NICKEL NANOWIRE ARRAYS BASED ON IMPRINT LITHOGRAPHY

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In recent years nanomagnet arrays have attracted a lot of scientific interest due to their potential application for perpendicular patterned magnetic media. Using interference lithography C.A. Ross et al. [1] has obtained large scale arrays of nickel columns, which have an aspect ratio of up to 2.5 (column length/diameter). Self-ordered porous alumina is very suitable template for the fabrication of nanomagnet arrays, in order to achieve magnetic columns with large aspect ratios (>10). Up to now these magnetic arrays exhibits a so-called 2D polycrystalline arrangement of the nanowires and have a deviation of the nanowire diameter of about 10% or even more. In this paper, the fabrication of Ni nanowire arrays based on imprint lithography will be presented, which show a perfect hexagonal arrangement on a cm^2-scale. Additionally, we will analyze the influence of the ordering degree of the Ni nanowire arrays on its magnetic properties, i.e. coercivity and squareness.

For the sample preparation, polished Al substrates were patterned by an imprint mold developed [2] in house and consisting of a hexagonal arrays of Si_3N_4 pyramids with 500 nm-pitch (Fig. 1**(a)**). The imprinted etch pits on the Al surface act as initial sides for the pore formation (**b**). The prestructured Al surface was anodized with 1 wt.% phosphoric acid at 195 V for 75 min and an alumina templates (**c**) with a perfect hexagonal arrangement for the pore channels on a cm^2-scale was obtained. Subsequently, the thickness of the barrier layer at the pore bottom was thinned (**d**) from about 250 down to less than 7 nm, which results also resulted to the formation of small dendrite pore at the pore bottom. Nickel was directly plated onto the nearly insulating barrier by current pulses (**e**) and nearly 100% pore filling was obtained. Subsequently, Si substrates were fixed on top of the area **(f)**, the Al substrate was selectively removed by chemical etching and the sample was turned upside down **(g).** Finally, the

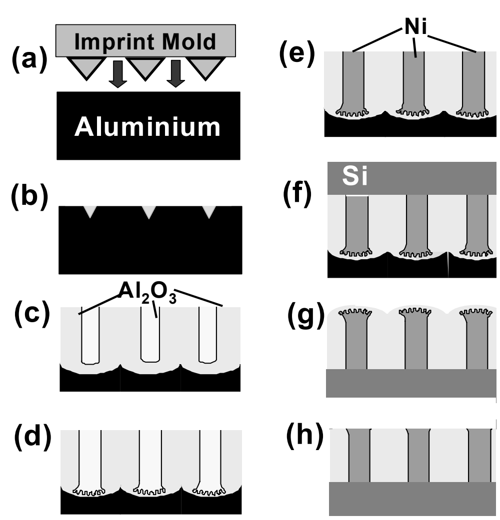

Fig. 1: Preparation steps for fabrication nickel nanowire arrays embedded in an alumina matrix and fixed to a Si substrate via imprint lithography.

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barrier layer and the dendrite part of the nanowires were removed by sputtering with a focused ion beam **(h),** in order to reduce the stray field interactions between the nanowires.

Scanning electron micrographs (**Fig. 2(a)**) of the nanowire structures revealed a wire length of about ~4 µm, column spacing of 500 nm, and column diameter of 180 nm with a deviation of less than 2%. In comparison, **Fig. 2(b)** shows a Nickel nanowire arrays with 2D-poly-crystalline arrangement of the nanowires. Instead of imprint lithography, a two step anodisation process based on the Masuda approach [3] was used. This nanowire array has a short range ordering and a larger deviation of the nanowire diameter (~12%). Nevertheless, both samples were fabricated under the same electrochemical conditions.

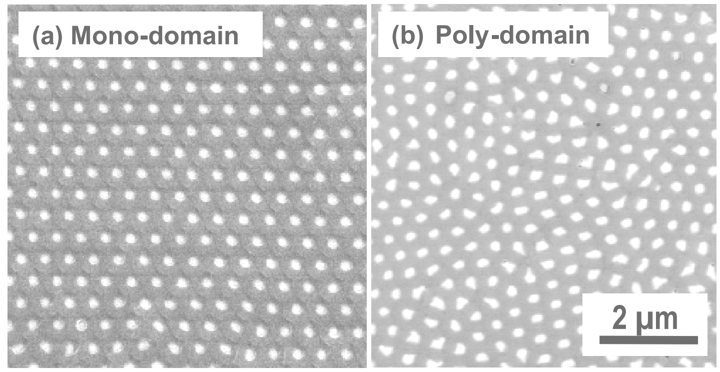

Fig 2: Nickel filled alumina templates fabricated via imprint lithography **(a)** and via self-ordering **(b)**.

The hysteresis loops were measured for both samples in the direction of the nanowire axis. In the case the nanowire have a monodisperse pore diameter and the nanowire are arranged monocrystalline, a coercive fields of 250 Oe and a squareness of 0.42 was detect. Due to larger dipolar interaction in the nanowire array, based on the larger deviation of the nanowire diameter and the higher disorder of the magnetic array, the second sample exhibits a reduced coercivity of 160 Oe and a squareness of 0.3. Additionally, results of the effect of ordering on the magneto-optical properties will be presented. As an example, the polar Kerr rotation spectra of both samples are presented in Fig. **3(a)**. Micromagnetic simulations (**Fig. 3(b)**) for a single Ni nanowire with a diameter of 180 nm and a length of 1 µm reveals a vortex-like magnetization pattern at the nanowire extremities, whereas almost the complete magnetization of the nanowire is aligned along the column axis. In contrast to our earlier results on Ni nanowire with a diameter between 25 and 55 nm [4], the single Ni nanowire with 180 nm diameter do not exhibit a box-like magnetization loop and has a reduced squareness of 0.79. Finally, we will analyze the switching field distribution of these 500 nm-period Ni nanowire arrays.

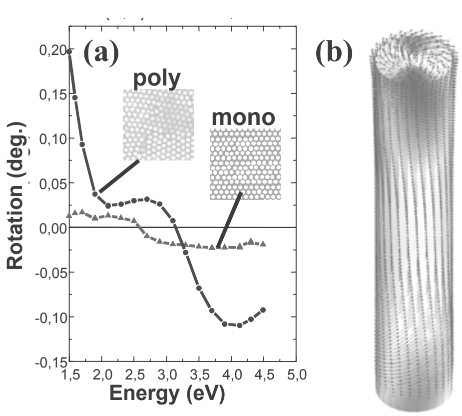

Fig. 3: (a) Magneto-optical spectra of 500 nm-period Ni nanowire array with 2D-poly- and monocrystalline arrangement in two dimensions. **(b)** Micromagnetic simulation of the magnetization for a single Ni nanowire with a diameter of 180 nm and a length of 5 µm.

References

[1] C.A. Ross et al., *J. Vac. Sci. Technol.* **B17**, 3168, 1999.

[2] J. Choi et al., *MRS Symp. Proceedings (2002),* pp. (2002).

[3] H. Masuda and K. Fukuda, *Science* **268**, 1466, 1995.

[4] K. Nielsch et al., *Appl. Phys. Lett.* **79**, 1360 (2002) & *IEEE Trans Mag.* **38**, in press (2002).