Structure and Microstructure of Ni-Mn-Ga thin films

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Abstract

Ni-Mn-Ga thin films were dc magnetron sputter deposited onto well cleaned substrates of si(100) and glass in high pure argon atmosphere of pressure of 0.01 mbar using NiMnGa alloy targets prepared in our laboratory by vacuum induction melting technique. Pristine thin films were investigated. Crystal structure of the films was studied using x-ray diffraction (XRD) technique. Microstructure of the films was investigated using scanning electron microscope (SEM). XRD reveals that the films on glass substrates are amorphous and films on si(100) substrates posses $L2_1$ structure. SEM microstructure shows that the films on si(100) are polycrystalline in pristine form.

1. Introduction

NiMnGa is a ferromagnetic smart material capable of producing large magnetic field induced strains of about 10% using ferromagnetic shape memory effect and useful for making magnetic actuators. Production of such high magneto-actuations in thin films is potential and attracts researchers recent days for realization of miniaturized magneto mechanical systems such as MEMS, NEMS, Microbotics and control systems. The large magnetostrains associated with NiMnGa alloy is due to a relatively newly discovered phenomenon ferromagnetic shape memory effect by Ullakko et. al, in the year 1996. The ability of certain materials to remember their original shape under appropriate environments by self accommodation through structural transformation is the principle of ferromagnetic shape memory effect. Twinning and de-twinning of martensitic structural variants are the basis for such huge strains [1-7]. The aim of the present work is to prepare and study the structure and microstructure of dc magnetron sputter deposited pristine thin films of off-stoichimetric NiMnGa ternary alloy of composition $Ni_{55}Mn_{24.5}Ga_{20.5}$.

2. Experimental details

Sputtering targets of composition $Ni_{50}Mn_{30}Ga_{20}$ were prepared by vacuum induction melting technique in our laboratory. Required weight percentage of 99.9% pure Ni, Mn and Ga elements were melted using an alumina crucible under argon atmosphere by induction heating. The melt is transferred into 60 mm diameter steel mould and the required shape of bulk alloy was prepared. Hot isostatic pressing was performed on the bulk alloy to avoid porosity. The sample was heated up to 900^0 C and pressed at 100 MPa argon pressure for 3 hours. After hipping process the homogeneity and density of the alloy are increased and the porosity is considerably reduced. Thin disks of dimensions about 2” diameter and 0.5 mm thickness were cut from the bulk alloy using electrical discharge machining (EDM) wire cutting technique and the same was used as targets for the preparation of thin films. Thin films of Ni-Mn-Ga were dc magnetron sputter deposited at a sputtering power of 36W onto well cleaned si(100) and Glass substrates under argon atmosphere at a pressure of 0.01 mbar. The composition of the thin films was studied using energy dispersive x-ray analysis (EDX). Crystal structure of the thin films was studied using an x-ray diffraction (XRD) technique. Microstructure of the films was investigated using scanning electron microscope (SEM). The flow chart for the preparation of the films is given Fig.1. Photographs of NiMnGa alloy sputtering targets used for the preparation of thin films are shown in Fig.2.

3. Results and Discussion

a) Structure:

Fig.3 shows the x-ray diffraction (XRD) pattern of the thin films deposited on Si(100) substrates and Fig.4 shows the XRD pattern of the thin films deposited on as on glass substrates. The XRD pattern shows that the pristine films on si(100) substrates at room temperature are quasi-crystalline with atomic orientation along (220), (400) and (422) planes correspond to austenite phase of $L2_1$ structure [8-13]. Even though the targets possess martensitic microstcruture at room temperature, the sputtered films do not reveal any martensitic property and shows only austenite behavior. This variation is attributed to the variation in the composition of the target as well as the sputtered thin films [2, 14]. The XRD for the pristine films on glass substrates reveal that they are amorphous as evidenced by non-existence of any preferred orientations of atoms.

b) Microstructure :

Fig.5. shows the typical microstructure of the pristine thin films deposited on si(100) substrates studied using a scanning electron microscope (SEM). The microstructure reveals the existence of polycrystalline nature of the pristine films witnessed by large number of grain boundaries [15].

4. Conclusion

Thin films of Ni-Mn-Ga ferromagnetic shape memory alloy were prepared using dc magnetron sputtering technique. Structural and microstructural properties of the thin films were investigated. Crystal structure of the pristine films on Si(100) found to be $L2_1$ austenite phase. No crystal structure was observed on the films deposited on glass substrates in pristine form. Growth orientation of the thin films found to depend of the substrate material. Microstructure reveals the pristine films on Si(100) exhibit polycrystalline nature.

