Development of laser powder bed fusion fabricated Ni–Mn–Ga magnetic shape memory alloys for actuator applications

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Abstract

This presentation discusses recent advances in the processing of Ni–Mn–Ga-based magnetic shape memory alloys (MSMAs) using laser powder bed fusion (PBF-LB/M), with emphasis on the role of process parameters in determining microstructure and functional performance. Ni–Mn–Ga single crystals are capable of exhibiting giant magnetic field induced strains (MFIS) of up to 6–12%, enabled by magnetic field-induced lattice reorientation through the motion of martensitic twin boundaries. Under suitable conditions, this response can occur in both modulated and non-modulated martensite, depending on twinning stress, magnetic anisotropy, and the prevailing martensitic structure. Replicating this behaviour in additively manufactured polycrystalline materials is challenging. Grain boundary constraints restrict twin boundary motion and reduce the degree of lattice reorientation, and the functional response is highly sensitive to small variations in chemical composition and crystal quality. The presentation explains how PBF-LB/M process parameters influence the selective vaporisation of Mn during processing and how this effect can be systematically controlled. This provides a route for in-situ tuning of the final alloy composition, martensite structure and transformation temperatures, and ultimately the attainable MFIS. Processing and post processing strategies to promote the formation of coarse grained, bamboo like microstructures are addressed, focusing on reducing grain boundary density and promoting crystallographic textures that enable more effective twin boundary motion and lattice reorientation. The influence of build direction and thermal gradients on grain growth is discussed in relation to functional optimisation. Selected examples demonstrate that PBF-LB/M fabricated Ni–Mn–Ga can develop large, fully reversible MFIS approaching those achieved in conventionally grown single crystals. These results underline the potential of PBF-LB/M for manufacturing functional materials for ultrafast actuator applications.

Keywords: additive manufacturing; laser powder bed fusion; magnetic materials; functional materials; magnetic shape memory; Ni–Mn–Ga