



Influence of a tip's magnetic configuration on domain structures during magnetic force microscopy measurements

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Magnetic Force Microscopy

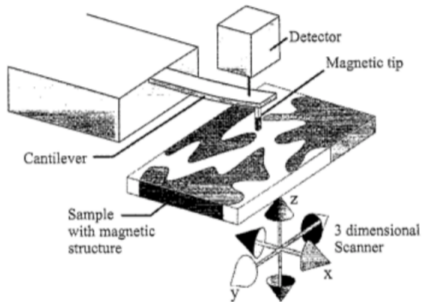


Figure – Magnetic force microscopy operation representation.
Source: Porthun, Sbelmann and Lodder (1998).



Figure – Photography of the Park Systems NX10 atomic force microscope, available at UFSM. Source: the author.

Lift mode

- van der Waals forces $\propto 1/r^6$
- magnetic forces $\propto 1/r^2$

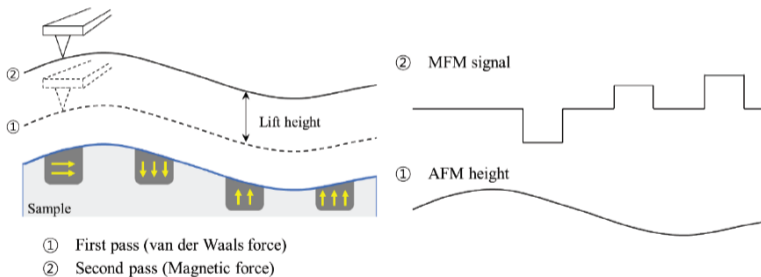


Figure – Schematic representation of the lift mode used for MFM measurements, with the numbers representing the scan order. Source: Park Systems (2022).

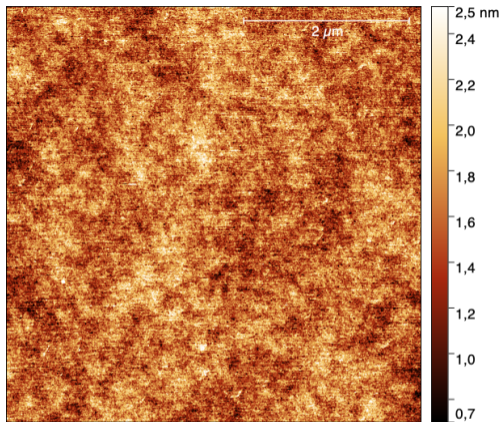


Figure – Topography image of a sputtered multilayer thin film of composition [Pd (10 Å)/Co (5 Å)/Pd (10 Å)] \times 15. Source: the author.

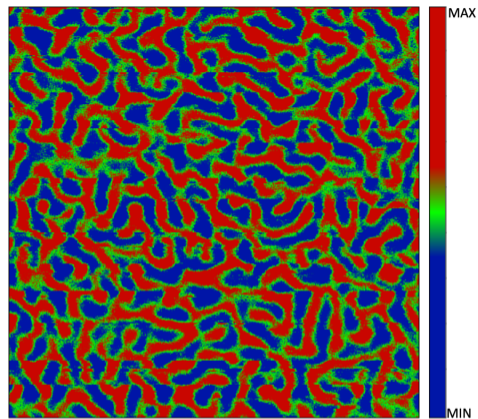


Figure – MFM phase image of the same Pd/Co/Pd sample. Source: the author.

For the topography, the white line in the upper left corner represents the resolution scale of the figure and the color scale indicates the height of the elements. For the MFM image, the color scale indicates the projection of magnetization along an axis perpendicular to the sample plane. The regions in red show magnetization that has a projection in one direction, the ones in blue in the opposite direction and the ones in green are the transition regions.

Tip influence

- Tip-sample interactions during measurements can affect both (Zanette, 2010).

