Enhancement of microstructure-based magnetic, electronic, and lattice contribution in a CoNiAl ferromagnetic shape memory alloy

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Abstract

In this study, a Co-Ni-Al system with nominal compositions $Co_{42}Ni_{31}Al_{27}$ and $Co_{41}Ni_{32}Al_{27}$ was synthesized. The structural and microstructure of these confirm the presence of a non-ferromagnetic face-centered cubic (γ) phase interspersed between the grains of a ferromagnetic body-centered cubic (β) phase. Notably, γ phase is increased by 1.5 times in the $Co_{41}Ni_{32}Al_{27}$ sample due to the 1% substitution of Co by Ni. The microstructural tuning induced a higher thermal hysteresis in the shape memory effect of $Co_{41}Ni_{32}Al_{27}$ with an increase in enthalpy during the phase transition (Austenitic ↔Martensitic). In addition, the temperature-dependent resistivity, $\rho(T)$ was measured to study the electron-phonon and electron-magnon scattering around the phase transition of the studied samples. The dynamic elastic properties of the studied samples were tracked by the relative change in sound velocity $(\delta v/v)$ with temperature and elastic recovery was confirmed in both alloys across the 120 K to 300 K range. However, the $Co_{41}Ni_{32}Al_{27}$ exhibits a high amount of lattice contribution to the shape recovery compared to the $Co_{42}Ni_{31}Al_{27}$. Moreover, a larger variation in relative resistivity $(\Delta\rho/\rho)$ for $Co_{41}Ni_{32}Al_{27}$ compared to $Co_{42}Ni_{31}Al_{27}$ during the phase transition indicates a larger shape change due to decreased Co content. Furthermore, the $Co_{41}Ni_{32}Al_{27}$ sample shows higher temperatures of martensitic start ($T_{Ms} \approx 260$K) and Austenitic finish $(T_{Af} \approx 290\text{K})$ along with high Curie temperature ($T_c = 330K$). Consequently, the temperature-dependent susceptibility (χ') confirms the higher magnetoelastic recovery in the $Co_{41}Ni_{32}Al_{27}$ sample, indicating an enhancement of magnetic field-induced strain (MFIS). Stress-induced Q^{-1} is lower for $Co_{41}Ni_{32}Al_{27}$ ($\sim 2.9 \times 10^{-3}$) compared to $Co_{42}Ni_{31}Al_{27}$ sample ($\sim 5.0 \times 10^{-3}$) signifying the enhanced mechanical strength.

Keywords: Co-Ni-Al FSMA, Microstructure, Phase fraction, Lattice contribution, Martensitic Transformation.