Magnetic domain structure of a Ni-Mn-Ga magnetic shape memory alloy studied by electron holography

K. Vogel, M. Linck, A. Lubk, D. Wolf and H. Lichte

Triebenberg-Labor, Institut für Strukturphysik, Technische Universität Dresden, 01062 Dresden, Germany

karin.vogel@triebenberg.de
Keywords: electron holography, Lorentz microscopy, magnetic shape memory alloys

Ni-Mn-Ga magnetic shape memory alloys are considered to have a high potential for new actuating devices and sensors. The large magnetic-field-induced strain (6-9%) observed in these alloys is caused by magnetic-field-controlled twin boundary motion [1], [2]. For understanding the mechanism of twin boundary motion and the correlation between microstructure and magnetic domain structure a comprehensive characterization of microstructure as well as magnetic structure is required. Here we report on application of electron holography in addition to conventional transmission electron microscopy and Lorentz TEM for the characterization of a polycrystalline $Ni_{50}Mn_{30}Ga_{20}$ alloy.

While the conventional in-focus bright-field image shows the twin-band microstructure of the martensitic material (Figure 1a), the strongly defocused Lorentz image of the same sample area (Figure 1b) shows the magnetic domain walls as bright and dark lines. Two types of magnetic domain walls are observed: 1) walls that coincide with the twin boundaries, and 2) walls that run through the twins and form a typical zig-zag pattern when they cross the twin boundaries.

In order to get more information on the magnetization distribution inside the domains we apply electron holography. The reconstructed phase image (Figure 2b) gives a coarse impression of the magnetization distribution projected into the recording plane. However, the phase image also contains information on thickness variations. Since we know from the amplitude image that the investigated sample area is not completely flat but slightly wedge-shaped, a thickness correction as suggested in [3] was applied. From the thickness-corrected phase image one can calculate a gradient image that shows the shape of the domains and the direction of the magnetization in the domains [4]. From the phase gradient image (Figure 2c) we conclude that the domain walls within the twins are 180° walls.

1. S. J. Murray, M. Marioni, S. M. Allen, R. C. O´Handley, T. A. Lograsso, Applied Physics Letters **77** (2000) p886.
2. A. Sozinov, A. A. Likhachev, N. Lanska, K. Ullakko, Applied Physics Letters **80** (2002) p1746.
3. M. Gajdardziska-Josifovska, M. R. McCartney, Ultramicroscopy **53** (1994) p291.
4. V. C. Solomon, M. R. McCartney, D. J. Smith, Applied Physics Letters **86** (2005) 192503
5. We thank Dr. Andrea Böhm (Fraunhofer IWU Dresden), and Dr. Stefan Roth (IFW Dresden) for the specimens. This work was supported by Deutsche Forschungs-gemeinschaft within DFG Priority Programme 1239.

DOI: 10.3217/978-3-85125-062-6-494 , © Verlag der TU Graz 2009

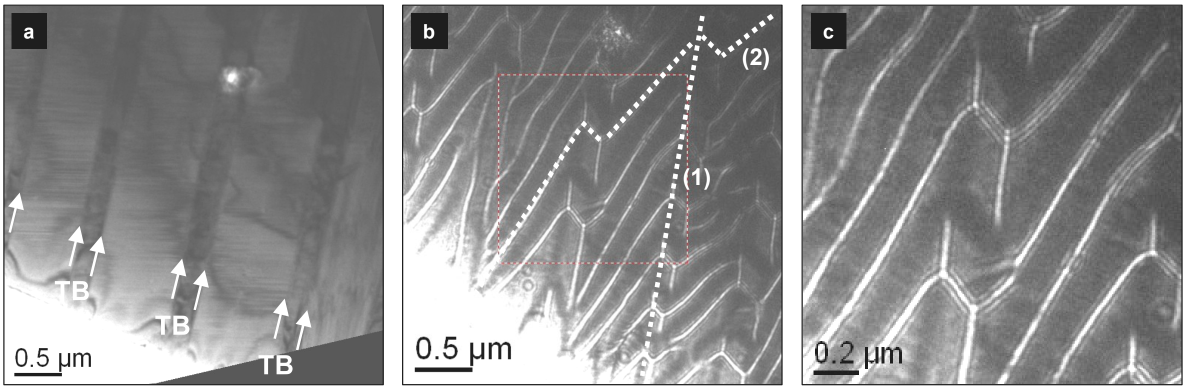

Figure 1. a) In-focus bright-field image of the twin-band microstructure, twin-boundaries (TB) are marked by arrows. b) Lorentz image (underfocus) showing magnetic domain walls as bright and dark lines. Domain walls appear at the twin boundaries (1) and within the twins (2). c) Subimage from image b) revealing interference fringes in the bright lines.

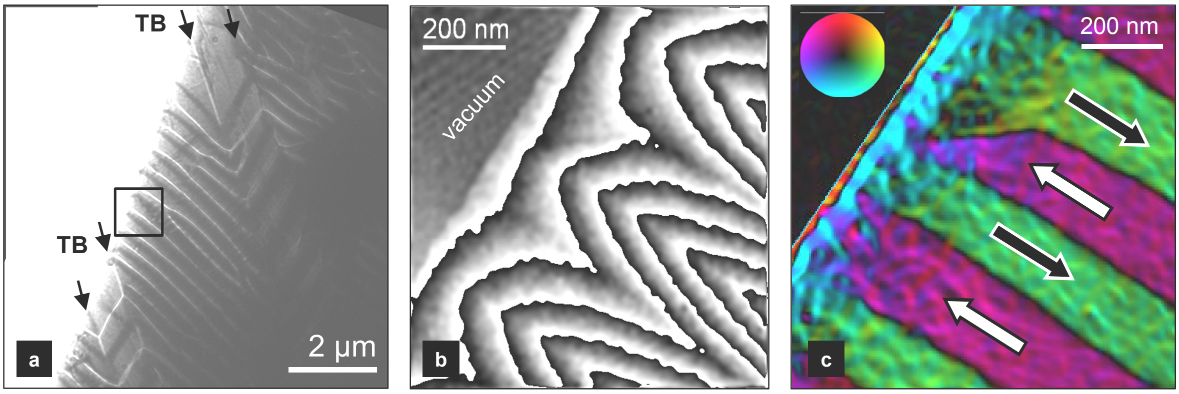

Figure 2. Analysis of domain walls within a broad twin-band. a) Lorentz image (overfocus) showing the position of hologram acquisition marked by the box. b) Reconstructed phase image containing information about the magnetization and the thickness variations. c) Color-coded gradient image calculated from the thickness-corrected phase image. The color wheel indicates the direction of magnetization. In neighboring domains the direction of magnetization changes by 180° as indicated by the arrows.

W. Grogger, F. Hofer, P. Pölt (Eds.): MC2009, Vol. 3: Materials Science,
DOI: 10.3217/978-3-85125-062-6-494 , © Verlag der TU Graz 2009