Magnetization switching in high-density magnetic nanodots by a fine-tune sputtering process on large area diblock copolymer mask

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Electronic Supplementary Information (ESI)

Film thickness calibration

The procedure, described in the following and based on Atomic Force Microscopy (AFM), was used to obtain the deposition rate of $Ni_{80}Fe_{20}$ and Co magnetic materials in order to subsequently deposit the thin films with thickness of 10 and 13 nm, respectively:

- A calibration sample of Co and $Ni_{80}Fe_{20}$ is deposited by RF-sputtering on a Si substrate for the deposition time equal to 270 and 240 s, respectively. The deposition parameters are reported in the main text.
- An optical lithographic process or a scratch is performed on the calibration samples in order to obtain a well-define step between the magnetic film and the underlying substrate.
- The film thickness is evaluated by means of Atomic Force Microscopy (AFM) measuring the step height. In panels (a) and (c) of Fig. S1, the AFM images of Co and $Ni_{80}Fe_{20}$ are shown and the step is clearly visible. The white line, indicated in each AFM image, represent the line along which the height profile has been evaluated. The selected height profiles are shown in the panels (b) and (d) of Fig. S1 and measure a film thickness of 34.5 and 32.1 nm for Co and $Ni_{80}Fe_{20}$ calibration samples respectively.

  The high peak visible in the profile image is the typical metallic rim formed by the lift-off process; obviously it is not considered in the measure of the step height.
- The deposition rate of each calibrated material is calculated dividing the film thickness by the corresponding deposition time. In both calibration samples, the deposition rate is found to be around 1.3 Å/s
- Finally, the film thickness of 13 and 10 nm for Co and $Ni_{80}Fe_{20}$ respectively, is obtained by selecting the correct deposition time with respect to the calculated deposition rate (100 and 77 s for Co and $Ni_{80}Fe_{20}$, respectively). In these deposition, all parameters are kept equal to the deposition of calibration samples.

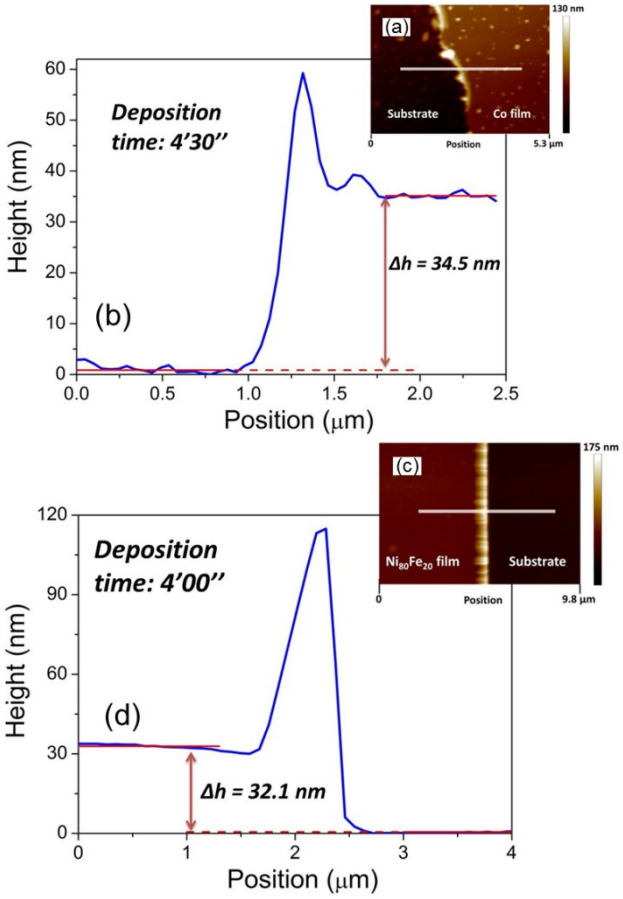

Fig. S1. AFM images of calibration sample for Co and $Ni_{80}Fe_{20}$ are reported in panel (a) and (c) respectively; AFM profile of calibration step for Co and $Ni_{80}Fe_{20}$ in panel (b) and (d) respectively. The deposition time for each material is indicated in the corresponding panels.

Low temperature magnetization measurements on $Ni_{80}Fe_{20}$ nanodot array.

Isothermal hysteresis loops of $Ni_{80}Fe_{20}$ nanodot array measured at T = 5 K in different cooling conditions (Fig. S2). The zero-field cooling loop (black line) is taken with the sample cooled from room-temperature to 5 K under zero applied magnetic field. On the other hand, the field cooling loop (red line) is taken after cooling the sample from room-temperature to 5 K under an applied magnetic field of 10 kOe . The two measured hysteresis loops are almost perfectly superimposed not revealing any exchange bias effect coming from the possible presence of a Ni-oxide layer natively developed on top of the $Ni_{80}Fe_{20}$ dots.

