which alternates deposition and etching [2, 3] (see Fig 3). However, overdeposition at the edge of the patterns, as well as non-uniformities over different patterns on the wafer was not ameliorated by this technique.

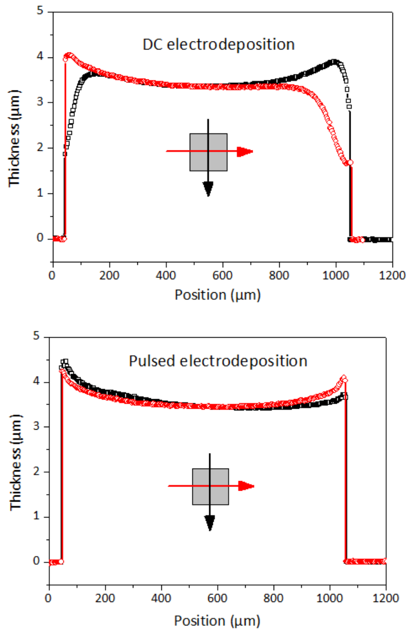

Fig. 3: Horizontal and vertical profiles of NiFe 1mm x 1mm patterns deposited using DC (20 mA/cm^2) and positive/negative pulsed current

Thickness non-uniformity over the wafer is in the range of 30% and is characterized by a higher deposition rate on the top. This result is expected to be linked to hydrogen generation leading to a vertical movement of the electrolyte. Horizontal positioning of the cathode did not give good results, as hydrogen bubbles were trapped at the surface, but the thickness variations were lowered to 5% in the vertical position by rotating 3 times the wafer a quarter turn.

EDS measurement and hysteresis loops of samples show that the pulsed current mode does not largely modify nor the composition nor the magnetic softness compared to DC current (see Fig 2 and 4). However, the global deposition rate (taking into account the dead times) is lowered by a factor 3.

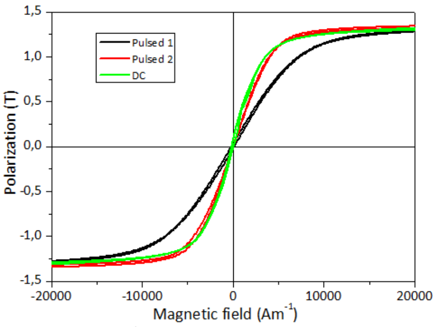

Fig. 4: Hysteresis loops of pulsed and DC electrodeposited NiFe films. Pulse 1 and 2 corresponds to current configuration in [2] and [3]

Technological steps following the films deposition (in particular annealing) have brought to the fore a lack of adhesion for NiFe containing large amount of Fe. This has been ameliorated by using a Au/Ti seed layer.

[1] J.-M. Quemper et al., Sens. Act. A, 74 Is. 1–3 (1999), 1-4
[2] F. Giro et al., Microsyst Technol vol. 14 (2008), 1111–1115
[3] S. Roy et al., Journal of Magnetism and Magnetic Materials vol. 290–291 (2005), 1524–1527