

Experimental report

13/10/2023

Proposal: 5-25-290

Council: 4/2023

Title: Investigating the Kinetics of the Magnetoelastic Transformation of Fe-Rh Magnetocaloric Alloys

Research area: Materials

This proposal is a new proposal

Main proposer: Pablo ALVAREZ

Experimental team: Kenny PADRON ALEMAN

Pablo ALVAREZ

Jose Luis GARRIDO ALVAREZ

Local contacts: Gabriel Julio CUELLO

Samples: Fe_{100-x}Rh_x (x = 50, 51)

Instrument	Requested days	Allocated days	From	To
D20	1	1	25/09/2023	26/09/2023

Abstract:

Binary Fe_{100-x}Rh_x (48 ≤ x ≤ 54) alloys exhibit record-breaking giant magnetocaloric effect near room temperature in terms of the adiabatic temperature change. This result is originated from the first order magnetoelastic phase transition that these alloys undergo when the CsCl-type crystal structure (B2) cell volume changes by around 1 % changing the magnetic structure from antiferromagnetic to ferromagnetic upon heating. In the last few years, several works have highlighted the poor repeatability in the magnetostructural phase-transition characteristics. One of the aspects highlighted by some authors is an intriguing crystal or magnetic structure kinetics. To obtain systematic information on the matter, we have investigated the time dependence of the isothermal magnetization within the magnetostructural transformation for the near-equiatomic Fe₄₉Rh₅₁ and Fe₅₀Rh₅₀ bulk alloys, finding magnetic transition timescales up to 200 s long. To include the effect of the temperature on the kinetics of the transformation, we propose a neutron diffraction experiment in D20 in which we will analyze the time evolution of the magnetic transformation of Fe₄₉Rh₅₁ and Fe₅₀Rh₅₀ bulk alloys.

Report D20 Proposal 5-25-290

$\text{Fe}_{100-x}\text{Rh}_x$ ($48 \leq x \leq 54$) alloys undergo a first-order phase transition (FOPT) from the low-temperature antiferromagnetic (AFM) to the high-temperature ferromagnetic (FM), with complex nucleation and growth processes involving local strains and/or electronic structure modifications. These two magnetic phases exist in the CsCl-type crystal structure (B2 phase). The large variation of the magnetization from the AFM to FM phases, together with a strong magnetoelastic coupling, entails a large magnetocaloric (MC) effect. The use of MC material in magnetic refrigeration applications requires a good performance under high operating frequency, for which it is fundamental to investigate the kinetics of the transition. In the case of Fe-Rh alloys, the reported results are controversial. Keavney et al., for example, interpreted the evolution of the FM phase as islands arrested by zones in which the transition has not yet occurred, remaining static on the measurement time scale ($\lesssim 10^3\text{s}$) [1]. On the contrary, Feng et al. observed quite long incubation times ($\gtrsim 10^3\text{s}$) that increase monotonically as the equilibrium temperature approaches [2].

With this experiment, we will study the evolution of the cell parameter (see Fig. 1) and magnetic structure with time at specific temperatures on cooling and on heating around the FOPT. In the heating branch, the measuring temperature at which the neutron diffraction (ND) patterns were collected as a function of time (every 12 s for 12 min) was reached after increasing the temperature from 300 K, and decreasing from 350 K in the cooling branch. This thermal protocol was repeated for each temperature where the relaxation experiment was carried out. We selected the experimental configuration with the higher neutron flux (i.e., $\lambda = 2.41 \text{ \AA}$ and take off angle 42°). A motor was installed to rotate the bulk samples around the cane axis to find a position where the texture was less predominant. Owing to the allocated beam-time (1 day), we selected the sample $\text{Fe}_{49}\text{Rh}_{51}$, in which previous experiments showed the most intense relaxation phenomena.

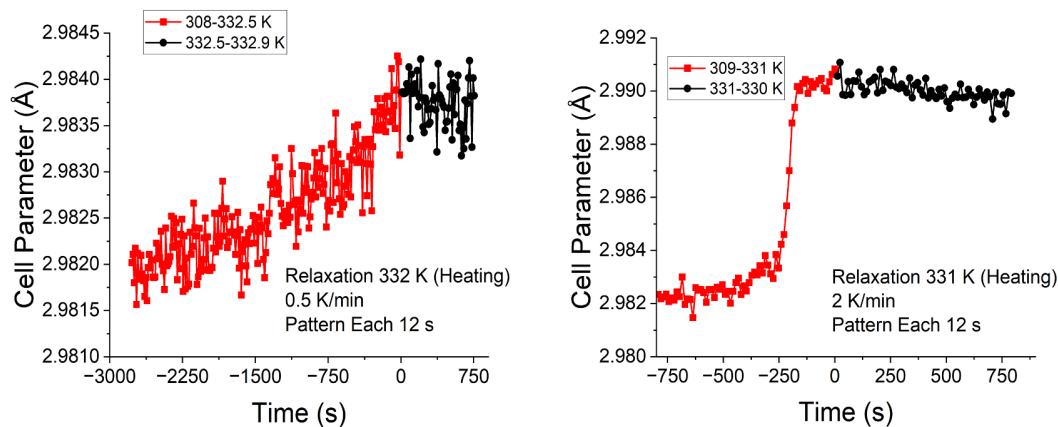


Figure 1. Preliminary results of the time dependence of the cell parameters obtained for the on-heating branches with T-ramps of (a) 0.5 K/min and (b) 2 K/min.

References

- [1] Keavney, D. J., et al. (2018). *Sci. Rep.*, 8, 1–7.
- [2] Feng, Y., et al. (2012). *J. Alloy. Compd.*, 538, 5–7