MA 21: Magnetic Shape Memory Alloys I

Time: Wednesday 10:15–13:00 Location: HSZ 103

MA 21.1 Wed 10:15 HSZ 103

Straining of Fe70Pd30 Films by Coherent Epitaxial Growth — •Jörg Buschbeck[1], Ingo Opahle[1,2], Gerhard Jakob[3], Ludwig Schultz[1], and Sebastian Fähler[1] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]Institute for Theoretical Physics, Johann Wolfgang Goethe University, Frankfurt am Main, Germany — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55128 Mainz, Germany

Martensitic transformations in the Fe70Pd30 magnetic shape memory alloy follow the Bain path, describing the conversion from fcc to bcc structure by a tetragonal distortion. According to density functional calculations, a flat energy landscape is expected along the Bain path. Since changes in tetragonal distortion only cost little energy, this allows for the stabilization of intermartensitic phases in strained Fe70Pd30 films. Straining is realized by pseudomorphic epitaxial growth of Fe70Pd30 films using magnetron-sputtering at room temperature on different epitaxial buffer layer prepared on MgO(100) substrates. Pseudomorphic film growth of 50 nm thick disordered Fe70Pd30 films is observed. In agreement, XRD measurements show a tetragonal distortion in the films which is determined by the lattice parameter of the buffer layer. The tetragonal distortion reaches exceptionally high values of up to 27.5%, covering most of the Bain path from fcc to bcc phase, reflecting the structural instability of Fe70Pd30 as predicted by theory. The stabilization by an epitaxial interface allows for the thorough investigation of the physical properties of intermediate phases inaccessible in bulk materials.

MA 21.2 Wed 10:30 HSZ 103

Stress relaxation and structure of vapor deposited FePd MSM films — •Tobias Edler, Lisa Kühnemund, and Stefan Georg Mayr — I. Physikalisches Institut, Georg-August-Universität Göttingen

The magnetoelastic properties of magnetic shape memory alloy thin films are fundamentally affected by the microstructure. For optimum performance epitaxial films are desirable, which requires a detailed understanding of processing parameters and their impact on film morphology. In the present contribution, we focus on $Fe_{70}Pd_{30}$ epitaxial films, which have been grown by vapor deposition on MgO single crystal substrates, both with and without the presence of an additional ion beam during film growth. A key parameter for epitaxial growth proves to be the stresses inside the film, as measured in situ with a laser-beam deflection method during film growth. Together with high-resolution TEM studies, these experimental results are compared to molecular dynamics simulations of the stress relaxation to track down the underlying atomic mechanisms. *Funded by the DFG-SPP 1239 (C4)*

MA 21.3 Wed 10:45 HSZ 103

Characterization of the transformation behavior of Fe-Pd ferromagnetic shape memory splats — •Iris Kock[1], Sven Hamann[2], Stefan Mayr[1], and Alfred Ludwig[2] — [1]Georg-August-Universität Göttingen, I. Physikalisches Institut, 37077 Göttingen, Germany — [2]Institute of Materials, Faculty of Mechanical Engineering, Ruhr-University Bochum, 44780 Bochum, Germany

The $Fe_{70}Pd_{30}$ system is part of the promising new class of ferromagnetic shape memory alloys (FSMA). $Fe_{70}Pd_{30}$ shows a reversible martensitic transformation and a magnetic field induced strain (up to 3%) by detwinning of martensite variants (MFIS effect). In comparison to conventional SMAs the speed of actuation is not limited by heat conduction. If the material could be arranged as a freestanding thin film and showed this MFIS effect, it would be best suited for micro-actuator applications. Therefore freestanding $Fe_{70}Pd_{30}$ films were fabricated using the splat-quenching technique. Temperature-dependent changes in crystal structure (x-ray diffraction), resistance and magnetization of the splats were investigated. It was found that all three methods allow the determination of transformation temperatures. The results were used to investigate the influence of different post-annealing treatments on the martensitic transformation behavior of $Fe_{70}Pd_{30}$ splats. A significant increase of transformation temperatures with increasing post-annealing temperature was observed. The authors gratefully acknowledge funding by the DFG SPP 1239.

MA 21.4 Wed 11:00 HSZ 103

Epitaxial growth of Ni_2MnGa films on perovskite manganite oxides — •Yuansu Luo, Jan Petersen, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen

Magnetic sharp memory (MSM) films Ni_2MnGa were sputtered onto perovskite manganite oxide layers, such as $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) to show a potential affect coupled with Jahn-Teller distortion and MSM effect. The manganite layer (80 nm) was deposited at deposition temperature T_s= 700°C on MgO(100) substrate and subsequently the MSM layer (150nm) at varied T_s in the range 500-600°C. Structural investigation was carried out by x-ray diffraction and scanning electron microscopy. The initial result indicates a well epitaxial growth of Ni_2MnGa on the LCMO layer, showing a martensitic phase at room temperature with twin structure strips along two vertical orientations. The microstructure of the samples strongly depends on T_s used. Compared to polycrystalline samples prepared on SiO_2, the epitaxial growth used here is advantageous to form the martensitic phase. (Supported by BMBF-project 13N10061 MSM-Sens)

