Effect of the Co/Ni ratio on the FCC phase stability and shape recovery properties of CrMnFeCoNi high-entropy alloys

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ABSTRACT

We investigated the effect of the Co/Ni ratio on shape memory effect and tensile properties of non-equiatomic $Cr_{20}Mn_{20}Fe_{20}Co_{40-x}Ni_x$ high-entropy alloys (x = 0, 2, 4, 6 at.%). Increasing Ni content stabilizes the FCC stability of the CrMnFeCoNi alloys, thus converting the FCC+HCP dual-phase structures (x = 0, 2, 4 at.%) to the FCC single-phase structures (x = 6 at.%). Dual-phase alloys show a recovery strain of less than 0.9 %, whereas FCC single-phase alloy shows a high recovery strain of 1.2 %. From the EBSD analysis, the different microstructural evolutions of dual- and single-phase alloys during tensile deformation are identified. These results could give us strategies for the design of the new CrMnFeCoNi high-entropy alloys with shape memory effect.

KEY WORDS

High-entropy alloys, shape memory alloys, martensitic transformation

1. INTRODUCTION

The concept of 'high-entropy alloys (HEAs)', consisting of multiple elements with near equimolar ratios, has attracted many researchers to design new materials with superior properties in the multi-component system.[1] CrMnFeCoNi-based HEAs, the most famous HEA systems, have been developed by changing composition to increase their strengths, thus non-equiatomic CrMnFeCoNi HEAs with twinning- or transformation-induced plasticity have been designed by reducing their stacking fault energies.[2,3] Recently, shape memory effect (SME) has been observed in the $Cr_{20}Mn_{20}Fe_{20}Co_{40-x}Ni_x$ alloys (x=0, 5 at.%), which undergo reversible transformation between FCC and HCP phases.[4] It is derived from the reduced FCC phase stability of CrMnFeCoNi HEAs by increasing the Co/Ni ratio. SME of CrMnFeCoNi HEAs could be modulated by FCC phase stability, and the FCC phase stability of the CrMnFeCoNi HEAs is strongly dependent on the Co/Ni ratio. Thus, the Co/Ni ratio significantly influences the microstructures and SME of CrMnFeCoNI HEAs. However, the effect of the Co/Ni ratio on the FCC phase stability and SME is not fully understood. In this study, the Co/Ni effect of CrMnFeCoNi HEAs on the FCC phase stabilities, microstructural evolutions, FCC/HCP martensitic transformation, tensile properties, and shape memory properties were investigated.

We prepared recrystallized $Cr_{20}Mn_{20}Fe_{20}Co_{40-x}Ni_x$ (x=0, 2, 4, 6 at.%) HEAs. Using X-ray diffraction (XRD) and electron backscatter diffraction (EBSD) analysis, an increased trend of FCC stabilities with the Ni contents was identified, converted from the FCC+HCP dual-phase structures (x = 0, 2, 4 at.%) to the FCC single-phase structures (x = 6 at.%) with the Ni content. In addition, Martensitic transformation start temperature (M_s) and reverse martensitic transformation start temperature (A_s) measured by differential scanning calorimetry (DSC) were drastically decreased by 31 K/at.% and 24 K/at.%, respectively. Recovery strains of dual-phase and single-phase HEAs were less than 0.9 % and 1.2 %, respectively. with EBSD analysis of deformed samples, the different deformation behaviors and microstructural evolutions were identified. These results would give us strategies for the design of the new CrMnFeCoNi HEAs with SME.

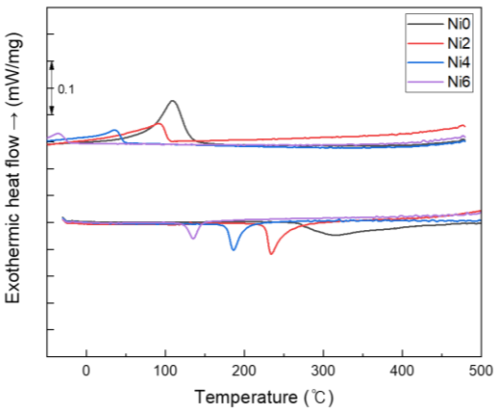

Fig.l. DSC results of $Cr_{20}Mn_{20}Fe_{20}Co_{40-x}Ni_x$ HEAs (x = 0, 2, 4, 6, at.%)

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