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Comparison of the shape memory effect obtained from R and B19' NiTi martensites using nanoindentation and atomic force microscopy

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Abstract – Quantification of the shape memory effect of a near equiatomic NiTi alloy in the R and B19' martensite phases using nanoindentation and atomic force microscopy was made. It was shown that the shape memory effect was similar for the two phases and that the quantity of the effect decreases with increasing load.

The shape memory effect (SME) is the ability of a material to recover its original shape under heating, after plastically deformed. Near equiatomic NiTi shape memory alloys may present three different crystallographic phases according to the temperature and thermomechanical history [1]. The alloy studied in this work is austenitic above 40°C, with a B2 structure, and upon cooling a trigonal structure is formed in the range 40-20°C, the R-phase [2]. On further cooling, a second transformation takes place in the range -30 to -60°C changing to the monoclinic B19' phase. Both are martensitic transformations. Upon heating, there is hysteresis and the structure remains martensitic up to 10°C. Above this temperature the martensite start to transform to R and then to austenite, finishing at 40°C. Thus at room temperature two different crystallographic phases can be present: the R-phase, when cooled from temperatures above 40°C, and the B19' phase and a small amount of R-phase, when heated from temperatures under -60°C. This characteristic makes possible the study of the shape memory effect (SME) upon deformation at two different conditions: R and B19' martensites[2].

Nanoindentation and atomic force microscopy combined are efficient techniques to study SME in small samples or thin films [1]. In this work, these techniques were used to quantify the recovery of indentations made on samples of a 0,7mm diameter wire of a near equiatomic NiTi. Indentations were performed in the R phase of the sample submitted to cooling and in the B19' submitted to heating from -60°C. Tests were carried out at room temperature using a Berkovich indenter and a maximal load in the range of 1 to 10mN. AFM images were also obtained at room temperature. Figures 1 and 2 show indentations made at the R-phase. Figure 1 shows AFM images after indentation test (a) and after heating the sample to 80°C (b) and topographical profiles, respectively (c and d). The SME was obtained measuring the residual depths before and after heating: SME = $(h_1-h_2)/h_1$. Figure 2 shows AFM images of the indentations with the two different maximal loads: (a) after the indentation test and (b) after heating. Results showed that all the indentations made at R and B19´ phases are pile-up in shape, with borders bent downwards. After the recovery of the indentations they are sink-in with borders bent upwards (Figure 1b,d). No significant differences of the SME value for the R and the B19' phases were observed. On the other hand, the SME of the two phases increased with decreasing load.

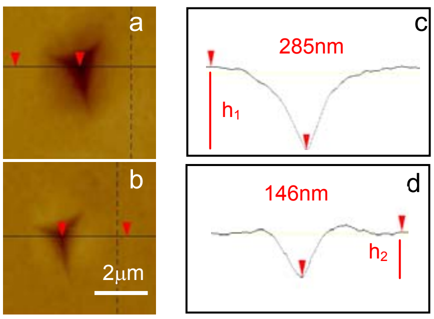

Figure 1: AFM images of an indentation before (a) and after (b) heating the sample to 80°C and the respective topographical profiles, (c) and (d).

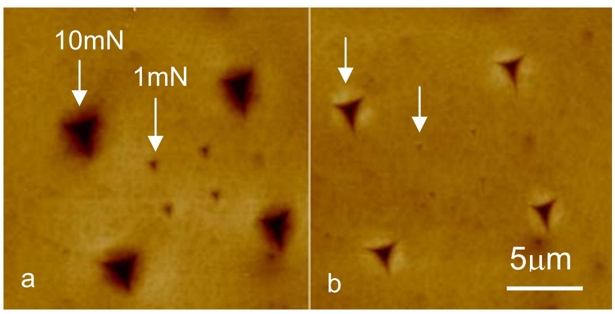

Figure 2: AFM images of indentations made at the R-phase with 10mN and 1mN maximal loads before (a) and after (b) heating the sample to 80°C.

References

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