Ni-Mn-In Based Shape Memory Alloy Thin Plate for Energy Harvesting Devices

E. Abe[1], M. Gueltig[2], H. Ossmer[2], H. Miki[3], M. Ohtsuka[4], M. Kohl[2], and T. Takagi[5]
[1] *Graduate School of Engineering, Tohoku University, Aramaki aza Aoba 6-3, Aoba-ku, Sendai, Miyagi, 980-8578, Japan*
[2] *IMT, Karlsruhe Institute of Technology (KIT), Postfach 3640, Karlsruhe 76021, Germany*
[3] *FRIS, Tohoku University, Aramaki aza Aoba 6-3, Aoba-ku, Sendai, Miyagi, 980-8578, Japan*
[4] *IMRAM, Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai, Miyagi, 980-8577, Japan*
[5] *IFS, Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai, Miyagi, 980-8577, Japan*
miki@fris.tohoku.ac.jp

Abstract :

1. Introduction

Shape memory alloys (SMAs), especially metamagnetic shape memory alloys (MSMAs) are attractive for micro-actuation due to their multifunctional properties. MSMAs show a martensitic transformation (MT) from a ferromagnetic austenitic (A) phase to an antiferromagnetic or paramagnetic martensitic (M) phase [1]. This induces a large magnetization change (ΔM), which can be used for actuation.

MSMA films produced by sputtering show very high *ΔM,* low hysteresis, and sharp transformations [2]. A stack of MSMA films can be used for thermal energy harvesting as shown in [2]. However sputtering is not suitable for making thicker films than a few µm. Recently, we proposed a novel way for making thin plates: Compression Shearing Method at Room Temperature (COSME-RT) [3]. COSME-RT is a powder metallurgy technique. Using this method, it is possible to make thin plates from MSMA sputtered films.

In this study, MSMA thin plates with 50 µm thickness fabricated by COSME-RT are characterized regarding magnetization, transformation temperatures, and mechanical properties. They are then applied to a device for thermal energy harvesting.

2. Results

Fig. 1 shows the thermomagnetization curve in a magnetic field of 0.05 T for a MSMA plate made by COSME-RT after annealing. From this curve, MT temperatures and the Curie temperature (T_c) are calculated. The T_c is 384 K, the MT starting and finishing temperatures, M_s and M_f are 366 and 356 K, respectively. The reverse MT starting and finishing temperatures, A_s and A_f are 368 and 373 K, respectively. Differential scanning calorimetry (DSC) was performed to validate the MT temperatures. The MT temperatures are close to the result of thermomagnetization curve, and the latent heat is measured to be 19 J/g.

A demonstrator device is fabricated based on the principle in [2]. The schematic of the application for energy harvesting is sketched in Fig. 2. A MSMA plate is fixed on the tip of a polyester foil cantilever. Additionally a miniature coil is applied as a power conversion unit. When the plate contacts the heat source, heating induces the reverse MT to the ferromagnetic phase and the magnetization increases. Because of the magnetic attraction force, the cantilever tip approaches the magnet. At the magnet, the MSMA plate cools below the transformation temperature and it returns to the heat source due to the low magnetization and the elastic reset force of the cantilever. This movement repeats and the periodic actuation leads to an induced current in the coil according to Faraday's law, as it moves through the magnetic field gradient of the magnet.