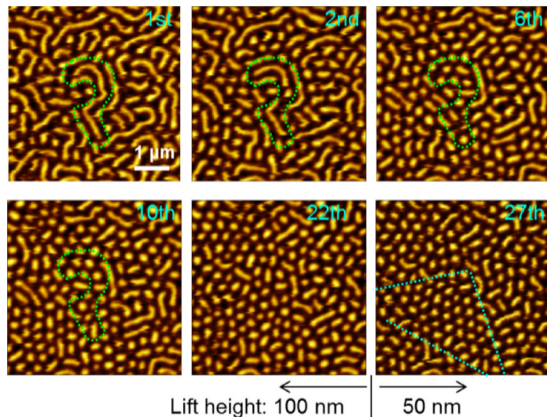


Figure – Representative MFM images of 27 scans over the same area of a Ta (47 Å)/[Pt (40 Å)/Co(13 Å)/Ta (19 Å)] \times 20 sample made with the same tip (Nanosensor PPP-MFMR). Source: Zhang et. al. (2018).

- Tip must have a small and spatially confined magnetic field (Zanette, 2010).

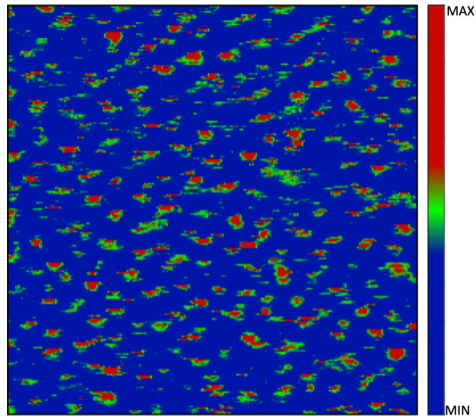


Figure – MFM image of a sputtered multilayer thin film of composition $[\text{Pd} (10 \text{ \AA})/\text{Co} (5 \text{ \AA})/\text{Cu}(4 \text{ \AA})/\text{Pd} (10 \text{ \AA})] \times 15$ made when the tip was magnetically saturated. Source: the author.

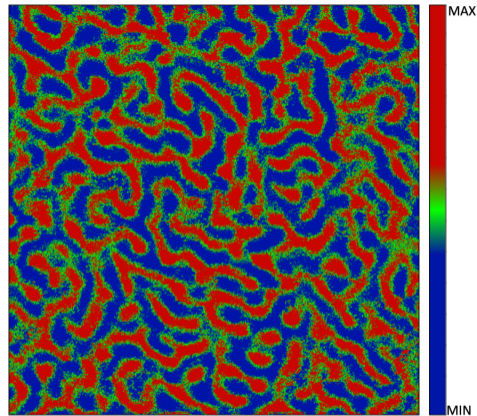


Figure – MFM phase image of the same Pd/Co/Cu/Pd sample when the tip had a demagnetization protocol applied. Source: the author.

Tip Magnetization

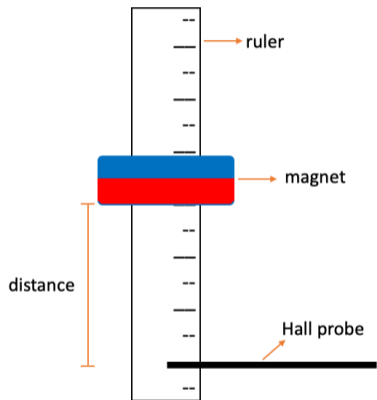


Figure – Illustration of the apparatus for determining the magnitude of the magnet's magnetic field. Blue indicates the magnet's north pole and red the south pole. Source: the author.

Distance (cm)	Magnetic Field Magnitude (Oe)
0	4058
1	1416
2	521
3	292
4	183
5	87

Table – Magnitude of the magnetic field as a function of the distance between the magnet and the Hall probe. Source: the author.

Protocols

- tip: MagneticMulti75-G with coercitivity of roughly 300 Oe (Budget Sensors, 2022).

