Intermartensitic transformation between modulated structures in Ni-Mn-Ga(-Fe) single crystal

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Heusler alloys close to stoichiometric Ni_2MnGa undergo a sequence of difussionless, displacive phase transformations from parent, cubic austenite to various martensitic or ferroelastic phases, modulated 10M and 14M (also marked 5M and 10M) and non-modulated (NM) tetragonal phase depending on composition. Often the cascade of intermartensitic transformations (10M-14M-NM) is observed with decreasing temperature or with increasing mechanical stress [1]. Owing to ferromagnetic state and highly mobile twin boundaries in modulated phases the relatively weak magnetic field can induce the reorientation of ferroelastic domains via twin boundary motion resulting in giant magnetic-field-induced strain up to 12% in single crystal [2] called magnetic shape memory (MSM) effect [3]. Although the martensitic transformation is relatively well understood the nature of intermartensitic transformation (IMT) is still disputed. One reason is that even the character of modulated phases is not settled [4-6]. Understanding IMT can provide some clue to the character of modulated phases and has also practical impact as IMT limits the operational range of MSM effect. Despite the various studies performed on polycrystalline samples, little neutron research has been done on single-crystals. Regarding the complex nature of the modulated phases and continuing discussion about their character (nanotwinning v. harmonic modulation) [4-6] only single crystalline studies represent proper way in attempt to understand the 10M-14M intermartensitic transformation. The neutron diffraction as bulk method is particularly suitable for direct comparison with magnetic [7] and transport measurements [6].

Here we present study of 10M-14M transformation by neutron diffraction using the D9 and D10 single-crystal four-circle diffractometers and CYCLOPS (neutron Laue single-crystal diffractometer) in ILL Grenoble. The Laue method allowed continuous tracing of the transition and broader survey of the reciprocal space with temperature revealing any changes in crystal orientation and newly occurring twinning in transformed phase. Additional laboratory X-ray diffraction using rotating anode diffractometer gave an further insight and better precision. The q-scans measured across the transition revealed the details of the modulation pointing to their nanotwinning character. Fine features in the q-scan patterns suggested the traces of 10M within 14M phase in the temperature well below IMT. The structural changes indicated by the diffraction were related to the changes of magnetic properties. In presentation we will also look on preference of 14M phase in epitaxial thin films compared to bulk single crystal.

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