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Structural evolution on thermal cycling in Ti-rich NiTi SMA

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Abstract

Shape-memory alloys (SMA) represent a class of metallic materials that has the capability of recovering a previously defined initial shape when subjected to an adequate thermomechanical treatment. Annealing of a Ti-rich Ni–Ti alloy has been followed by in situ high temperature diffraction in order to register the texture as well as the microstrain/microstress evolution. This type of study is relevant to the envisaged applications, because the type of preferential orientation and the corresponding anisotropic response of the material conditions contributes to the success of the SMA application. In the present study we have tested the feasibility of high temperature pole figures determination at ROBL (BM20) at the ESRF, and we have shown that there is a relation between the preferential orientation changing and the structural evolution taking place during annealing.
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1. Introduction

The Shape-memory effect (SME) is a phenomenon where deformation suffered below a critical temperature can be recovered on heating. This phenomenon relies on the crystallographic reversibility of the austenite $\Longleftrightarrow$ martensite transformation. *Martensite* (the product-phase) has a lower symmetry (monoclinic B19' structure in the Ni–Ti alloys) and, therefore, a great number of variants can be formed from the same parent-phase, austenite (cubic B2 structure in the Ni–Ti alloys), which has a higher symmetry. Increasing the temperature, the martensite transforms into austenite and, if this transformation is crystallographically reversible, the original crystallographic orientation of the parent-phase is

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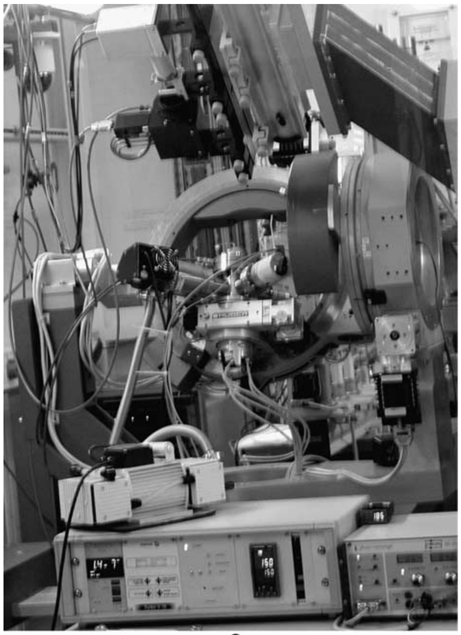
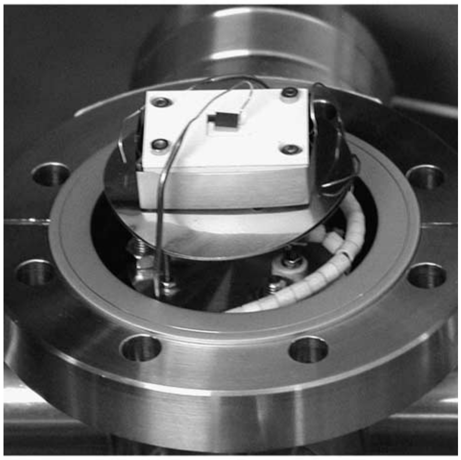
recovered. Besides the SME, shape-memory alloys (SMAs) present a singular combination of thermomechanical properties, such as superelasticity and rubber-like behavior, thus ensuring interesting characteristics (e.g. a high damping capacity and high specific energy output) that enable them for a wide variety of applications as sensors and/or actuators. Amongst the SMAs, Ni–Ti based alloys, are very attractive due to their extended recoverable deformation, good ductility and good oxidation resistance. The degree of efficiency of the SME for a specific application strongly depends on the type of preferential orientation that is present. The relationship between the recoverable strain and texture has been analyzed by Shu and Bhattacharya [1]. According to these authors, the texture usually developed during rolling, extrusion and drawing of Ni–Ti alloys is extremely favorable for SME applications requiring extensive recoverable deformations. The α-fiber I (⟨1 1 0⟩//RD, the rolling direction, with the relevant components being {0 0 1}⟨1 1 0⟩–{1 1 2}⟨1 1 0⟩–{1 1 1}⟨1 1 0⟩) in Ni–Ti exhibits two maxima of recoverable deformation in RD and TD (transverse direction) of the rolled sheet, making it particularly suitable for uniaxial applications since it is easy to extract good specimens from a rolled sheet. The α-fiber II (⟨1 1 0⟩// RD, with the relevant components being {1 1 1}⟨1 1 0⟩–{1 1 0}⟨1 1 0⟩) is the most characteristic texture in rolled Ni–Ti. In this case, Shu and Bhattacharya predict a maximum recoverable strain along the RD and a minimum along the TD. On the other hand, the γ-fiber (⟨1 1 1⟩// ND, the sample normal direction, with the relevant components being {1 1 1}⟨1 1 0⟩–{1 1 1}⟨1 1 2⟩) is associated with the least anisotropy, making this texture desirable if the recoverable strain is required in every direction of the rolled sheet.

The evolution of the texture during annealing, after a deformation process, becomes then a very important phenomenon to be analyzed. The only high temperature texture determination for polycrystalline Ni–Ti that is reported in the literature [2] has been made at 120 °C. In the present study we have used in situ high temperature XRD to follow the structural evolution up to 700 °C.



a



b

Fig. 1. Six-circle goniometer of ROBL (BM20) at ESRF (a) and close-up view of the vacuum furnace used for in situ XRD (b).

2. Experimental set-up

The samples were extracted from a plate $420 \times 70 \times 2\ mm^3$ supplied by Memory-Metalle GmbH, the chemical composition being 44 wt.% Ni–56 wt.% Ti, i.e. 49 at.% Ni–51 at.% Ti. Before examination by XRD, all the samples were previously submitted to a chemical etching (10 vol%