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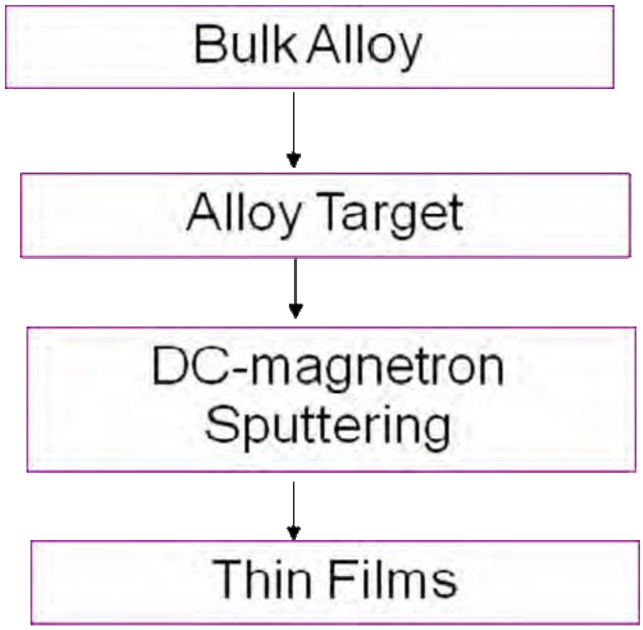

