Investigating the magnetization process of Ni-Mn-Ga films with different types of microstructure

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Magnetic shape memory materials show outstanding and multifunctional properties (e.g. “giant” magnetomechanical, magnetocaloric, barocaloric), originating from the occurrence of both a martensitic transformation and magnetic order. Thin films of these materials have a great potential for different applications, such as microactuators, valves and solid-state microrefrigerators. We have demonstrated that a huge and reversible magnetization jump can be achieved in 200 nm Ni-Mn-Ga films [1, Figure 1]. This is possible when the proper microstructure is obtained: growth conditions and a stress applied to the substrate enable the proper microstructure, where differently twinned martensitic regions are aligned anisotropically. The films were epitaxially grown on Cr/MgO(100) by r.f. sputtering. Their characterization was carried out by different techniques, thus realizing a multi-scale structural and magnetic study.

We here examine the relation between the film microstructure and magnetization process. The occurrence of magnetization jumps is in fact typically attributed to the magnetically induced reorientation of twin variants, similarly to what occurs in bulk materials [1 and references therein]. We have instead simulated magnetization processes of purely magnetic origin in films with different martensitic microstructures, e.g., showing different orientation and spatial organization of the martensitic twin variants. The micromagnetic simulations demonstrate that magnetization jumps of purely magnetic origin and with variable intensity can take place in the first quadrant of the (M,H) diagram (Figure 1). The results of the simulations will be compared with a detailed experimental investigation realized by magnetometry and vectorial magnetometry: we have measured magnetization curves along different directions of the substrate crystal, simultaneously recording parallel and transverse components of magnetization.

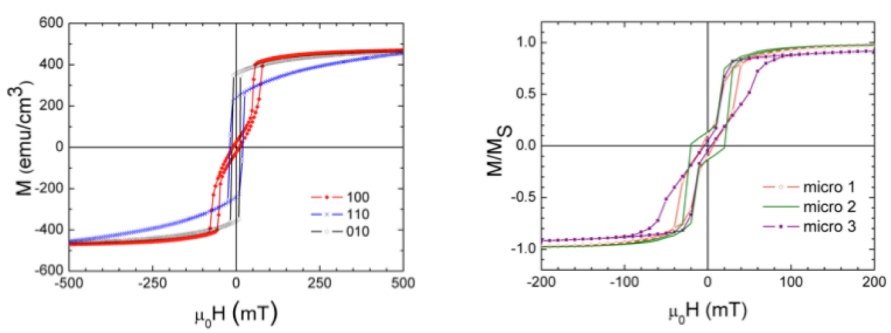

Figure 1. Left: Experimental hysteresis curves along different MgO directions. Right: Hysteresis curves simulated for different types of microstructures.

[1] P. Ranzieri et al., Adv. Mater. 27, 4760 (2015)