Experimental report

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Proposal: **1-01-139**

Council: 4/2014

Title: Magnetic ordering in Ni-Co-Mn-Sn-based ferromagnetic shape memory alloy (FSMA)

Research area: Materials

This proposal is a new proposal

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Samples: Ni-Co-Mn-Sn

Instrument	Requested days	Allocated days	From	To
D11	2	2	17/11/2014	19/11/2014
D22	2	0		
D33	2	0		

Abstract:

Co-doped Ni-Mn-Sn-based Heusler alloys manifest many interesting magnetic and magneto-structural effects like IMCE (inverse magnetocaloric effect), MFIRT (magnetic field induced reverse transformation) and KA (kinetic arrest), as a result of a combination of first order structural (martensitic) transformation and multiple second order magnetic transitions. However, its low-temperature magnetic transitions in martensitic state are particularly complex with the possible presence of a paramagnetic to anti-ferromagnetic and / or ferromagnetic ordering. Small-angle neutron scattering (SANS) is especially suited to decipher these complex transitions since the mesoscopic density fluctuations due to formation of spin clusters can be probed by this technique. The current study will explore the magnetic transitions in Ni45Co5Mn38Sn12 using in-situ SANS at several key temperatures, in combination with detailed temperature-dependent magnetometry and thermal analyses. Combination of these complementary techniques would provide valuable insight into multiple magnetic transitions and resolve the underlying mechanism with the help of direct observation of spin clusters.

Experimental report (1-01-139)

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Magnetic ordering in Ni-Co-Mn-Sn-based ferromagnetic shape memory alloy (FSMA): Low-temperature magnetic transitions in martensitic state of the Co-doped Ni-Mn-Sn-based Heusler alloys are particularly complex with the possible presence of a paramagnetic to anti-ferromagnetic and / or ferromagnetic ordering. Small-angle neutron scattering (SANS) is especially suited to decipher these complex transitions since the mesoscopic density fluctuations due to formation of spin clusters can be probed by this technique. The current study explores the magnetic transitions in $Ni_{45}Co_5Mn_{38}Sn_{12}$ using in-situ SANS at several key temperatures, in combination with detailed temperature-dependent magnetometry and thermal analyses. Combination of these complementary techniques provides valuable insight into multiple magnetic transitions and resolves the underlying mechanism with the help of direct observation of spin clusters.

$Ni_{45}Co_5Mn_{38}Sn_{12}$ shows a 5M martensitic microstructure at RT, whereas the high temperature austenite phase has a $L2_1$ structure (Fig. 1a-c). DSC analysis shows (Fig. 2a) the first order martensitic transformation along with the second order magnetic transitions (marked by dashed lines). Temperature-dependent magnetization plots in different applied fields in ZFC condition is displayed in Fig. 2b; inset highlights the low temperature magnetization behaviour in low field. Likewise, FCC and FCW plots in low field are shown in Fig. 2c, where all the transition temperatures determined by DSC are also superimposed (marked by dotted lines).

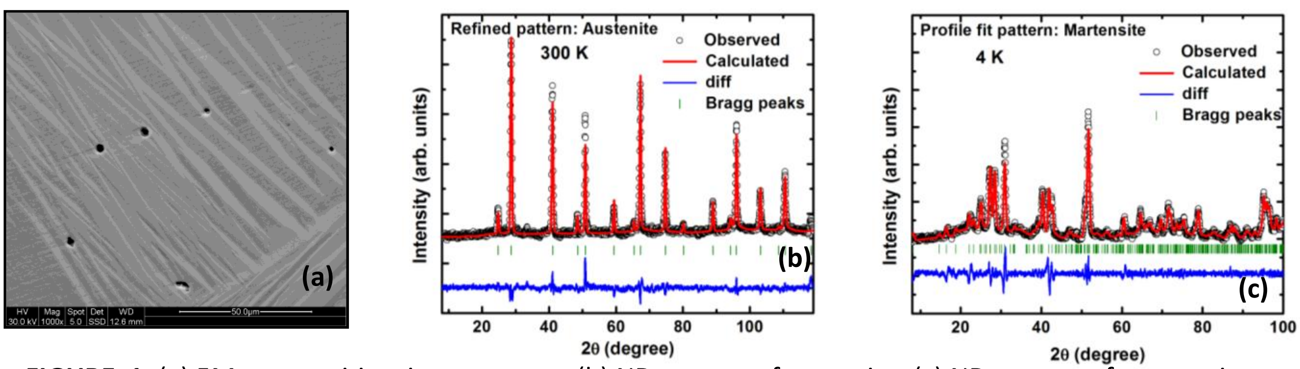

FIGURE 1. (a) 5M martensitic microstructure; (b) ND pattern of austenite; (c) ND pattern of martensite

