NANOSTRUCTURAL CHARACTERISATION OF Ni-BASED SHAPE MEMORY MATERIALS

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Several Ni-based intermetallic systems such as Ni-Ti, Ni-Mn-Ga, Ni-Al and Ni-Mn are well known for their shape memory and superelastic characteristics. These functional behaviours are due to martensitic or related transformations occurring in these materials. In order to improve the existing properties, the underlying structural changes have to be documented by advanced TEM methods on the micro- as well as nanoscale.

In bulk and splat-cooled Ni-Al the atomic structure of macrotwin boundaries in the martensitic tetragonal \(L_10\) structure has been investigated by HRTEM and explained on the basis of linear elasticity theory. Bending of microtwin needles as well as crossing variants have been observed (figure 1). The bending can be related with the change in volume fraction when approaching the macrotwin interface and follows the expected curvature when taking the lattice distortions of the martensitic transformation into account. In melt-spun Ni-Al several structural inhomogeneities have been found. Due to the severe dependence of the martensitic transformation temperature on composition, slight composition fluctuations at the nm range induce severe local changes in the structure, i.e. retained austenite islands inside a twinned martensite plate as well as small martensite nuclei in the austenite matrix.

The effect of the structural transformation and local composition fluctuations on the electronic structure of some Ni-based intermetallics (Ni-Al, Ni-Ti, Ni-Mn) has been documented by a detailed EELS and ELNES study. It is concluded that the formation of these intermetallic compounds causes measurable changes in the fine structure of the Ni \(L_{3,2}\) edge (see figure 2) which can be explained by hybridisation between Ni and transition metal d bands, although the charge transfer does not exceed 0.1e/atom. The structural transformations, however, do not cause significant changes in the EELS spectra that were obtained with an energy resolution of 1.1 eV.

In Ni-Ti the multi-slice least-squares (MSLS) method in which digitally captured electron diffraction data is treated by the Rietveld method was used to optimise the atomic structure of the R-phase. Diffraction patterns are obtained with a 50 nm probe, thus avoiding overlapping intensities from different variants, which hampers the investigation by classic SAED, CBED or X-ray diffraction. As a result the \(P\bar{3}\) space group is suggested with a symmetric shuffle of the 2d Ni and Ti atoms located in one out of three original \{111\}B2 planes, as seen in figure 3. Observed domain walls are explained as mirror walls switching the up/down shift.

References
1 Ball, J.M., Schryvers, D., in The formation of macrotwins in NiAl martensite, Hong Kong, 2001 (Kluwer), (in press).

Figure 1. Some structural features observed at crossing microtwinned plates in Ni-Al martensite

Figure 2. Experimental ELNES of (a) different Ni-based compounds and (b) different structures in NiTi structures. (c) and (d) calculated spectra for the same compounds and structures.

Figure 3. P3 cell of the R-phase as suggested on the basis of an MSLS investigation