Growth and characterisation of magnetic tunnel junction thin film structures

Charlotte Bull[1], Paul Nutter[1], Meg Smith[1], and Tom Thomson[1]

[1]Nano Engineering and Spintronic Technologies group, Department of Computer Science, University of Manchester, Oxford Road, Manchester, M13 9PL, UK

Introduction

↑ Currently conventional electronics rely on the charge of electrons for their functionality, by utilising the spin of the electron in addition to its charge, more energy efficient devices can be manufactured.

↑ Spin-transfer-torque magnetoresistive random access memory (STT-MRAM) and spin-orbit torque MRAM (SOT-MRAM) has enormous potential as a non-volatile data storage technology, due to its scalability, energy efficiency and fast read/write speed.

↑ However, one issue to overcome for the future development of STT-MRAM is the need to maintain thermal stability, whilst aiming to reduce the critical switching current of their key component the magnetic tunnel junction (MTJ) [1].

↑ This project will be looking at building, characterising and optimising MTJs, a key component of any spintronic device. The transport properties of MTJ films will also be looked at using patterned point contacts to perform electrical measurements on MTJ films [2-3].

↑ The overall goal of this project is to study the magnetoresistance ratio dependence with annealing conditions.

Methods

↓ To fabricate magnetic tunnel junction structures, optimisation of individual layers is essential. Each layer is grown by magnetron sputter deposition at relatively low powers and long deposition times to create smooth pinhole free layers. To date the structure {current structure here} has been grown.

↓ The properties of the film are measured using X-ray reflectivity (XRR) and a fitting software GenX is used to fit the XRR data and determine the values of the thickness, density and surface roughness for each layer in the film. XRR comprises of reflecting a beam of x-rays off the thin film structure and measuring the intensity of the reflected x-rays [4-5].

↓ The films magnetic properties have also been measured, using a vibrating sample magnetometer (VSM), whose operation is constructed around the flux change when a magnetic sample, in this case a thin film, is vibrated near it. From this the saturation magnetisation, the coercivity and the direction of magnetisation (in plane and out of plane) can be calculated [6].

↓ Combining all these techniques will allow analysis and the subsequent optimisation of STT-MRAM and SOT-MRAM.