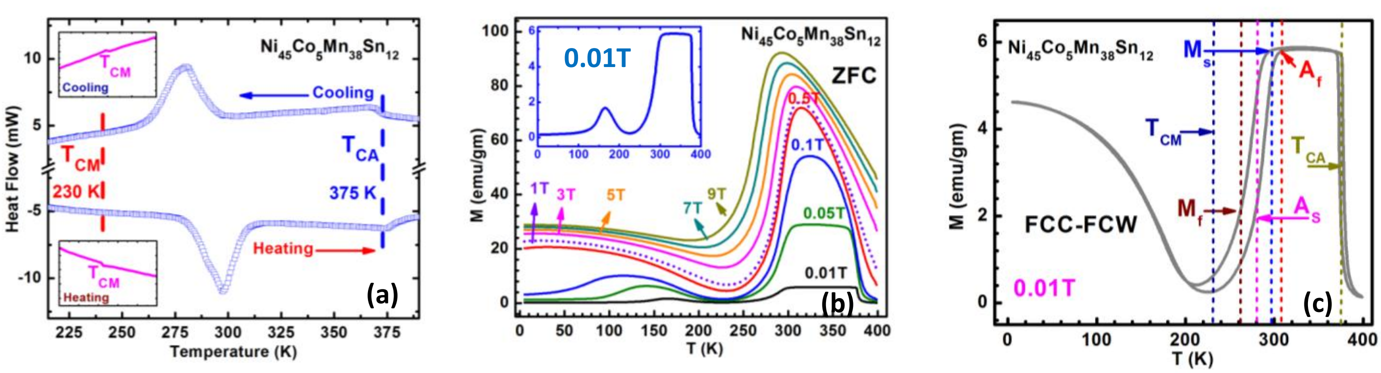

FIGURE 2. (a) DSC plot showing martensitic transformation and magnetic transitions; (b) ZFC plots at different fields. Inset highlights the low temp. magnetic transition; (c) FCC & FCW plots at low field. All major transition temps. obtained from DSC are marked on the plot.

Magnetization measurements show that at very low temperature (below 150 k) the ZFC curve separates from FCC curve indicating the possible presence of ferromagnetic spin clusters in anti-ferromagnetic matrix (Fig. 3 (a)). This is successfully verified by direct observation in SANS.

SANS experiments were carried out at ILL, Grenoble using 6 Å beam of neutrons to ascertain the validity of the above-mentioned hypothesis. Analysis of our SANS data shows a peak around 0.5 $Å^{-1}$ which is a function of temperature; this confirms our hypothesis. The data were fitted for spherical particles and plotted in Fig. 3(b). The inset of Fig. 3(b) shows only the zoomed portion of the fitted peak of 190 K data taken as example. Parameters like size, poly-dispersity etc were extracted from the peak in the Guinea region. The fitted parameters for the Porod region indicate the presence of some kind of larger structures, probably the magnetic domains in our case. Figure below shows the fitted SANS patterns for 30 K and 150 K data. Table 1 below shows the extracted parameters. The detailed study is underway.

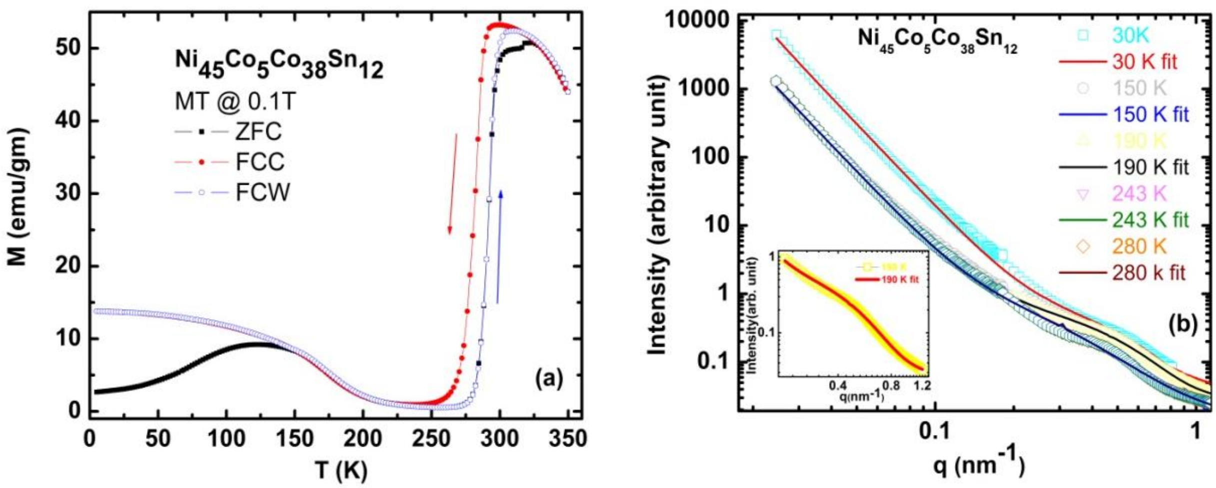

FIGURE 3. (a) Magnetization data showing ferromagnetic clustering in anti-ferromagnetic matrix; (b) Fitted SANS data from 30 K to 280 K.

TABLE 1. Extracted Spin cluster information from SANS data

$Ni_{45}Co_5Mn_{38}Sn_{12}$	Spin cluster size (nm)	Poly-dispersity of cluster	Magnetic domain size (nm)
30 K	0.98	0.36	146
150 K	1.79	0.42	168.6
180 K	2.08	0.38	152
243 K	3.14	0.24	212.8
280 K	3.3	0.32	224