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Control of magnetic properties of NiTi Alloys and NiTi/Ni bilayers

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In the last decade, a huge amount of work has been devoted to constructing a composite thin film where magnetic anisotropy becomes tunable by coupling ferromagnetic layer to a functionalized layer. Electrical control of interfacial anisotropy with an insulator and interfacial strain transferred from an electrically controlled piezoelectric or ferroelectric material are still heavily pursued. Here, we propose a novel approach to manipulate magnetic anisotropy by interfacial strain transferred from a thermally controlled material, like a shape memory alloy [1]. This innovative architecture benefits from the shape memory effect, in particular, from the two-way shape memory effect (TWSME). The TWSME consists in a reproducible hysteretic transformation of shape memory alloys from a strained B19' structure (at low temperature) to a differently strained B2 structure (at high temperature) during the thermal cycle. NiTi-based alloys are among the most used shape memory alloys within a wide range of applications in industry, military technologies, health care, etc. [2]. They are metallic and may be grown by regular microelectronics industry deposition techniques. NiTi-based SMAs can produce as much as 4% of TWSME strain and recover up to 10% of the initial deformation [3]. The transformation temperatures can be easily tuned from 250 K to 1000 K [2].

In our talk, we demonstrate that the NiTi alloy can be used to reproducibly switch by 90° the in-plane uniaxial anisotropy of a 20 nm thick Ni thin film during a thermal cycle between room temperature and 100°C (as shown in Figure 1) [4]. We first properly quantify NiTi sample longitudinal strain and transverse strain produced by an external uniaxial tensile stress followed by a thermal cycle, required to setup the TWSME. We demonstrate that NiTi is a Pauli paramagnetic material and explain temperature variations of its magnetic susceptibility by comparing experimental data with ab-initio calculations [5]. We show that both martensitic transition temperature and magnetic susceptibility depend on NiTi lattice structure, which we tuned through strain and characterized by TEM and XRD techniques. Secondly, we characterize magnetic anisotropy of the Ni layer, deposited by PVD on top of NiTi after tensile deformation. As shown in Fig. 1, when NiTi is in its martensite (respectively, austenite) phase, Ni anisotropy points along (respectively, perpendicular to) the initial tensile axis. Variation of Ni anisotropy up to 1.10^5 J.m-3 was achieved. It is a promising result since the strain transfer at NiTi/Ni interface is not yet optimized. During the TWSME strain in NiTi varies from 0% to 2.7% whereas Ni strain varies only from 0% to 1.3. We performed transmission electron microscopy to reveal that a thin oxidized interface layer is the main origin of strain loss at the NiTi/Ni interface.

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