Global and Local Textures in Ni_2MnGa Ferromagnetic Shape-Memory Alloys

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Abstract

Ferromagnetic shape-memory alloys (FSMAs) have attracted great interests during the past several years, due to their potential applications as sensors and actuators. Among those FSMAs, Ni-Mn-Ga alloys with the chemical compositions close to the stoichiometric intermetallic compound, Ni_2MnGa, are mostly studied on many aspects, as they exhibit a giant shape-memory effect (SME) under applied magnetic fields. However, many fundamental issues remain unclear, such as crystallographic textures, stresses, and their interactions. Here we present the in-situ investigations of global and local textures in the Ni_2MnGa alloys by the neutron diffraction technique and the synchrotron X-ray diffraction technique during deformation and phase transformation. The in-situ measurements reveal the good 'memory' of both textures and stresses for the FSMAs, which is closely related to their functional performances.

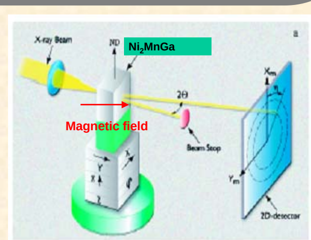
Introduction

- In FSMAs, giant magnetic-field-induced strains are produced through the motion of twin boundaries or reselections of twin variants.
- It is of great significance to develop some methods to improve the performance (responses to the magnetic field) by introducing textures (**texture design**), stresses (**stress design**), and high magnetic-field treatments (**training of variants**).
- Here we use the neutron diffraction technique and the synchrotron X-ray diffraction technique for characterizing *in-situ* the evolution of preferred orientations and stresses on the multi-scale.

Experimental Procedure

- Two 380g button ingots of $Ni_{48}Mn_{25}Ga_{22}Co_5$ and $Ni_{48}Mn_{30}Ga_{22}$ (at.%) were prepared by the induction method. The ingots were heated to 950 °C and kept for 2 hrs and, then, forged at 900 °C in the dies of a cast Ni_3Al alloy under a strain rate of about 10^{-2} s^{-1} to a final strain of about 60%. The martensite transformation temperatures, M_s, are 443K and 280K for $Ni_{48}Mn_{25}Ga_{22}Co_5$ and $Ni_{48}Mn_{30}Ga_{22}$, respectively.
- In-situ compression experiments were conducted on Residual Stress and Texture (REST) diffractometer at Studsvik Neutron Research Laboratory (NFL Studsvik). The in-situ phase transformation experiments under magnetic fields were conducted on the beam-line ID-11-C at the Advanced Photon Source (APS), Argonne National Laboratory.

Residual Stress and Texture (REST) diffractometer at NFL Studsvik



High-Energy X-ray beam-line (ID-11-C) at APS, Argonne National Laboratory

Figure 1. The instruments for in-situ measurements of textures and stresses

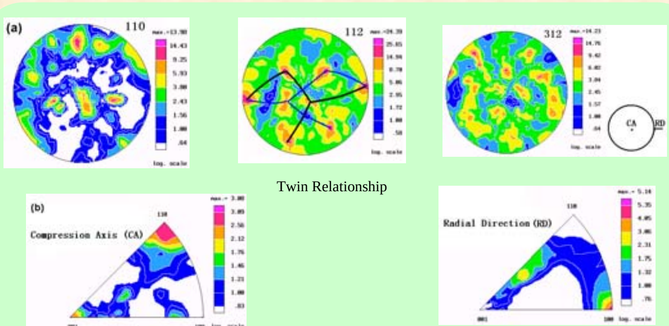


Figure 2. Global Textures in Deformed Ni48Mn25Ga22Co5

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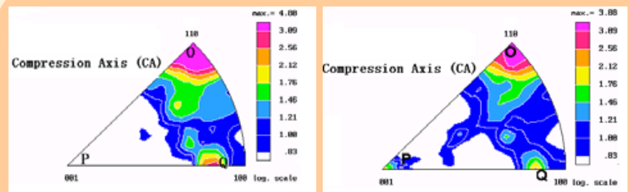

After compression (3%)

Heated to above M_s and cooling

Figure 3. Memory of textures after heating to above M_s

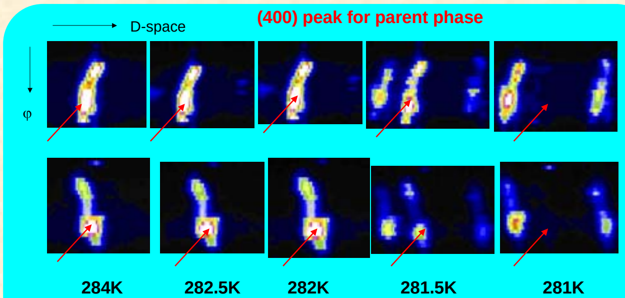

Figure 4. Memory of stresses after heating and cooling around M_s

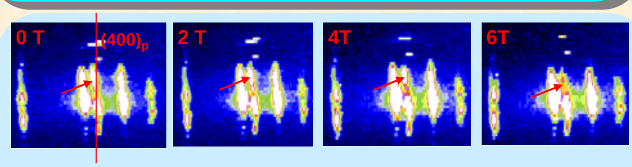

Figure 5. Diffraction pattern for Ni_2MnGa alloy under the magnetic field at 280K

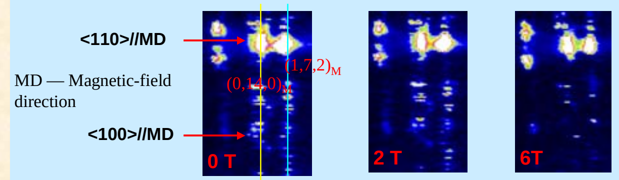

Figure 6. Diffraction pattern for Ni_2MnGa alloy under magnetic field at 4K

Conclusions

- **The shape-memory effect in FMSAs during deformation and heating can be revealed by the memory of textures and stresses.**
- **The local heterogeneity of phase transformation is clearly demonstrated by the in-situ measurements using the high energy X-ray diffraction technique.**
- **We find sharp phase transformations during the change of temperature, but no sharp transformation under magnetic fields (up to 6 T).**

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