Results

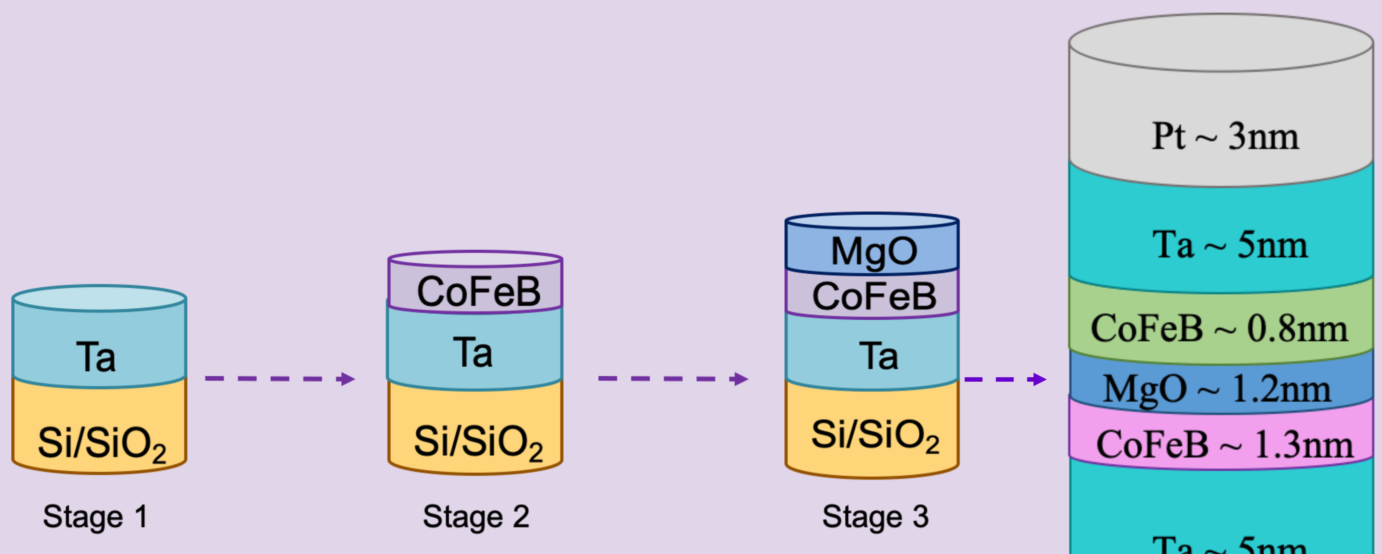


Figure 1. (Left) Rate test progression and final structure of prototype MTJ that has been grown by sputter deposition.

