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Irradiation-induced changes of martensitic transformation temperatures in a TiNiNb shape memory alloy

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Abstract

Effects of electron irradiations on the transition behavior of 1123 K annealed $Ti_{44}Ni_{47}Nb_9$ shape memory alloy specimens were studied. The transformation temperatures and the latent heat of phase transformation were measured by differential scanning calorimeter (DSC). The microstructure changes were determined by XRD and TEM. The 1.7 MeV electron irradiation increases the martensitic transformation start temperature, finish temperature, austenite transformation start, finish temperature by ~20 K. The XRD and TEM observation showed that the volume fraction of β-Nb precipitate increased after electron irradiation, which contributed to the observed changes of the transformation temperatures.

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Keywords: TiNiNb shape memory alloys; Electron irradiation effects; Transmission electron microscopy; Differential scanning calorimeter; Martensitic transformation

1. Introduction

Ternary TiNiNb shape memory alloys (SMAs) are distinct from TiNi binary SMAs for its wide phase transformation temperature hysteresis [1–7]. The constitutional phases of TiNiNb SMA are β-Nb particles and TiNi matrix. During deformation at low temperature, β-Nb particles and the matrix are deformed simultaneously. Upon heating the matrix to its original shape, the soft β-Nb particles prohibit the recovery of the matrix. Thus the expanded joining, fastening and sealing device can be shipped and stored at ambient temperature in the martensitic state, i.e., in the as-expanded shape. Therefore, this ternary alloy has great potential applications as mechanical components in the field of fission and fusion engineering and space technology [1,5]. There are some reports on the irradiation effect of TiNi(Cu) SMAs under neutron, proton, electron and heavy-ion irradiation [6–18]. As far as the authors' knowledge is concerned, the irradiation effect of TiNiNb SMAs has not been reported.

The martensitic transformation characteristics in SMAs are very sensitive to various physical factors (such as precipitates, dislocations, point defects and chemical composition) so that the radiation effect of SMAs is perplexing. The neutron irradiation up to about 1 dpa was found to produce a strong decrease of the transition temperatures [6,12]. This decrease is believed to be due to the pronounced

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chemical disordering of the crystal lattice [6,13]. The electron irradiation to about 1.7×10^{21} e/m^2 (10^{-5} dpa) led to a higher equilibrium temperature and martensitic stabilization, had little effect on reverse martensitic transformation temperature in a ternary TiNiCu shape memory alloy [14]. It was found in high voltage electron microscopy that the electron irradiation (2 MeV) decreased reverse martensitic transformation temperature above a dose of 7×10^{24} e/m^2 [10].

In the present work, the irradiation effect on the martensitic transformation characteristics and microstructures in a near-equiatomic TiNiNb SMA have been studied by means of 1.7 MeV electron electrostatic accelerator, differential scanning calorimeter (DSC), X-ray diffraction (XRD) and transmission electron microscope (TEM).

2. Experimental

$Ti_{44}Ni_{47}Nb_9$ SMA samples with a thickness of 1 mm, provided by the Institute of Metal Research of the Chinese Academy of Sciences, were annealed at 1123 K for 1 h in an evacuated silica tube and then cooled in the air. After the

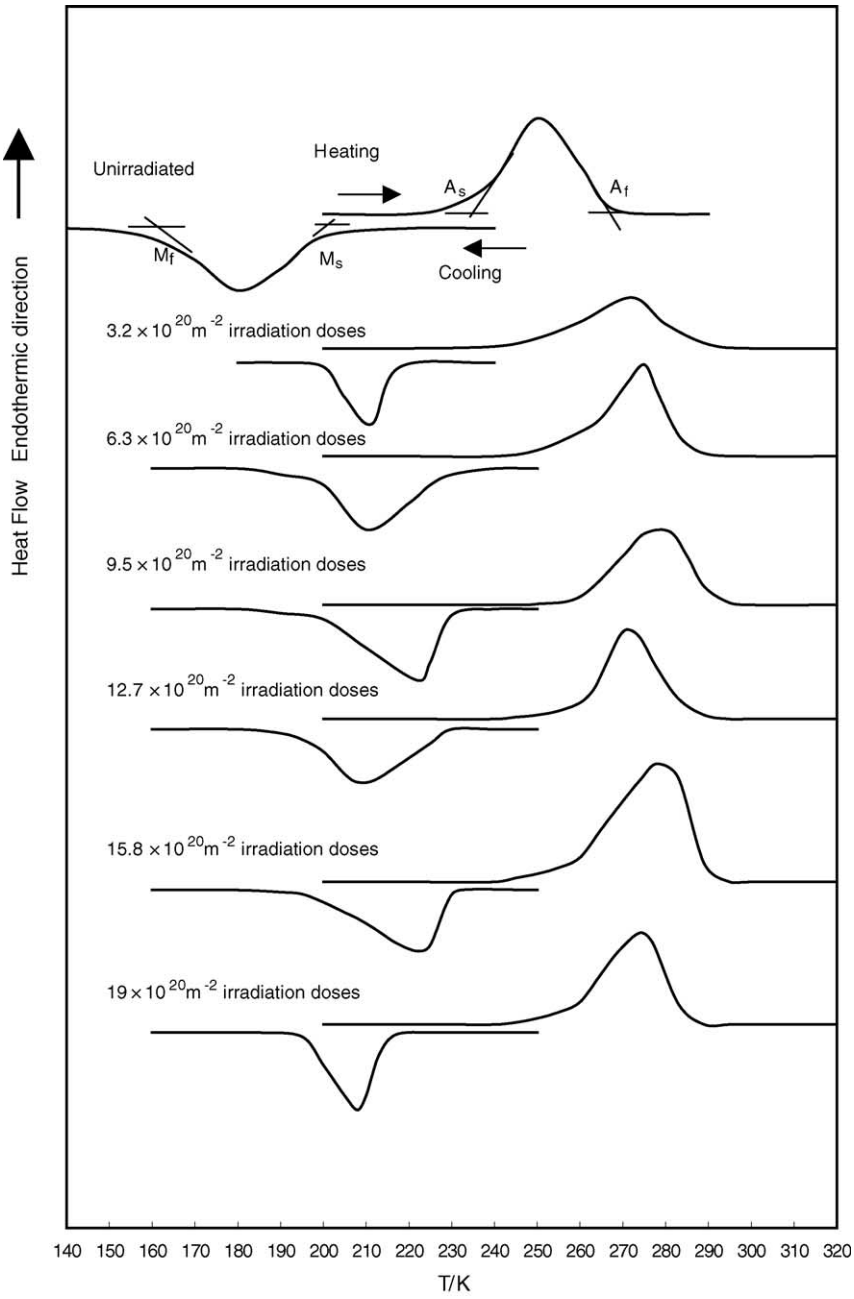

Fig. 1. DSC curves of the electron irradiated and unirradiated TiNiNb samples.