Fig.1. Flow chart for the preparation of films

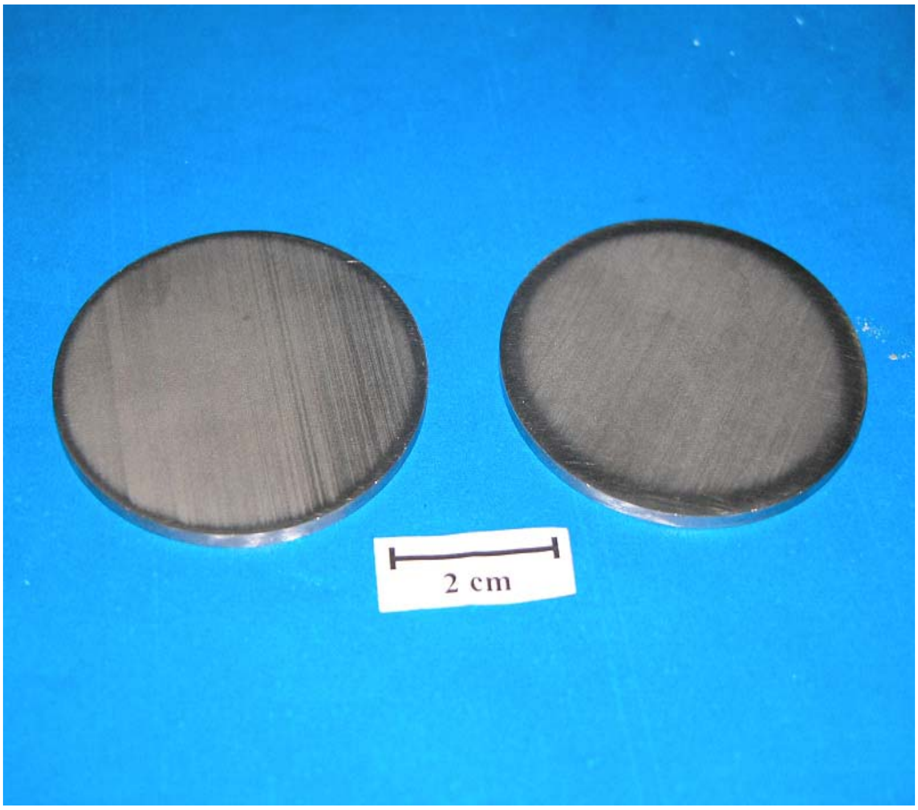

Fig.2. Photographs of $Ni_{50}Mn_{30}Ga_{20}$ Thin Film Targets

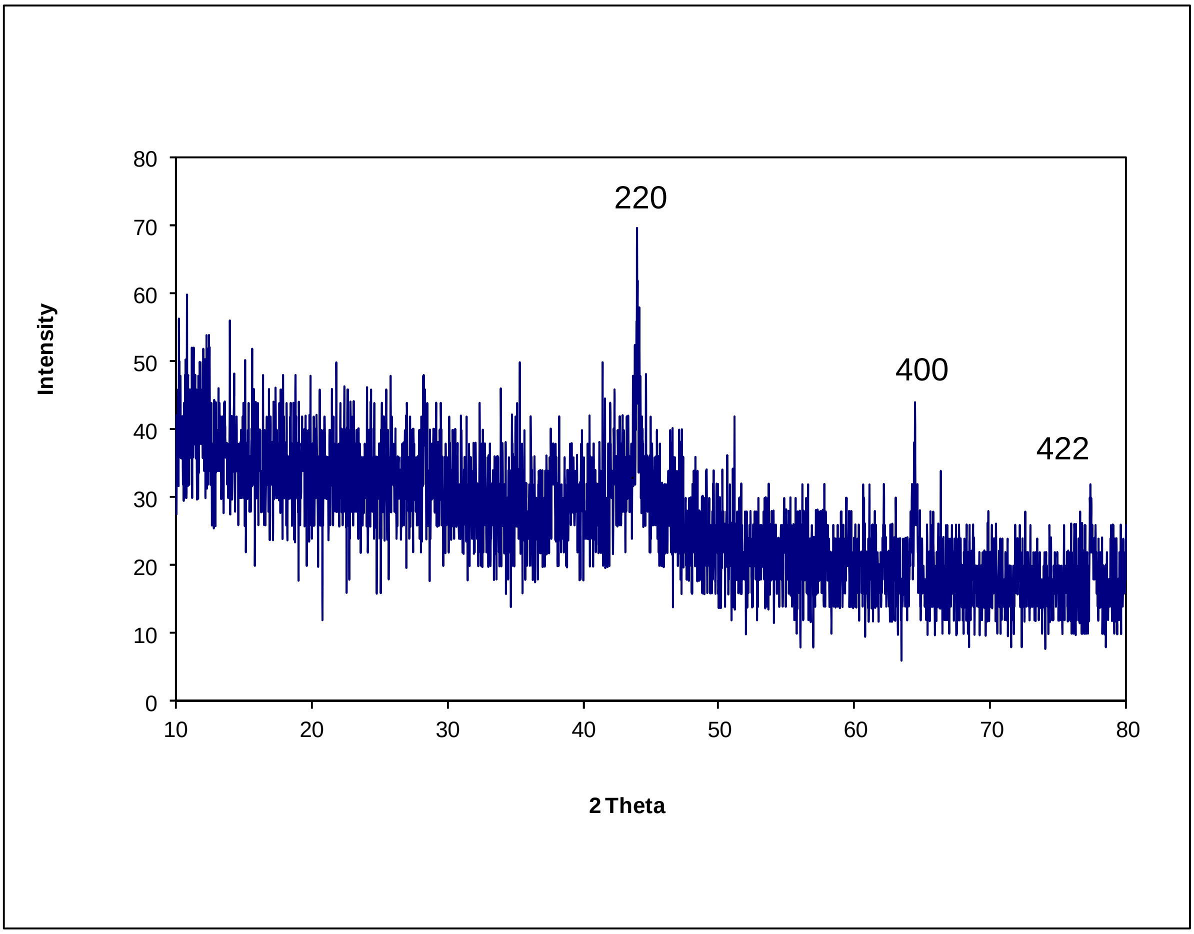

Fig.3. Typical XRD pattern of the thin films deposited on Si(100) substrates