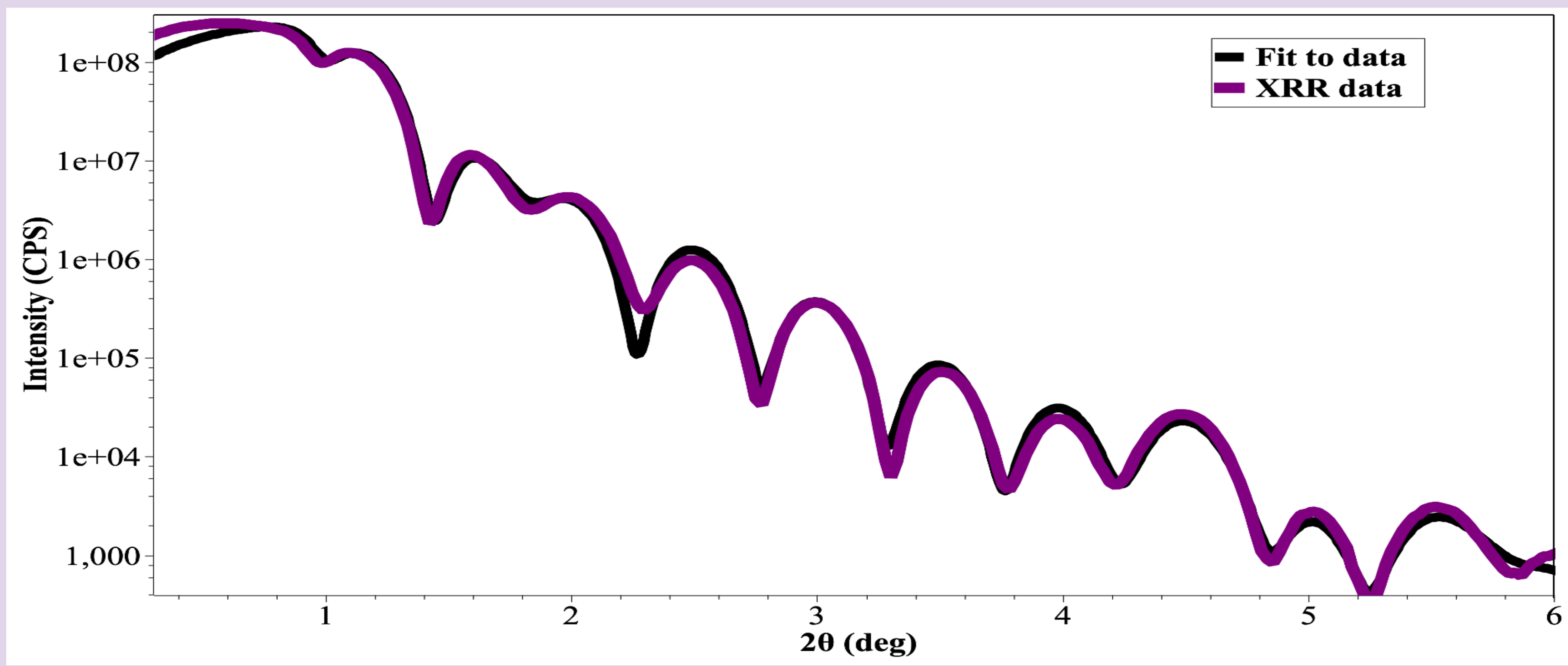
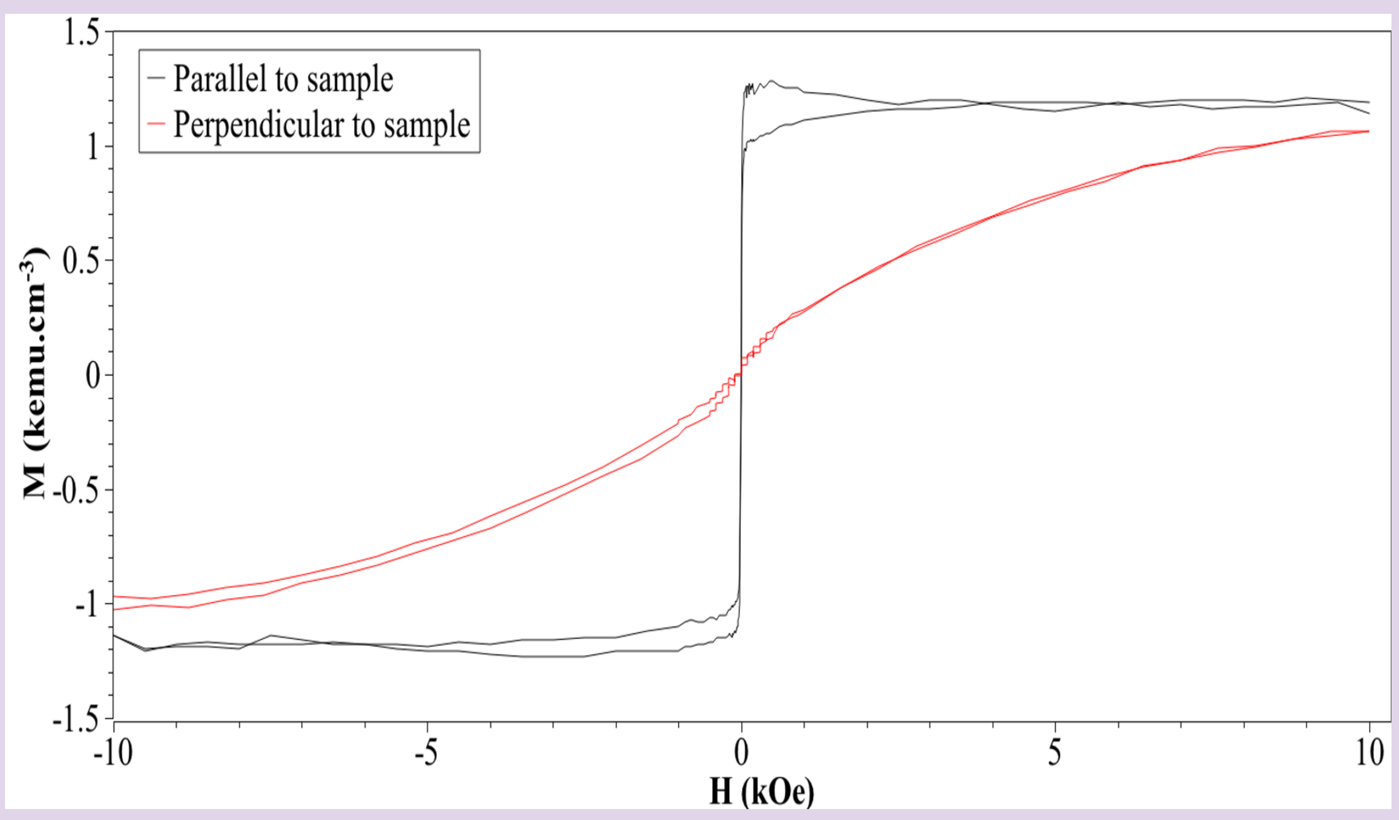


Figure 2. (Top right) XRR data for prototype MTJ.



