Shape memory alloys (SMA) are materials that exhibit a martensitic phase transformation, leading two interesting thermo-mechanical properties, the shape memory and the superelasticity effects. The martensitic phase transformation is a first order and diffusionless crystal phase transition between two crystallographic phases, which can be induced thermally (shape memory effect) or by the application of stress (superelasticity effect). These thermo-mechanical properties make SMA very useful in a wide variety of applications like actuators and sensors [1].

The current device miniaturization tendency has led to growing interest in developing SMA for microelectromechanical systems (MEMS) motivated by its high work output per volume unit. This approach has been applied mainly using NiTi based alloys, with which some MEMS have already been fabricated [2]. Nevertheless, in recent years it was demonstrated that Cu-Al-Ni SMA have also notable properties at micro and nano-scale [3-5], opening a new promising possibility in this area.

In this work we present the microscopic characterization of the top shape of Cu-Al-Ni micro-pillars during a long superelastic cycling in nano-compression tests. The array of 4x4 micro-pillars studied were milled by Focused Ion Beam technique using a 3D-nanoprototyping program on a (100) Cu-Al-Ni single crystal. All pillars were tested in an instrumented nanoindenter with a sphero-conical diamond indenter. Electron and scanning probe microscopy images were taken along nano-mechanical tests (Figure 1). A residual plastic deformation was observed on the top of all tested pillars and its evolution and stabilization during de tests is explained and discussed. Fully recoverable and reproducible superelastic behaviour has been obtained during long term cycling tests above thousand cycles (Figure 2). These promising results open the door for designing potential applications doing use of 3D devices of SMA, which could be integrated in MEMS technology.


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Fig. 1: CuAlNi 4x4 micro-pillars array. a) SPM image of array before nano-mechanical tests, b.) SPM image of single pillar before nano-mechanical tests, c.) and d.) SEM and SPM of array and single pillar respectively after nano-mechanical tests.

Fig. 2: Superelastic nano-compression tests performed on single pillar, after 1005 previous cycles, in load control mode at a loading rate of 250 mN s⁻¹. The loading-unloading cycles for cycles 1006 to 1010 have been superimposed to show the reproducibility of the behavior.