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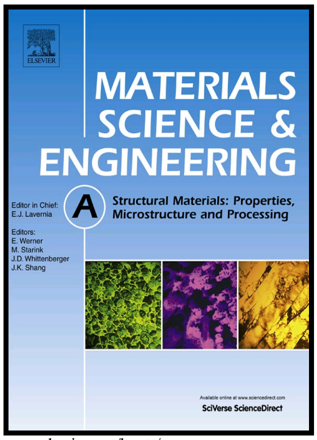

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Identifying the effects of heat treatment temperatures on the Ti50Ni45Cu5 alloy using dynamic mechanical analysis combined with microstructural analysis

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Abstract

The properties of NiTiCu alloys strongly depend on their microstructure, which is greatly influenced by the temperature of the heat treatment (HT) carried out as a final step in their processing. This study investigates the effect of HT temperatures on the Ti50Ni45Cu5 alloy using dynamic mechanical analysis (DMA). To confirm the results obtained by the DMA as regards the effects of HT on the microstructure, they were checked against differential scanning calorimetry (DSC), synchrotron X-ray diffraction (SXRD), hardness measurement and stress-strain tests. By combining all these experimental techniques with the DMA measurements, the effects of the HT were determined and attributed to different factors: density dislocation morphology introduced by prior cold work, recovery and recrystallization processes with texture changes, grain growth, precipitation processes and wt(%) of retained martensite. The results showed that low HT temperatures (400 and 450ºC) are not high enough to eliminate the effects of the cold work but do provide suitable mechanical properties and lower transformation temperatures. Medium temperatures (500 to 575ºC) lead to higher transformation temperatures and maximum martensitic transformation capacity (ΔH and tan δ) because of the recovery and recrystallization process, but they also cause a reduction in the mechanical properties (slip stress). High temperatures (600 and 650ºC) produce a reduction in transformation capacity and a huge decrease in the mechanical properties (slip stress and ultimate tensile stress).

Keywords

SMA; shape memory alloys; NiTi; NiTiCu; XRD; DMTA

Introduction

Because of their peculiar features and functional properties, shape memory alloys (SMAs) have attracted increasing interest over recent years in connection with a number of applications such as actuators, fittings, biomedical applications, clamping systems, etc. [1,2]. The underlying mechanism behind these special functional properties is the reversible thermoelastic martensitic transformation between austenite (A) and martensite (M) phases in solid state. This diffusionless martensitic transformation can be induced either upon cooling from the austenitic phase or upon application of stress. As a result, SMAs exhibit two distinct mechanical responses depending on the temperature at which they are deformed. The shape memory effect (SME), which occurs when the SMA is deformed in the martensitic condition, is a result of the detwinning of the martensite (i.e. with an energetically-favored martensite variant growing at the expense of the others). The superelasticity or pseudoelastic effect arises due to stress-induced martensite (SIM) formation when the SMA is deformed in the austenitic state. Both these processes can be reversed, either by increasing the temperature or by releasing the load, respectively. Martensitic transformation in SMAs is characterized by four specific temperatures known as transformation temperatures (A_S and A_f for the initial and final austenitic transformation, and, M_S and M_f for the initial and final martensitic transformation) [3].