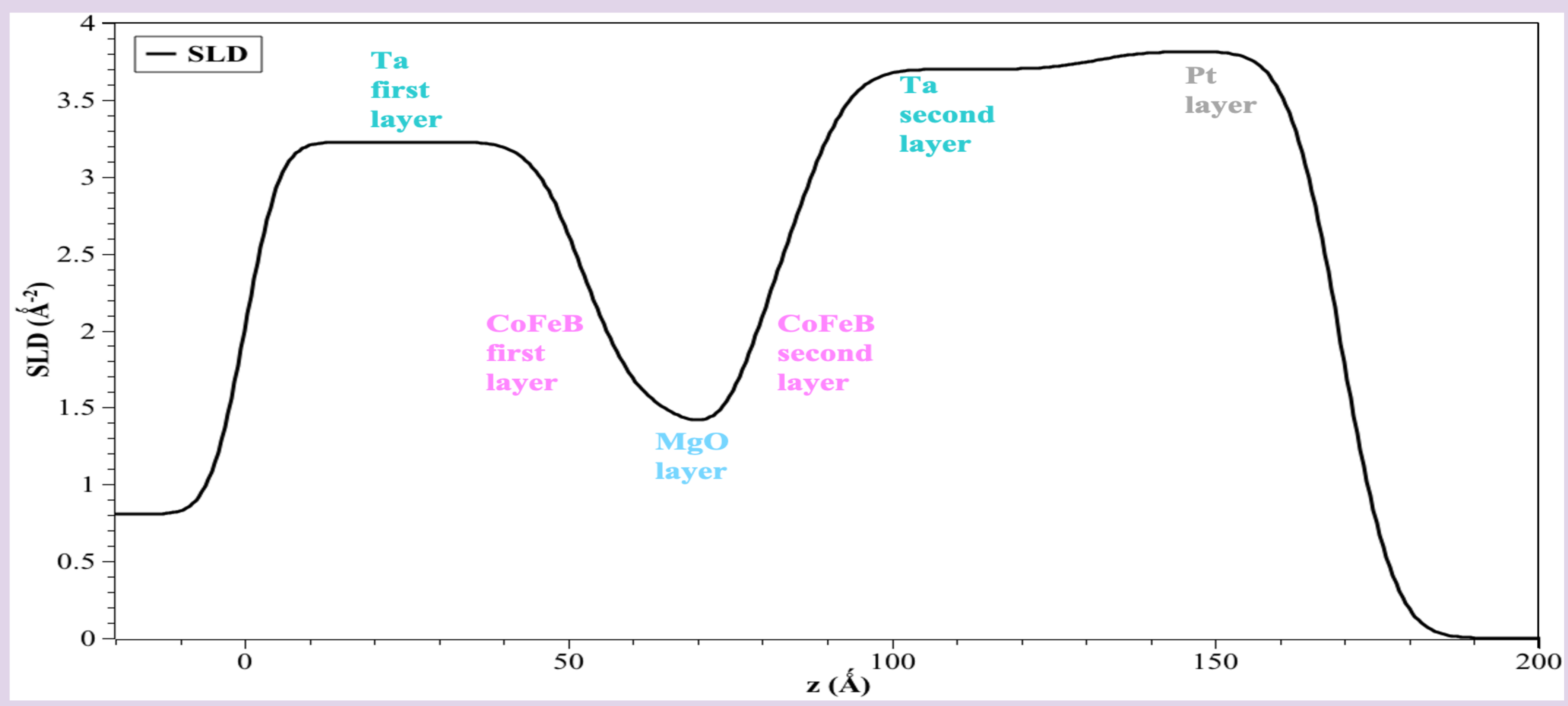
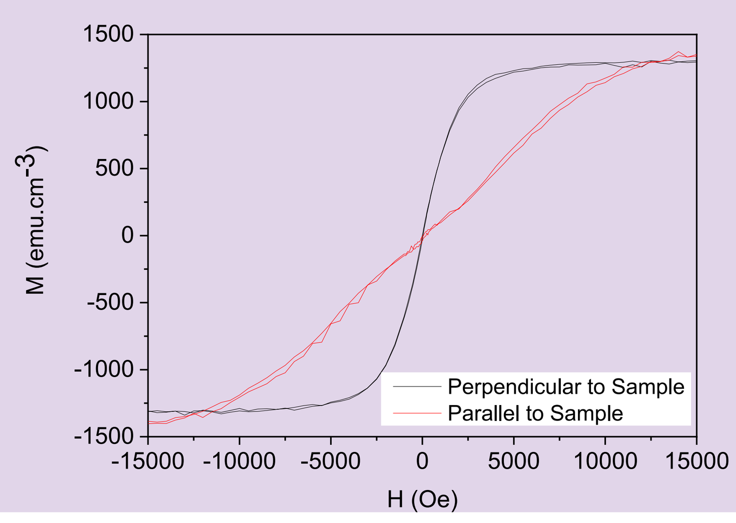


Figure 3. (Bottom right) SLD data for the prototype MTJ.

