Domain Sizing Results

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1 Background

A domain structure for a material related to the orientation of its magnetic moment. The studied material possessed perpendicular magnetic anisotropy - the magnetisation of it is either oriented in or out of the plane. In the images produced these are represented by red/blue regions. The white area shows the region where the magnetisation flips from one orientation to the other, and is known as a domain wall.

This code was written to calculate the average size of each red/blue region. To do this, it reads in the image and stores the number of regions which are red, blue and white. This is done by looking at the rgb values and using for statements to increment a counter. As red, blue and white have vastly different RGB values this was easy and allowed for all the pixels to be categorised as either red, blue or white, rounding them to the nearest one.

After this has been counted, the code then calculates the average size of the regions. To do this the code counts the number of pixels per row before it encounters a white one, stores the number then resets it and continues again from the next non-white pixel. It does this across all rows and then down all columns. As the shape of the regions does not matter, the average width is calculated from all the rows and columns together. Finally this is converted into physical units by converting it using the known physical width of the simulation.

The results of this simulation are detailed in the document below.

2 Results

The thickness of the film varied from 5 - 150 nm. Figure 1 shows a sample of the domain structures formed.

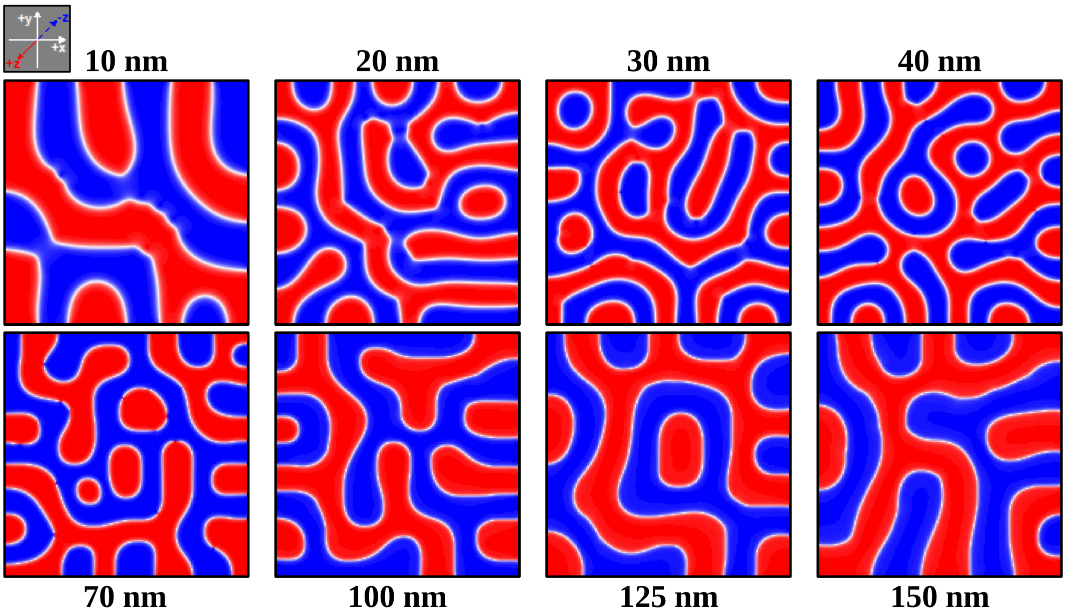

Figure 1: OOMMF simulated domain formation for samples of 800×800 nm with varying thicknesses shown.

The domains' size and shape are similar to previously measured MFM (Magnetic Force Microscopy) images of Ni/Co [1] and Co/Pt [2], suggesting that the simulation accurately depicted the material's domains. A graph of the sample thickness against the average domain size is plotted in Figure 2.