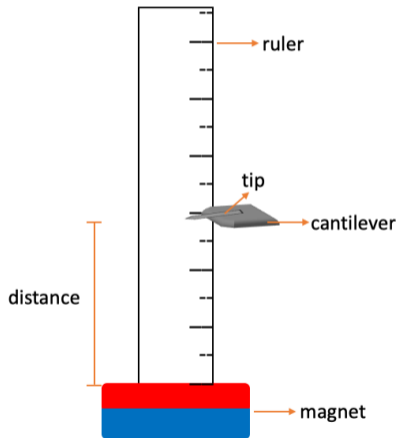


Figure – Illustration of the apparatus used for the tip demagnetization protocols. Blue indicates the magnet's north pole and red the south pole. Source: the author.

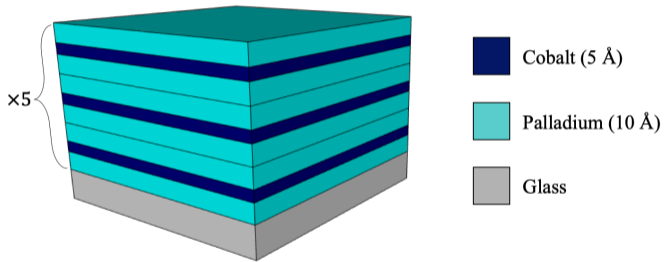


Figure – Out of scale representation of the sample's multilayers for the thin film of composition [Pd (10 Å)/Co (5 Å)/Cu(4 Å)/Pd (10 Å)] \times 15. Source: the author.

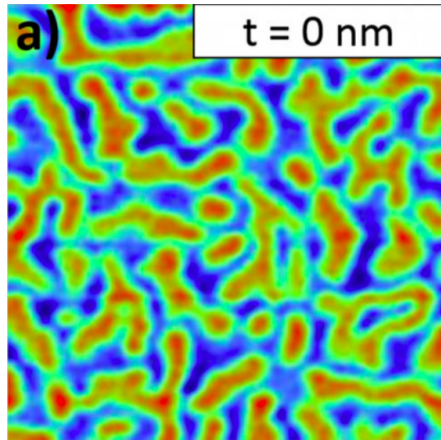


Figure – Magnetic force microscopy image of a [Pd (10 Å)/Co (5 Å)/W (t)/Pd (10 Å)] \times 15 sample, with (a) referring to the image labels of the original article. The scale bar in the image is 1 μ m, and the color scale ranges from blue (magnetization downward) to red (magnetization upward). Source: Dugato et al. (2019).

Results

- Tip with high parallel magnetization.

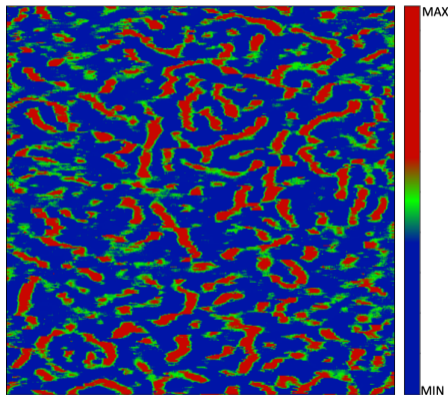


Figure – MFM phase image of a Pd/Co/Pd multilayered thin film, made when the tip approximated parallel to the magnet's high magnetic fields. Source: the author.

- Tip with high perpendicular magnetization.

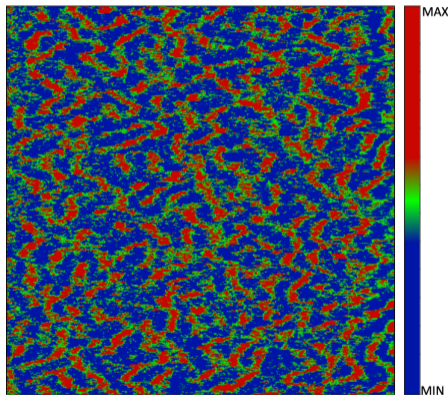


Figure – MFM phase image of a Pd/Co/Pd multilayered thin film, made when the tip was approximated perpendicular to the magnet's high magnetic fields. Source: the author.