Figure 4. (Bottom left) VSM data showing how the MTJ magnetisation prefers to lie in plane rather than perpendicular.

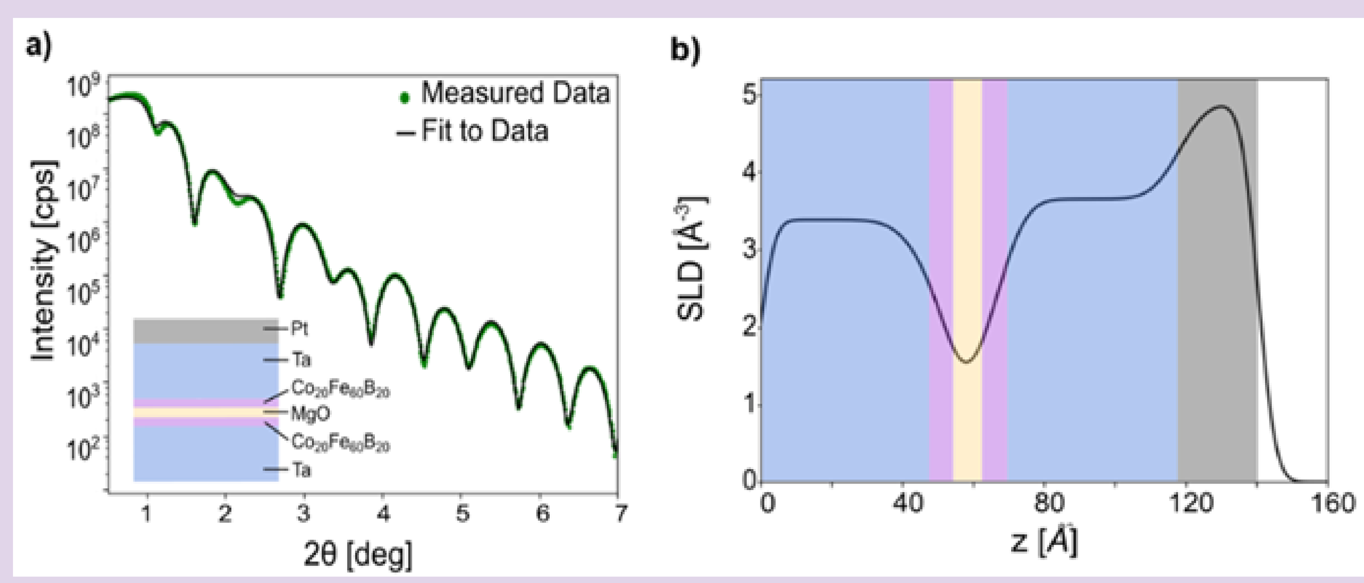
Future Work

The MTJs will be annealed post deposition at T_{ann}=340°C and T_{ann}=360°C, to achieve PMA as shown in Fig.5. Different annealing methods, using equipment such as the sputter coater, VSM, furnace, and X-ray diffraction system to see which method produces an enhanced MTJ structure and magnetic signal. Graded multilayers, will also be investigated as a method for further optimisation of the MTJs.



(Right) Figure. 4. (a) XRR and (b) scattering length density figures for MTJs annealed at a temperature of 340C. Inset shows a schematic of MTJ films deposited using RF and DC magnetron sputtering onto SiO_2 (290 nm) substrates under ultra-high vacuum conditions (below $9x10^{-9}$ Torr).

(Left) Figure. 5. Magnetic hysteresis loop for MTJ film measured by VSM, applying a 20kOe field perpendicular (black) and parallel (red) to the sample surface.



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Acknowledgements and Further Information

For further information please do not hesitate to contact Meg by email at:
meg.smith@postgrad.macnhester.ac.uk

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