MA 21.5 Wed 11:15 HSZ 103

Adaptive martensite phase in constrained epitaxial Ni-Mn-Ga films — •Stefan Kaufmann[1,2], Ulrich Rössler[1], Robert Niemann[1,2], Oleg Heczko[1], Jörg Buschbeck[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, PO Box 270116, 01171 Dresden, Germany — [2]Institute for Solid State Physics, Department of Physics, Dresden University of Technology, 01062 Dresden, Germany

Following the concept of Khachaturyan et al. [1] of adaptive martensite we show that the tetragonal, non-modulated (NM) and the orthorhombic 7M modulated phase in Ni-Mn-Ga magnetic shape memory films fulfil all requirements for an adaptive phase formation. By means of epitaxial film growth we could confirm this concept and probe the transformation path in detail. The constraint by the substrate leads to films with austenite, 7M and NM phase coexisting over a very broad temperature range, contrary to the first order phase transformation common for bulk. Since the pole figures for the NM martensite violate the 4-folded symmetry of the cubic austenite, this shows that NM was not formed directly from the austenite but through the adaptive 7M phase. The rigid substrate is used as a reference frame and allows confirmation of the transformation matrix from austenite to 7M martensite by the Wechsler-Lieberman-Read theory. The results prove the orthorhombic 7M phase not to be an intermediate, thermodynamically stable phase but an adaptive phase stabilized due to the constraint by the substrate-film-interface. The resulting complex microstructure is analyzed from a few *nm* to the μm range. [1] Khachaturyan A.G. et al., Phys. Rev. B 43, 10832 (1991)

MA 21.6 Wed 11:30 HSZ 103

Magnetic control of twinning structure in thin Ni_2MnGa films — •Tobias Eichhorn[1], Catherine Anne Jenkins[2], Michael Kallmayer[1], Hans-Joachim Elmers[1], Gerhard Jakob[1], and Michael Huth[3] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Department of Materials Science and Engineering, University of California, Berkeley, 94720, USA — [3]Physikalisches Institut, Goethe-Universität Frankfurt, 60438 Frankfurt/Main, Germany

We report on the preparation and investigation of thin epitaxial films of the ferromagnetic shape memory alloy Ni_2MnGa. Sample preparation is done by dc-magnetron sputtering from different NiMnGa targets onto heated substrates. The orientation of the film can be tailored by selecting different substrates. The complex crystal structure is studied by temperature-dependent x-ray diffraction in 4-circle geometry. Magnetometry measurements reveal the martenistic transformation that is crucial for the appearance of magnetically induced shape changes. To get insight on microscopic magnetism and electronic structure x-ray absorption spectroscopy and magnetic circular dichroism measurements have been performed at the German synchrotron light source BESSY II (Berlin). Free-standing films that will be needed for technical applications have been prepared using water-soluble NaCl substrates. Another approach is the fabrication of free-standing cantilevers that allow the observation of magnetically induced changes in the microstructure. This work is part of the priority program SPP

1239 and founded by the DFG.

MA 21.7 Wed 11:45 HSZ 103

Twin variant distribution and twin boundary motion in single and polycrystalline Ni2MnGa imaged by electron back-scatter diffraction — •Nils Scheerbaum, Jian Liu, Ludwig Schultz, and Oliver Gutfleisch — IFW Dresden, Institut für Metallische Werkstoffe, P.O. Box 270116, D-01171 Dresden, Germany

Magnetic shape memory (MSM) alloys show large magnetic field induced strain of several percent caused by a magnetic field-induced twin boundary motion within the martensite phase. Ni2MnGa single crystals show a maximum strain of 6% or 11% depending on the present martensite phase (5M or 7M, respectively). The existence of mobile twin boundaries is crucial in MSM alloys. Therefore, the twin distribution was analysed by electron back-scatter diffraction (EBSD) in a Ni49Mn27Ga24 single crystal (at.%) as well as in polycrystalline Ni50.9Mn27.1Ga22.0 fibres (produced by crucible melt extraction, 60-100um diameter, several mm length). EBSD was done at room temperature, at which in both samples the ferromagnetic 5M martensite phase is present (determined by XRD and magnetometry). In the single crystal, the twin variants are separated from each other by straight twin boundaries. Due to constraints from grain boundaries in the polycrystal, the twin boundaries are not always straight and their density increases near grain boundaries, especially in corners, where several grains touch. Both samples show magnetic field induced twin boundary motion giving rise to 1% and 6% strain for polycrystalline fibres and single crystal, respectively. This was investigated by magnetic measurements and imaged by EBSD for polycrystalline fibres.