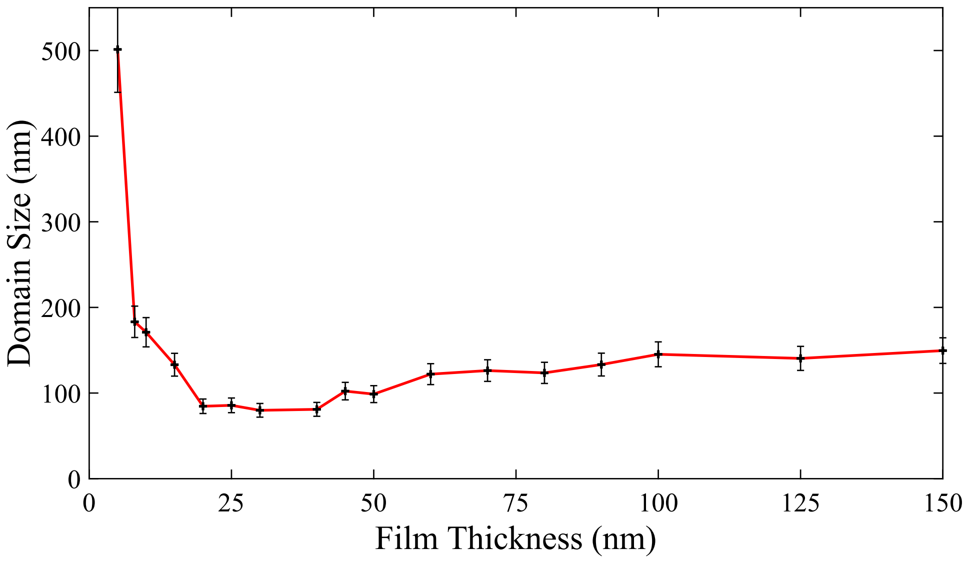

Figure 2: In-plane domain size variation with film thickness of a NiCo/Pt OOMMF simulation, calculated from a MATLAB script.

This figure directly matches experimental evidence obtained from [2] which can be seen in Figure 3, suggesting that the simulation is an accurate representation of real-world micromagnetic behaviour.

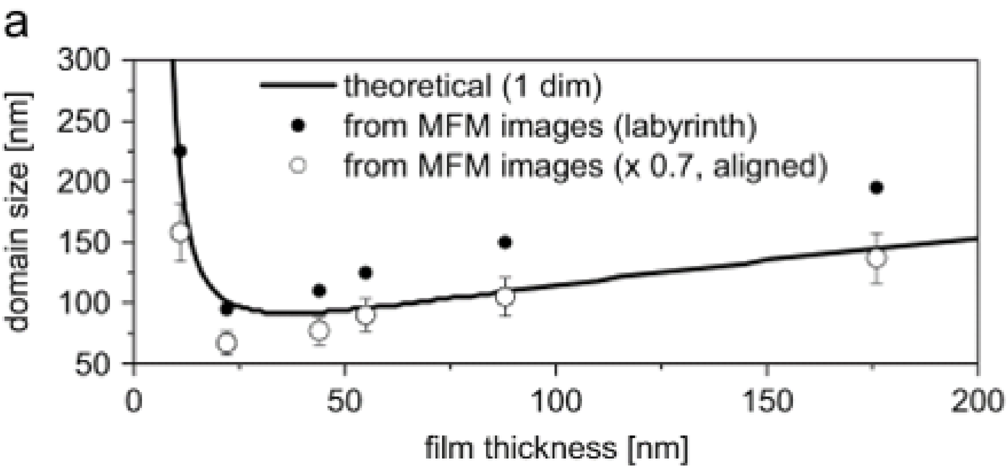

Figure 3: Figure of experimental and theoretical domain size for varying film thicknesses from [2]

The domain wall energy has a characteristic domain size associated with it, calculated to be ≈ 20 nm, and for larger thicknesses, the domain size scales proportionally to the thickness. For films with thickness less than the characteristic domain size, the domain size diverges exponentially. This behaviour is well studied [3–5] and so the correspondence of the simulation to this suggests that the domain structure of the NiCo/Pt was accurately represented.

References

[1] Subhi AA, Sbiaa R. Control of magnetization reversal and domain structure in (Co/Ni) multilayers. J Magn Magn Mater. 2019;489:165460.

[2] Hellwig O, Berger A, Kortright JB, Fullerton EE. Domain structure and magnetization reversal of antiferromagnetically coupled perpendicular anisotropy films. J Magn Magn Mater. 2007;319(1):13-55.

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[4] Allenspach R. Ultrathin films: magnetism on the microscopic scale. J Magn Magn Mater. 1994;129(2):160-85.

[5] Kooy C, Enz U. Experimental and Theoretical Study of the Domain Configuration in Thin Layers of $BaFe_{12}O_{19}$. Philips Res Rep. 1960;15:7-29.