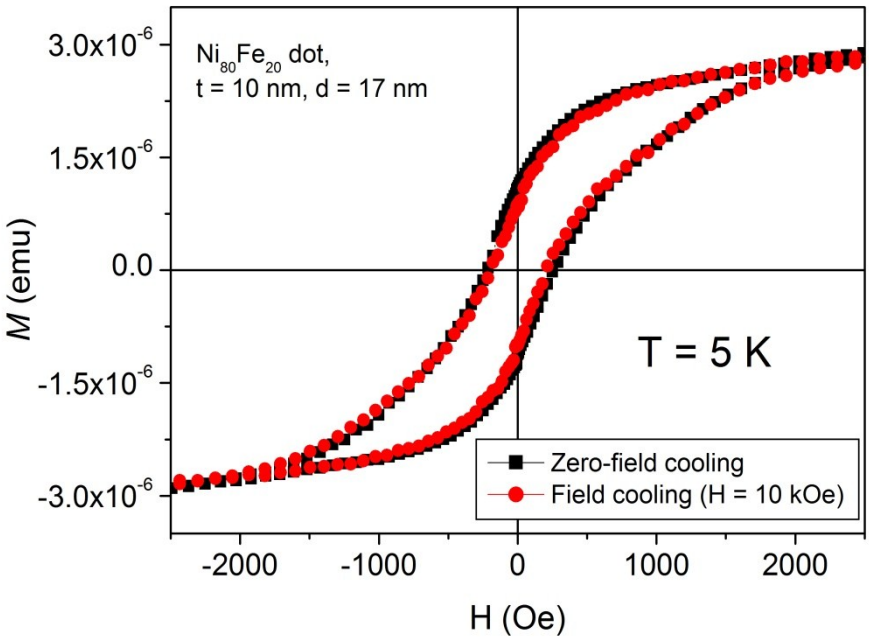

Fig. S2. Isothermal hysteresis loops of $Ni_{80}Fe_{20}$ nanodot array measured at T = 5 K in different cooling conditions: zero-field cooling (black line) and field cooling (red line).

X-ray diffraction measurement

In Fig. S3 is shown the X-ray diffraction (XRD) pattern of a Co film with thickness of ~ 500 nm. The substrate and the deposition parameters employed to obtain this sample are identical, except for the deposition time, to those used to deposit the Co thin film described in the main manuscript (thickness ~ 13 nm). A higher thickness was required for the XRD measurement in order to enhance the signal-to-noise ratio (S/N), since on the 13 nm films the diffraction peaks of the crystalline Co were barely detected. The XRD pattern was collected using the Co K_α radiation with a fixed glancing angle, omega, of 1° with respect to the sample surface, in order to minimize the substrate contribution to the observed diffracted intensities.

The XRD pattern reveals a dominant hexagonal close-packed (hcp) phase characterized by intense reflection peaks, whose width is typical of nanocrystalline materials. All the main reflections of the hcp phase are observed, so a substantial random orientation of the Co crystals can be inferred. Moreover, a minor face-centered cubic (fcc) phase, indicated by low intensity reflections, is observed.

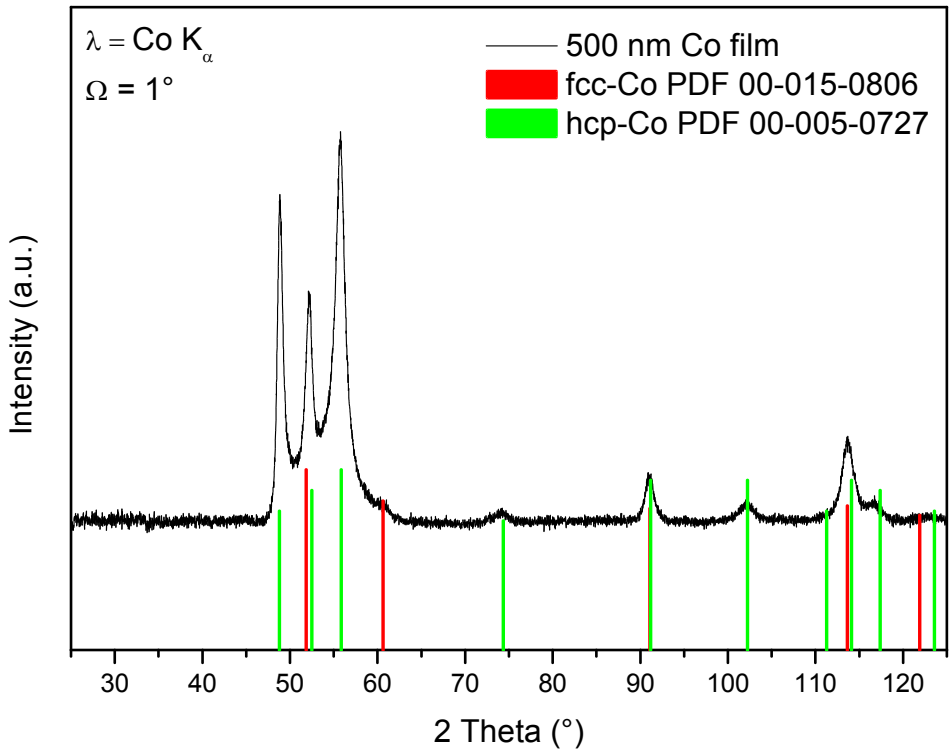

Figure S3. XRD pattern of Co thin film (thickness ~ 500 nm).