Experimental report

19/10/2022

Proposal:	**5-54-347**	**Council:**	4/2020
Title:	Determination of the magnetic structure in piezomagnetic Mn3SnN thin films using neutron diffraction		
Research area:	Materials		

This proposal is a new proposal

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Samples: MnSnN/STO

Instrument	Requested days	Allocated days	From	To
D10	10	7	12/05/2021	21/05/2021

Abstract:

The family of manganese antiperovskites with the formula Mn3AN have recently attracted much attention due to the range of interesting properties they display, such as barocaloric and Invar effects, baromagnetism and temperature independent resistivity. The interplay of magnetic and elastic properties, and the constraints due to the geometric frustration of the non-collinear antiferromagnetic (AFM) structure, underlies these phenomena. We have recently experimentally determined a giant piezomagnetic effect (PME) in Mn3NiN thin films, which provides a novel method for control of magnetism via electric field in spintronics applications. However, the low AFM transition temperature (TN = 260K) means that room temperature applications are not yet possible. To overcome this we have grown thin films of Mn3SnNx, where 500K ≥ TN ≥ 600K depending on nitrogen content [8], and the PME is predicted to be 4 times larger than Mn3NiN, making it an ideal candidate for spintronics applications. The non-collinear AFM structure underlies the giant PME properties in this material. We therefore propose to use the D10 diffractometer to determine the magnetic structure.

Determination of the magnetic structure in piezomagnetic Mn_3SnN thin films using neutron diffraction

Summary:

The family of manganese antiperovskites with the formula Mn_3AN (A = Sn, Ni, Ga…) have recently attracted much attention due to the range of interesting properties they display, such as barocaloric [1,2] and Invar effects [3,4], baromagnetism [5] and temperature independent resistivity [6]. The interplay of magnetic and elastic properties, and the constraints due to the geometric frustration of the non-collinear antiferromagnetic structure, underlies these phenomena. We have recently experimentally determined a giant piezomagnetic effect (PME) in Mn_3NiN thin films [7], which provides a novel method for control of magnetism *via* electric field in spintronics applications, with several advantages over current magnetostriction-based devices as complete reversal of the magnetisation can be achieved. However, the low antiferromagnetic transition temperature (T_N = 260K) means that room temperature applications are not yet possible. To overcome this we have grown thin films of Mn_3SnN_x, where 500K $\geq T_N \geq$ 600K depending on nitrogen content [8], and the PME is predicted to be 4 times larger than Mn_3NiN (see Fig. 1a), making it an ideal candidate for spintronics applications. The non-collinear AFM structure underlies the giant PME properties in this material. We therefore propose to use the D10 diffractometer to determine the magnetic structure.

The Experiment:

A 10x10x100nm film of $SrTiO_3/Mn_3SnN$ was loaded into the cryostat. The sample was extensively checked before hand and both XRD and reciprocal space mapping determined that the crystallinity of the film was very high and strongly scattered (See figure 1a-b). The highly crystalline nature of $SrTiO_3$ made aligning the substrate significantly easier than our previous experiment with $BaTiO_3$ substrates (5-41-931). At room temperature, we were able to observe the strongest film peaks ((002) type) with relatively short counting times (~2h) and therefore produce a UB matrix for the film. Further measurements of the (-1 -1 -1), (10-1), (-1 -1 0) and (-2 0 0) were possible, and 5h counting time for each was performed. These 5 peaks were measured at base and 150K, although no significant change in intensity was observed (See Figure 1c). Upon heating above the transition (T ~ 500K), only the (-1 -1 -1) peak showed a significant reduction in intensity. This did not fit with the model expected for the film and with only 1 magnetic peak observed we were unable to uniquely determine the magnetic structure. A further experiment on WISH, ISIS has been carried out to complement this data. Once this has been analysed, we plan to publish data from both experiments.

References

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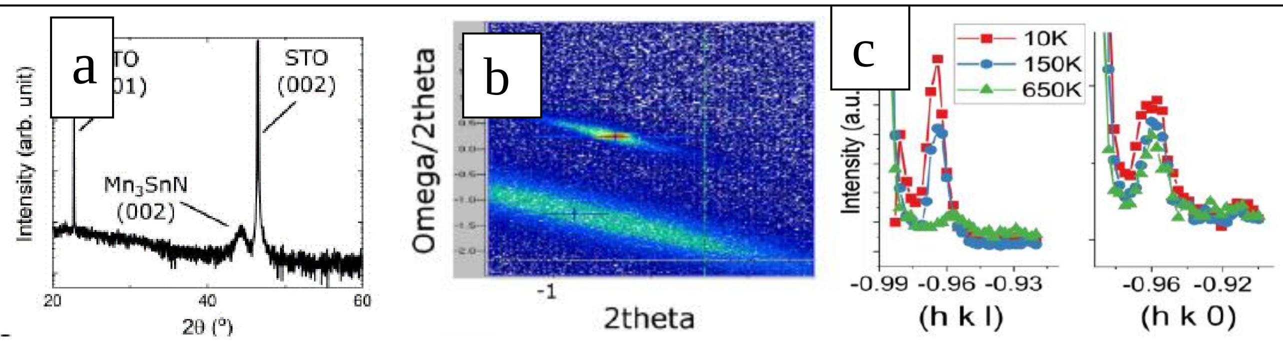

Figure 1: (a-b) High sample quality determined from XRD and reciprocal space mapping**. (c)** Temperature dependence of the (-1 -1 -1) and (-1 -1 0) reflections.