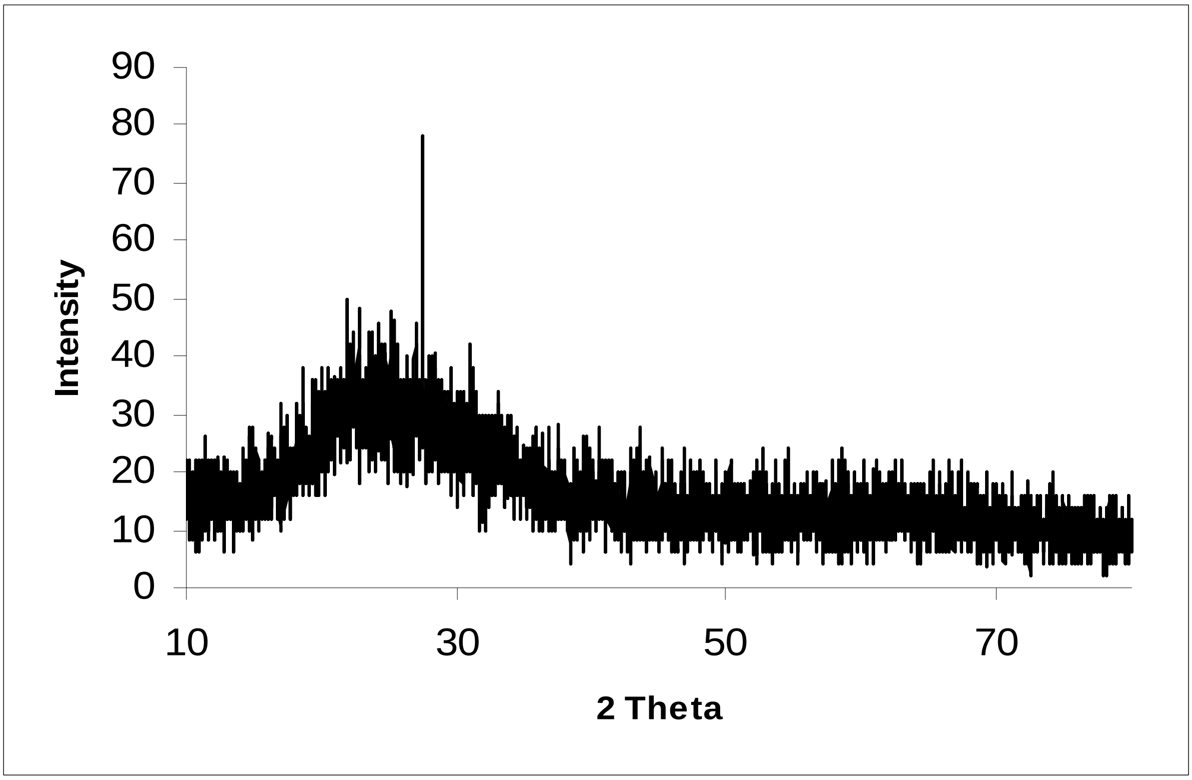

Fig.4. Typical XRD pattern of the thin films deposited on glass substrates

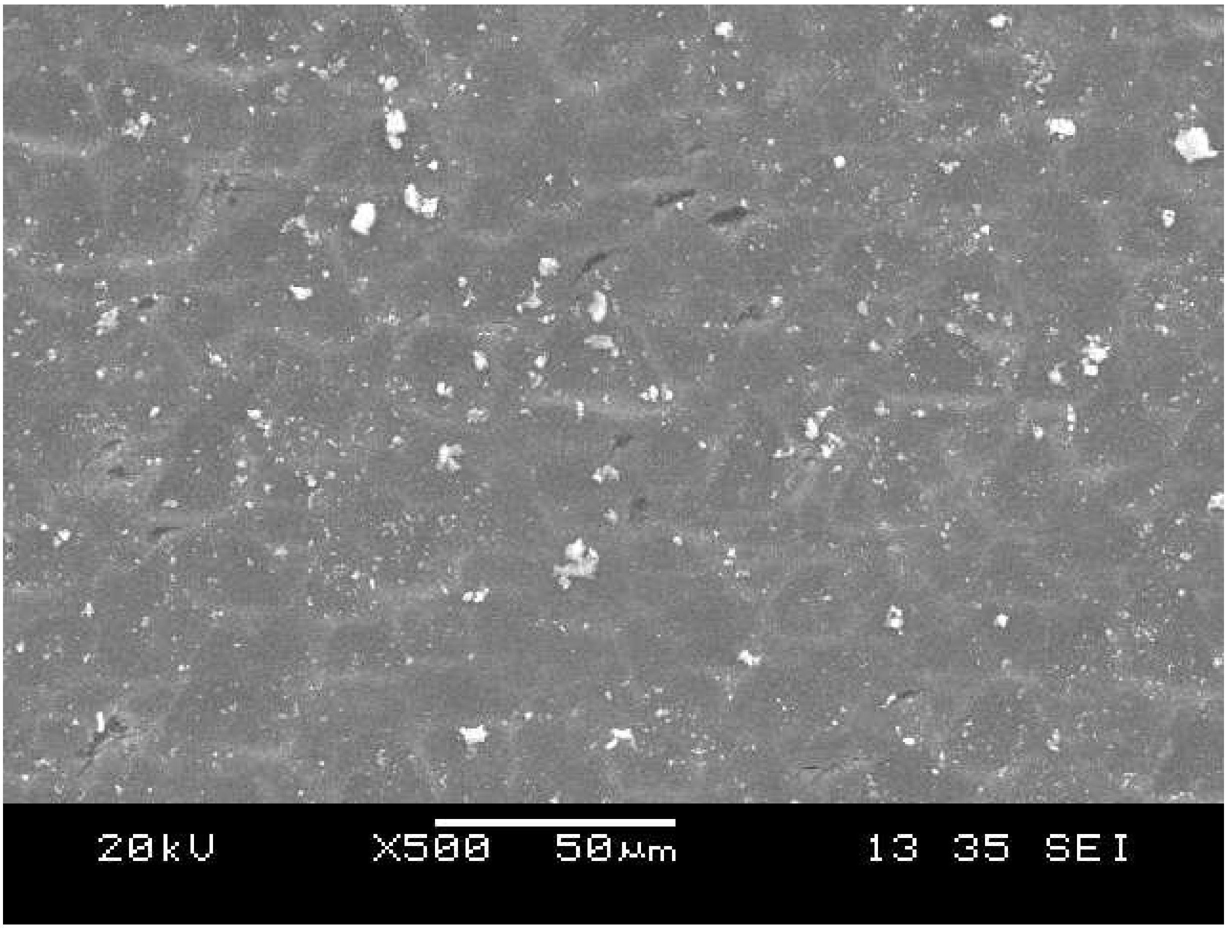

Fig.5. SEM Microstructure of Pristine Films on si(100)