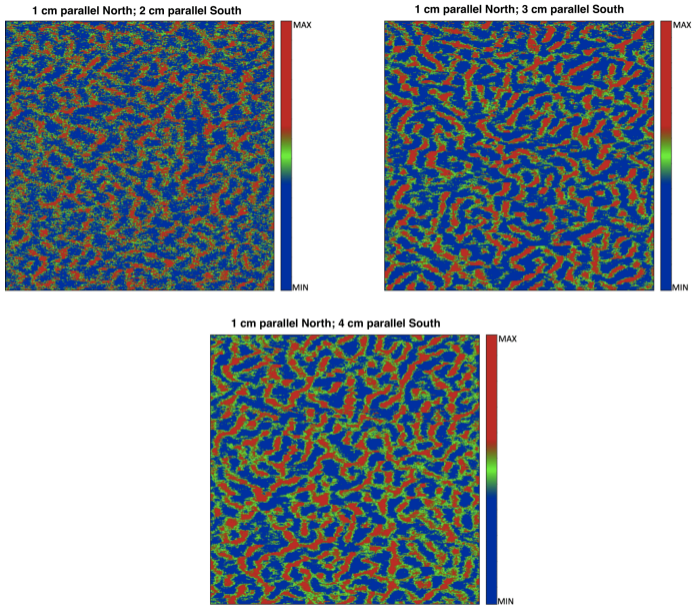


Figure – MFM phase images of a Pd/Co/Pd multilayered thin film, made after the tip was approximated 1 cm parallel parallel to the magnet's North pole and then 2 cm (left), 3 cm (right), 4 cm (middle) parallel to the magnet's South pole. Source: the author.

- Tip approximated 1 cm parallel to the magnet's North pole and then 2 cm perpendicular to the magnet's South pole.

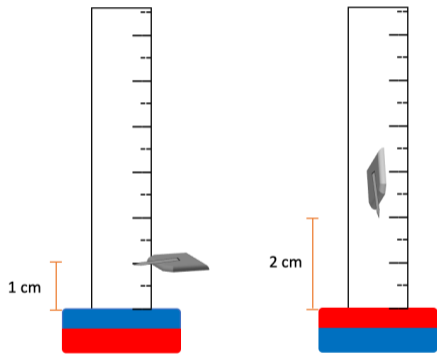


Figure – Illustration of the protocol for the tip demagnetization. Blue indicates the magnet's north pole and red the south pole. Source: the author.

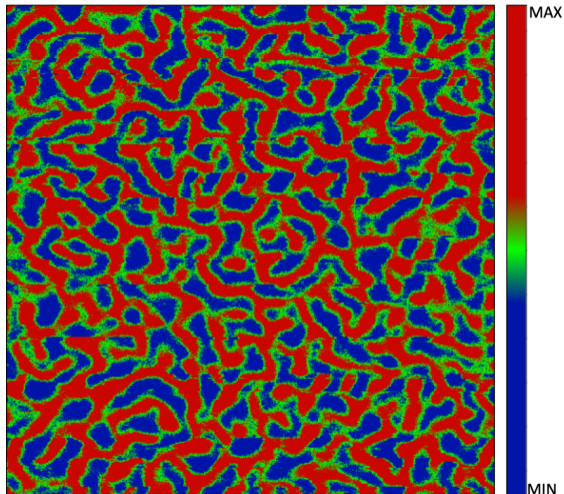


Figure – MFM phase image of a Pd/Co/Pd multilayered thin film, made when the tip was approximated 1 cm parallel to the magnet's North pole and then 2 cm perpendicular to the magnet's South pole.. Source: the author.

Final Considerations

Different magnetic force microscopy's tip demagnetization protocols were analyzed using MFM phase images of a Pd/Co/Pd multilayered thin film.

From that:

- The tip's magnetic configuration has an influence on the domains observed;
- Found, for our sample, a tip demagnetization protocol that reduces that influence;
- Inexpensive and uncomplicated way to work around that circumstance.

References

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