Experimental report

31/08/2022

Proposal: **5-32-905** **Council:** 4/2020

Title: Phase separation in the ferromagnetic shape memory alloy Mn50Ni40Sn10

Research area: Physics

This proposal is a new proposal

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Samples: Mn50Ni40Sn10

Instrument	Requested days	Allocated days	From	To
D33	3	3	19/03/2021	22/03/2021

Abstract:

The NiMnX family of functional magnetic materials promise many potential applications because of their excellent performance both magnetically and mechanically. In these materials the magnetic-field induced strain and exchange bias can be used in attenuators, sensors, magnetic recording, magnetic refrigeration and spintronic devices. One of the greatest challenges in the field is designing materials that can meet industrial requirements. An understanding of the physics on a microscopic level is key. Here we focus on a material that is a ferromagnetic shape memory alloy, Mn50Ni40Sn10. This proposal is a follow-up of earlier work done at D33 (#5-32-873), with the aim of concentrating on the low temperature exchange bias component of behaviour in this material.

Experimental Report
Instrument: D33
Experiment Number: 5-32-905

NEUTRONS FOR SOCIETY

Title: Phase separation in the ferromagnetic shape memory alloy $Mn_{50}Ni_{40}Sn_{10}$

Experiment Date: 19/03/2021 – 22/03/2021

Experimental Team: Emma Campillo, Lingjia Shen, Elizabeth Blackburn, Ahmed Alshemi, all from Lund University

Local Contact: Robert Cubitt

Abstract:

Exchange bias is an effect that describes the asymmetry of left and right coercive fields with respect to the zero-field line, i.e. $\mu_0H_1 \neq \mu_0H_2$, in a magnetization process. Experimentally, this is manifested by a shift of magnetization loop along the field axis. It has many important applications. A paradigmatic example is spintronics [1]. As a result, it is of great interest to understanding the microscopic mechanism that drives the exchange bias in a material.

Sample, Instrument Details and Results:

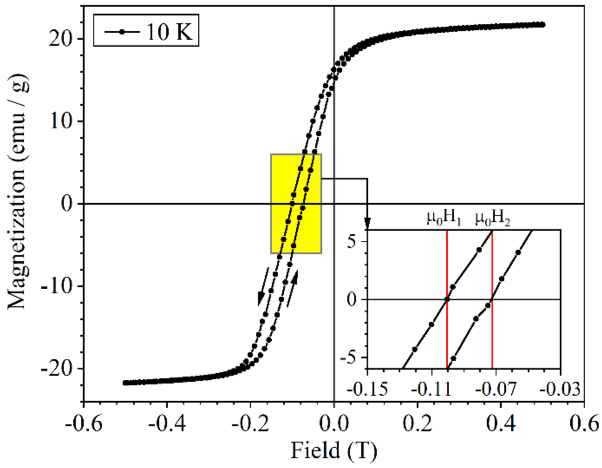

Figure 1 Exchange bias in Mn-Ni-Sn. Field-cooled (5.0 T) magnetization loop at 10 K. Inset: Enlarged view of the yellow region. Red lines mark the coercive fields.

A polycrystalline $Mn_{50}Ni_{40}Sn_{10}$ pellet (~ 7×5×1 mm^3) cut from an ingot prepared by arc-melting was used for this experiment. The exchange bias effect in this sample has been well established (Figure 1) [2].

We carried out the small-angle neutron scattering (SANS) measurements on the D33 instrument. The sample was loaded in the Birmingham 17 T horizontal field cryomagnet. In the experiment, we have used three combinations of collimation distance (m), neutron wavelength (Å), and sample-to-detector distance (m): 12.8/10.0/12.8, 5.3/7.0/5.3 and 2.8/5.0/2.0. They cover a momentum transfer (q) window between 0.0025 $Å^{-1}$ and 0.21 $Å^{-1}$.

Figure 1 shows some typical SANS intensity versus q curves at 2.5 K, where exchange bias dominates [2]. These data are fitted to a three-phase separation model – which contains one nonmagnetic phase (Lorentzian profile) and two magnetic phases of fractal nature (unified

Guinier/power-law approximation, see Ref. 3). We find that this model can well reproduce the experimental data. Currently, we are in a stage of studying the modelling parameters as a function of magnetic field. We also studied the magnetic phase separation at higher temperatures. These data are still being processed.

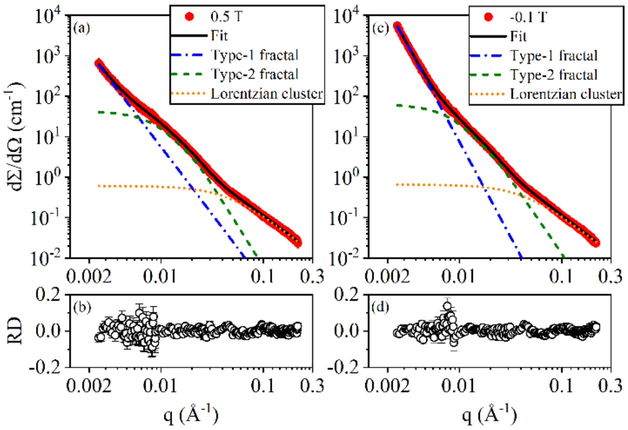

Figure 2 Total SANS intensity as a function of momentum transfer (q) at 2.5 K. (a), (c) Experimental data at 0.5 T and -0.1 T, collected when magnetic field was descending after the field-cooling at 5.0 T. Numerical fits based on the three-phase model are also plotted. These two fields correspond to regions where the sample is saturated and almost demagnetized, respectively (see Fig. 1). (b), (d) Relative differences (RD) characterizing the fitting quality.

Summary

This was a highly successful experiment. A preliminary data analysis reveals that the exchange bias effect in this sample is coupled to the spin fractals.

References:

[1] T. Jungwirth *et al.*, **Nature Nanotechnology** 11, 231 (2016)

[2] H. C. Xuan *et al.*, **Applied Physics Letters** 96, 202502 (2010).

[3] G. Beaucage, **Journal of Applied Crystallography** 28, 717 (1995)