Microstructural evolutions associated with martensitic and intermartensitic transformations in ferromagnetic Ni-Mn-Ga alloys

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Abstract

Over the last two decades, ferromagnetic Ni-Mn-Ga alloys have attracted considerable attention due to their potential applications in new-generation sensor and actuator devices. Giant magnetic-field-induced strains can be obtained in martensite state through the reorientation of martensite variants. Thus, the configuration of martensite variants is considered as a decisive factor to achieve large magnetic shape memory effect. Based upon the spatially-resolved electron backscatter diffraction analysis, the microstructural evolutions associated with the martensitic transformation (austenite to 7M martensite) and the intermartensitic transformation (7M martensite to NM martensite) were investigated on a polycrystalline $Ni_{53}Mn_{22}Ga_{25}$ alloy. As clearly evidenced, the grain-interior nucleation of 7M martensite led to the formation of the diamond-shaped microstructure over the parent austenite matrix. This diamond-like microstructure underwent further growth through an isotropic expansion with the coordinated outward movement of four sided habit planes, followed by an anisotropic elongation with the forward motion of type I twins. A two-step growth model was proposed to depict the specific morphology and crystallography of 7M martensite, produced as the consequence of energy minimization and kinematic compatibility. The characteristic combination of martensite variants and the underlying self-accommodation mechanism in the martensitic transformation were addressed in terms of minimum total transformation strain. For the 7M to NM intermartensitic transformation, it proceeded in an in-plate manner (through atomic reshuffling and lattice distortion) with specific orientation relationships between the two martensitic phases, accompanied by the thickening of martensite plates and the surface relief effect. A two-step shear mechanism was proposed to account for the formation of NM martensite during the intermartensitic transformation. The present results may not only deepen our understanding of special martensite microstructures in ferromagnetic shape memory alloys, but also provide some fundamental information on microstructure design and property optimization of these novel functional alloys.