Experimental report

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Proposal: 5-24-591 **Council:** 4/2016

Title: Atomic order and magnetic properties in Ni-Mn-Sn

Research area: Materials

This proposal is a new proposal

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Samples: Ni50Mn35Sn15
Ni50Mn37Sn13
Ni50Mn25Sn25
Ni50Mn40Sn10
Ni50Mn30Sn20

Instrument	Requested days	Allocated days	From	To
D2B	2	2	04/07/2016	06/07/2016

Abstract:

The functional properties of metamagnetic shape memory alloys Ni-Mn-Z (Z=In, Sn, Sb) ultimately rely on the magnetic coupling between Mn atoms, so the magnetic exchange strongly depends on the Mn-Mn distance and consequently in the atomic order. A complete correlation between atomic order and exchange interactions is therefore needed to properly tune the properties of these alloys. In Ni-Mn-Sn the high stability of the L21 structure precludes the variation of atomic order by means of conventional thermal treatments. To tackle this problem, a series of alloys has been elaborated with compositional range covering from fully ordered stoichiometric to well-disordered Mn-rich alloys. In addition to configurational disorder, the influence of mechanically-induced disorder has been also evaluated: all alloys have been studied both after mechanical milling and after a subsequent annealing. The proposed experiment is intended to analyze the variations on both the long-range atomic order and the magnetic structure resulting from both compositional and mechanically-induced disorder by means of high-resolution neutron diffraction, both in as-milled and annealed states,at different temperatures.

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In the so-called metamagnetic shape memory alloys, the martensitic transformation takes place between a ferromagnetic austenite and a weak magnetic martensitic phase, allowing the induction of the MT by an applied magnetic field, and thus giving rise to multifunctional properties. All the magnetostructural features giving rise to those functional properties depend on both the composition and the microstructure of the alloys. The influence of microstructure (including atomic order, defects, strains, etc.) has been scarcely investigated, in particular for the Ni-Mn-Sn system. One of the simplest methods to modify the microstructure is by mechanical and thermal treatments

The aim of this experiment was to correlate the effect of composition and microstructure in the magnetostructural properties of the series $Ni_{50}Mn_{25+x}Sn_{25-x}$ (x = 0,5,10,12,15). To do that, we made a systematic analysis with different sample composition at the same temperatures in two different states of mechano-thermal treatment: manually milled ("as-crushed") and annealed during 20 minutes at 400C. The data were taken in D2B diffractometer, equipped with a cryofurnace and operating at a wavelength of 1.59A, with acquisition times of typically ~2h per pattern. With the time available, we were able to analyze only half of the series. As an example, the main results obtained in $Ni_{50}Mn_{35}Sn_{15}$ analysis in austenitic phase in both states are the following [1]:

1.- The degree of atomic order is the same in both states: as-crushed and annealed (Table 1).

2.- The thermal treatment produces an increase on the grain size, as expected.

3.- The magnetic coupling is affected by the mechano-thermal treatment: in the as-crushed sample there is an antiferromagnetic coupling between Mn atoms in 4a and 4b sites, while in the annealed one the coupling is ferromagnetic.

Table 1. Atomic positions and occupancies in austenitic phase in as-crushed and annealed samples of $Ni_{50}Mn_{35}Sn_{15}$.

Site	**Atoms**	**Occupancy**	
		Treat	**As crushed**
4a (0,0,0)	Mn Ni	0.944(262) 0.056(262)	0.949(389) 0.051(389)
4b (1/2,1/2,1/2)	Mn Ni Sn	0.428(272) 0.049(0) 0.523(272)	0.412(402) 0.021(0) 0.566(402)
8c (1/4,1/4,1/4)	Ni Mn	2.000(n/a) 0.000(n/a)	1.858(n/a) 0.146(n/a)

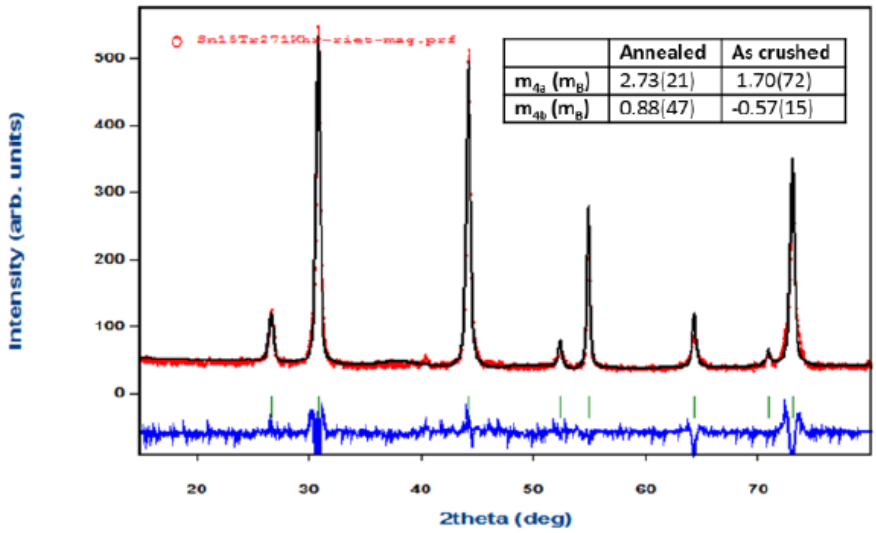

Fig. 1. Rietveld refinement and magnetic moments of Mn atoms at 4*a* and 4*b* sites obtained in the last experiment for $Ni_{50}Mn_{35}Sn_{15}$ alloy in austenitic ferromagnetic state at 271K.

In the light of these results, and with the aim of properly correlate atomic order and magnetic properties in Ni-Mn-Sn metamagnetic shape-memory alloys, a continuation experiment will be proposed to complete the study of the remaining members of this series: $Ni_{50}Mn_{25+x}Sn_{25-x}$ (x = 5, 12, 15)

[1] I. Unzueta, J. López-García et al. *In preparation*