TEXTURE AND STRUCTURE EFFECTS ON RECOVERY STRAIN OF Ti-Ni SMAs

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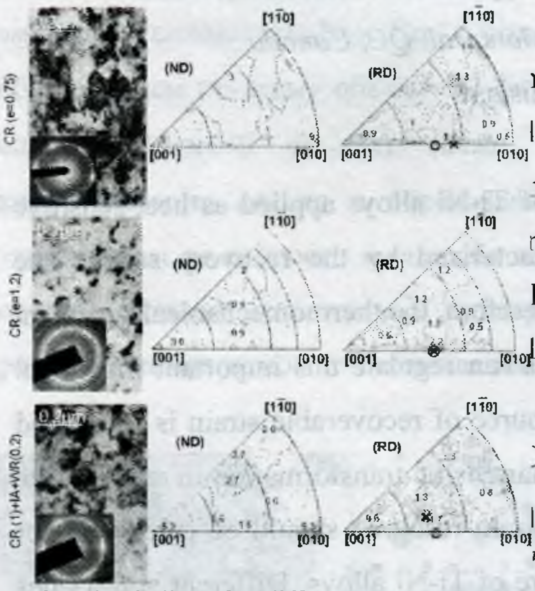
The shape memory effect and superelastisity of Ti-Ni alloys applied as heat-sensitive elements and thermomechanical actuators are characterized by the recovery strain. The recoverable strain is structure-sensitive parameters; therefore, the thermomechanical treatment (TMT) of Ti-Ni alloys creating the various structures can regulate this important functional property [1-4]. The theoretical (crystallographic) resource of recoverable strain is calculated as a maximum of crystal lattice strain as a result of martensitic transformation in an austenite single crystal. In practice, the theoretical recovery strain resource should be calculated for polycrystalline material taking into account the texture of Ti-Ni alloys. Different approaches can be used in the last case.

An as-drawn (30% of cold work) 1 mm diameter Ti-50.26 at.%Ni wire supplied by "SAES Getters" was primarily subjected to homogenization annealing (700°C, 1 h) and then to five TMT schedules comprising cold and/or warm rolling (CR/WR) and intermediate annealing (IA, 400°C, 1h) technological steps: **CR(0.75)**, **CR(1.2)**, **CR(1)+IA+CR(0.2)**, **CR(1)+IA+WR(0.2)**, **WR(1)+IA+WR(0.2)**. (Note that the true CR or WR strain values are indicated in the parentheses.) All the TMT schedules were followed by PDA at 400°C, 1h. The cold (RT) and warm (150°C) rolling was performed using a four-high "FENN" laboratory rolling mill.

The electron microscopy study was carried out using samples thinned by mechanical and electrolytic polishing. The texture analysis was carried out using a "PANalyticalX'pert Pro" X-ray diffractometer with $Cu_{K\alpha}$-radiation. The X-ray scanning for $(110)_{B2}$, $(200)_{B2}$ and $(211)_{B2}$ pole figures was performed, inverse pole figures were built and orientation distribution functions (ODF) were calculated. The lattice parameters and theoretical recoverable strain resources were calculated using the method described in [5].

The electron microscopy study identified the following specificity of the B2-phase structure formation in Ti-50.26%Ni alloy subjected to different TMTs followed by final PDA: (1) The greater the CR contribution, the larger the fraction of nanocrystalline (NC) structure compared to the nanosubgrained (NS) structure, and the lower the average dislocation density; (2) When the WR contribution increases, the NS structure becomes dominant, and the larger grains, subgrains and subgrained regions are observed; and (3) Introducing of IA in the technological sequence results in overall structure coarsening, i.e., in an increase in grain (in NC structure) and in subgrain (in NS structure) sizes.



50.26at.%Ni alloy after different TMT

The texture analysis using inverse pole figures ıd ODF showed that the main texture component is }100}<110>B2 after all the TMT schedules. The tensity of this component after CR(1.2) is several mes lower than after other TMT schedules while after R(1)+IA+WR(0.2) results in the sharpest }00}<110>B2 texture.

The crystallographic resource of recovery strain CRRS) in the single-crystal approach in recrystallized uenched) Ti-50.26 at.%Ni alloy which amounts to ^{ax} = 11.48% decreases down to 10.5...10.88% in nanostructured after all TMT schedules alloy.

This is due to different martensite lattice parameters like in [6]. Calculation of CRRS for a polycrystalline alloy taking into account a real texture and realization in each grain of a favorable martensite variant shows similar results: $\varepsilon_{poly}^{\max 1}$ = 10.56% after quenching and 9.75…10.18 after TMT.

The decrease in CR accumulated strain from e=1.2 to 0.75 and introduction in TMT of WR and IA lead to decrease in the CRRS value and degree of CRRS realization (Figure 2). The maximum experimental recovery strain value, $\varepsilon_r^{\max}$ =8%, is observed after CR(1.2), and minimum $\varepsilon_r^{\max}$ =6.7% after CR(0.75). The intermediate values $\varepsilon_r^{\max}$ =7.2-7.4% are obtained after other TMT schedules. In the same ratio value are realization degree of CRRS $\varepsilon_r^{\max}/\varepsilon_{poly}^{\max}$ (0.79:0.66:0.72…0.75) and the maximum completely recoverable strain values $\varepsilon_{r,1}^{max}$: 8 : 6.1 : 7.3. Two factors affect the value and realization degree of the recovery strain of polycrystalline Ti-Ni alloys. The "texture" factor (orientation distribution function) determines the theoretical CRRS $\varepsilon_{poly}^{\max}$. The role of "structure" factor (lattice defects defining structural hardening, and most importantly, the difference between the "dislocation" and "transformation" yield stresses) is dual. First, it determines the realization degree of recovery strain $\varepsilon_r^{\max}/\varepsilon_{poly}^{\max}$, maximum completely recoverable strain $\varepsilon_{r,1}^{\max}$ and shape recovery rate $\varepsilon_r/\varepsilon_i$

(where ε_i is induced strain). Second, it affects the CRRS value, its variation due to lattice parameters change.

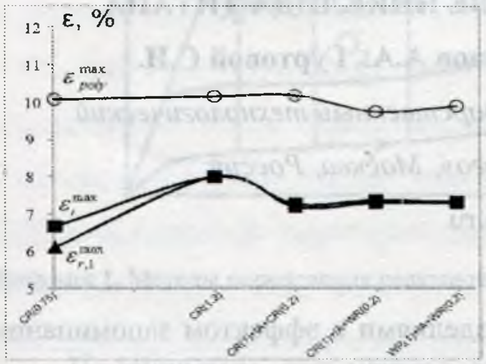


Figure 2. Experimental recovery strain and completely recoverable strains and calculated CRSR after various treatments

Under real TMT conditions for Ti-50.26 at.%Ni alloy including CR, WR, IA and PDA in different combinations, the "structural" factor exerts the main influence on the recovery strain. For realization the extremely high recovery strain, the nanostructure with sharp texture component (providing the maximum transformation strain in tensile axis direction) should be created.

Conclusions

1. The greater the heat energy input during processing (WR/IA contribution), the greater the quantity of nanosubgrained substructure at the expense of nanocrystalline structure, the larger the size of grain, subgrain and subgrained regions.

2. The main texture component of austenite after all the processing routes corresponds to {100}<110>B2, and after CR(e=1)+IA+WR(e=0.2) the austenite texture sharpness reaches its maximum.

3. The maximum recovery strain and completely recoverable strains of 8% are obtained after CR(1.2) when nanocrystalline structure is created.

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