MA 21.8 Wed 12:00 HSZ 103

Ni-Mn-Ga: annealing for microstructure development — •Franziska Thoss[1], Martin Pötschke[1], Gaitzsch Uwe[1], Jens Freudenberger[1], Wolfgang Anwand[2], Stefan Roth[1], Bernd Rellinghaus[1], and Ludwig Schultz[1] — [1]IFW Dresden — [2]FZ Dresden-Rossendorf

Recently the Magnetic Shape Memory Effect was observed in polycrystalline alloys near the stoichiometric composition Ni_2MnGa. The microstructure plays a crucial role for the achievable magnetic field induced strain, because grain boundaries inhibit twin boundary motion.

The microstructure development with regard to grain growth behavior was investigated for polycrystalline Ni-Mn-Ga samples of various compositions. Therefore, the influence of the annealing temperature and annealing time was studied. Grain growth was only observed for compositions with a Ni-content of less than 50 at.-%. The suspected existence of constitutional vacancies as a possible reason for the different grain growth behavior of such compositions was excluded by Positron Annihilation Spectroscopy. In order to activate grain boundary motion and henceforth grain growth in the MSM-active alloy $Ni_{50}Mn_{29}Ga_{21}$ the samples were compressed during the first minute at the annealing temperature at various degrees of deformation. At a deformation between 8 % and 10 % compression we observed a sharp threshold towards grain growth.

MA 21.9 Wed 12:15 HSZ 103

Twinning behaviour of textured polycrystalline NiMnGa — •Robert Chulist[1], Martin Pötschke[2], Andrea Böhm[3], Heinz-Günter Brokmeier[4], Thomas Lippmann[5], Carl-Georg Oertel[1], and Werner Skrotzki[1] — [1]Institut für Strukturphysik, Technische Universität Dresden, 01062 Dresden — [2]Institut für Metallische Werstoffe, Leibniz-Institut für Festkörper und Werstoffforschung, 01069 Dresden — [3]Fraunhofer-Institut für Werzeugmaschinen und Umformtechnik, 01187 Dresden — [4]GKSS Forschungszentrum, 21494 Geesthacht — [5]GKSS Forschungszentrum, 21502 Geesthacht

Magnetically actuated shape memory alloys such as NiMnGa have recently attracted special attention due to large strains achieved by the reorientation of martensitic twin variants in which twin boundaries are highly mobile. Until now, a magnetic field induced strain (MFIS) has been mainly reported for NiMnGa single crystals. Since for large-scale production growth of single crystals is economically unfavourable, it is necessary to investigate polycrystalline samples on their suitability for MFIS. Therefore, the texture of NiMnGa alloys obtained by the different fabrication processes has been measured by diffraction of high energy synchrotron radiation and neutrons. The twinning behaviour will be discussed with respect to type of texture, grain size, phase transformations including variant selection, and MFIS.

MA 21.10 Wed 12:30 HSZ 103

Preparation of textured Ni-Mn-Ga alloys — •Martin Pötschke, Uwe Gaitzsch, Claudia Hürrich, Franziska Thoss, Stefan Roth, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden, Helmholzstr. 20, 01069 Dresden

NiMnGa alloys have gained large research interest because of their possible application as magnetic shape memory materials. This effect is caused by the motion of twin boundaries in a magnetic field. Up to now most of the research was concentrated on single crystals. However, the preparation of single crystals is a time consuming and cost intensive process and compositional changes along the growth axis as well as segregations may occur. This is why for technical applications there is a great interest in polycrystals. To extend this effect to polycrystals, directional solidification was applied in order to prepare coarse grained, textured samples. Stationary casting in a pre-heated ceramic mold mounted on a copper plate was employed to generate a heat flow towards the bottom of the sample and thereby a directional solidification in the opposite direction. The martensitic transformation temperature which strongly depends on the composition was monitored by DSC, and it is shown that the chemical homogeneity along the sample axis is improved in likewise treated samples. The preferred solidification-induced growth direction was determined by EBSD. Investigations on the influence of MnS - precipitates in the samples, originating from the used rare Manganese, are discussed. The results are compared to samples, which were prepared by a Bridgeman method with draw rates in the range of several 100 mm/h to obtain a texture.

MA 21.11 Wed 12:45 HSZ 103

Observation of pulsed field induced twin boundary motion in bulk NiMnGa — •Ryan Yiu Wai Lai, Jeffrey McCord, Rudolf Schaefer, and Ludwig Schultz — Leibniz-Institute for Solid State and Materials Research, P.O.Box 270116, Dresden D-01171, Germany

A study of the twin boundary motion in bulk NiMnGa magnetic shape memory single crystals under pulsed magnetic fields with various rise-times is presented. A dynamic actuation experimental setup with the ability to apply mechanical stress and pulsed magnetic field perpendicularly is developed in cooperation with time-resolved microscopy. Reversible twin boundary motion activated by repetitive pulsed fields with rise-time down to 1 ms is directly observed. The maximum field induced strain increases with reducing rise-time. The mechanism of the enhancement of the twin boundary mobility will be discussed. Funding through the DFG priority program SPP1239 is gratefully acknowledged.