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Effects of Domain Structure on Diffraction from NiMnGa

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Abstract – Electron diffraction and STEM were used to investigate diffraction effects in NiMnGa martensite. At the smallest size scale, diffuse satellites were found to arise from regular features several atomic planes thick. At a slightly larger length scale, coherent scattering from twins a few nanometers thick introduced aperiod diffraction intensities that appear as streaks in the diffraction pattern. These streaks have been interpreted to arise from an incommensurate structure, or alternatively, from variations in the thickness of an adaptive phase. This work shows the intensity variation along the streaks is highly sensitive to the volume of difracting material.

The nature of the structural transformations associated with thermoelastic and magnetoelastic behavior in Ni-Mn-Ga ferromagnetic shape memory alloys is an area of continuing interest. Copious twinning on multiple size scales complicates structure studies in this system because diffraction data represents an average over a collection of many twins rather than a sum of a small number of single crystals. As a result, observed martensite phases are described using a variety of structural models including an adaptive tetragonal phase, commensurate modulated phases, and incommensurate modulated phases [1,2]. These descriptions account for various features found in diffraction patterns, but they are physically different structures. In this investigation, we investigate the martensite structure in a Ni-20Mn-25Ga alloy (e/a=7.65) using high-resolution transmission electron microscopy, scanning transmission electron diffraction and electron diffraction with various electron probe sizes to explore the origin of diffuse satellites and aperiodic diffraction spots.

The origin of diffuse satellites observed around the fundamental reflections in Figure 1 is a set of very regular features that are no more than several atom planes thick and found within individual twins (Figure 2). These features appear to be related to strain or chemical ordering. Also, the periodicity of diffraction spots along the streaking direction is very sensitive to the size of the region sampled by the electron beam. Figure 3 shows diffraction patterns taken from one region with two different beam diameters. A relatively large beam diameter of 10 nm (Figure 3a) produces streaks with aperiodic intensity along the streaks whereas the streaks almost disappear entirely when a smaller beam diameter of 2 nm is used (Figure 3b). This finding implies the streaks may not be an instrinsic feature of the martensite structure.

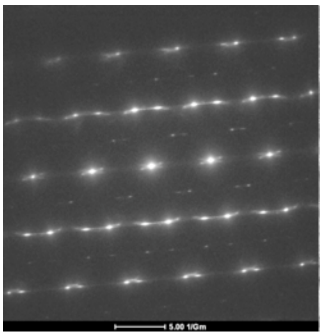

Figure 1: Electron diffraction pattern from Ni-20Mn-25Ga showing 2M twin spots, aperiodic intensity along direction of streaks, and diffuse satellites near fundamental reflections.

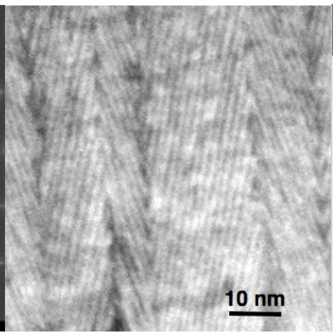

Figure 2: STEM image showing fine layer contrast responsible for the diffuse satellites.

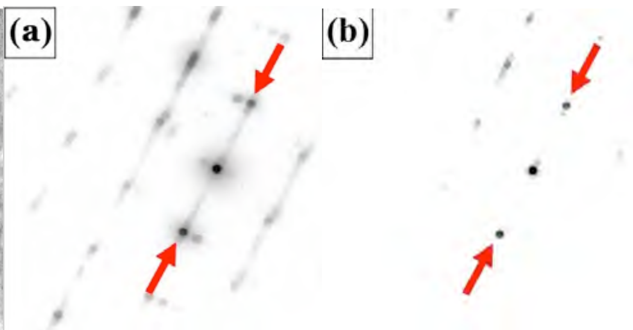

Figure 3: **(a)** Diffraction pattern obtained using an electron probe roughly 10nm in diameter; **(b)** diffraction pattern from the same region using a 2 nm probe showing loss of streaks.

References

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