Improvement of microstructure and texture of hot extruded $Ni_{50}Mn_{29}Ga_{21}$ alloy using post heat treatments

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It is the aim of the present paper to show the results of the microstructure and texture analyses of $Ni_{50}Mn_{29}Ga_{21}$ alloy after post heat treatments at 1000°C. The initial microstructure of the hot extruded alloy is dynamically recrystallized with average grain size of about 100 µm. The texture is characterized by a strong fibre texture along the extrusion direction. After the post heat treatments the average grain size increases up to 600 µm and the trace of twinning planes is mostly aligned along the compression axis. Finally, synchrotron radiation is used for texture characterization. The results are discussed with respect to texture, grain growth and twinning behaviour.

1 Introduction

The development of Ni-Mn-Ga magnetic shape memory alloys started about 15 years ago [1]. Until now, magnetic-field-induced strain (MFIS) has been mainly reported for Ni-Mn-Ga single crystals [2, 3]. Therefore, to also obtain this effect in polycrystals, fabrication processes are needed to produce a strong texture. It was proven, that coarse grained Ni-Mn-Ga polycrystals with solidification texture show MFIS by twin boundary motion as large as 1% after proper treatment [4]. Another practical way to achieve a preferred crystallographic orientation in polycrystalline materials is hot extrusion [5, 6].

It is the aim of the present work to show the results of the microstructure and texture analyses of a hot extruded $Ni_{50}Mn_{29}Ga_{21}$ alloy after post heat treatments. To improve the microstructure and texture of the hot extruded state with regard to MFIS additional short-time compression and annealing under load were applied in order to find out the optimum parameter for the compression and thermal treatment process.

2 Experimental

Polycrystalline $Ni_{50}Mn_{29}Ga_{21}$ rods of 25 mm diameter and 400 mm length were prepared by hot extrusion at 1000°C. The master alloy chosen had a chemical composition of $Ni_{50}Mn_{29}Ga_{21}$ with a 5M modulated martensitic structure. The details of the hot extrusion processing are described in [5].

After hot extrusion the post heat treatments of the Ni-Mn-Ga samples were performed by using a deformation/quenching dilatometer DIL 805 A/D. The cube-shaped samples with edge length of 5 mm were inductively heated to a temperature plateau of 1000°C in this equipment (resolution of Δl=0.05 µm, ΔT=0.05°C). The samples were compressed up to 3, 5, 10, 15, 20, 25% strain and then annealed under load in Argon atmosphere for 60 min. The compression axis was always perpendicular to the extrusion direction (ED). Finally, the Ni-Mn-Ga samples were continuously cooled with a rate of 10 K/s. To characterize the microstructure optical microscopy and electron backscatter diffraction (EBSD) in the scanning electron microscope were applied.

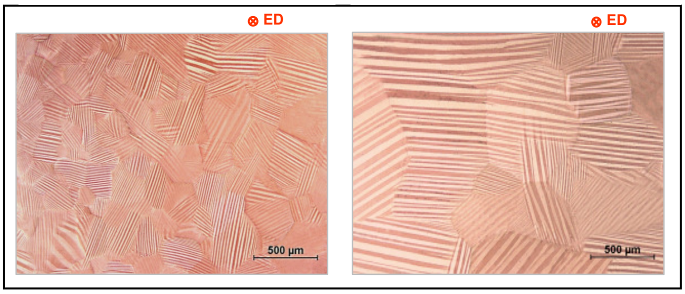
After the compression and annealing procedure the texture of the Ni-Mn-Ga samples was measured with high-energy synchrotron radiation (HESR). Due to the high penetration depth of synchrotron radiation, texture measurements in transmission allow for collecting orientation data from a large sample volume, i.e. with a good grain statistics. HESR (100 keV) on Ni-Mn-Ga alloys was carried out at DESY beam lines W2 and GKSS materials science beam line HARWI-II in Hamburg, Germany. A detailed description of the synchrotron texture measurement is given in [7].

3 Results and Discussion

3.1 Microstructure

Previous investigations have shown that the microstructure of the hot extruded $Ni_{50}Mn_{29}Ga_{21}$ alloy is dynamically recrystallized with a grain size of about 100 µm. Additionally, a strong fibre texture was found [5]. To approach single crystal behaviour Ni-Mn-Ga samples with a coarse grained microstructure and strong texture have to be produced. Therefore, to increase the grain size of the hot extruded alloy a heat treatment (T = 1000°C, from 1 h to 48 h) was applied. It was found that long-time annealing of 48 h is not necessary, because grain growth already ceases after short-time annealing of 60 min. The maximum grain size was approximately 300 µm [8]. Neutron texture measurements showed that the annealing step reduces the strength of the fibre texture [9].

3% strain 15% strain



a) b)

Figure 1. Microstructure of a hot extruded $Ni_{50}Mn_{29}Ga_{21}$ alloy after different compressive strains and annealing under load (compression direction perpendicular to ED).

With this background, further heat treatments with a short-time compression and annealing procedure were done. In Fig. 1 the microstructure after post heat treatments for two deformation degrees is shown. The grain size depends on the degree of deformation being 250 µm and 600 µm after compressive strains of 3% and 15%, respectively. After large deformation the trace of the twinning planes is preferentially aligned parallel to the compression axis.

3.2 Texture measurements

During extrusion the material mainly experiences axisymmetric tension. This deformation mode applied to Ni-Mn-Ga alloy in the B2 phase field produced a <100>/<110>/<111> cyclic fibre texture along ED with <110>/<111> clearly dominating in the off-central region of the extruded rod [10]. The compression test performed perpendicular to ED on samples cut from off-central regions yields a <111> fibre texture along the compression direction (Figure 2). All planes and directions mentioned in this paper are given in the cubic coordinate system which is related to the cubic axes of the parent $L2_1$ phase.

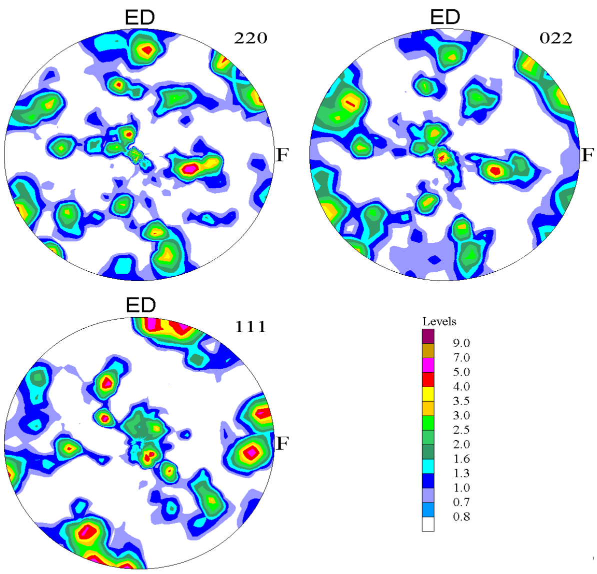


Figure 2. Pole figures of the hot extruded sample after post heat treatments (5% compressive strain and annealing under load) measured with HESR (ED - extrusion direction, F - compression direction)

4 Summary

Post heat treatments of a hot extruded $Ni_{50}Mn_{29}Ga_{21}$ alloy have shown that the microstructure can be improved with respect to grain size and texture by a further short-time deformation and annealing under load. A large grain size of 600 µm (average value) was achieved.

Optimal parameters found are:

- 15% compression and annealing under load at 1000°C,
- compression direction perpendicular to ED.

The texture of the heat treated material is a <111> fibre texture along the compression direction.

Acknowledgement

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