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Paper Title: Effects of annealing and cold rolling on microstructural features, magnetic properties, tensile behavior and electrical resistance of FeCoNi(MnAl)x high entropy alloys

Content :

In this study, the microstructure, magnetic properties, and tensile behavior of high entropy alloys of $FeCoNi(MnAl)_x$ (x = 0–0.6, in molar ratios) were investigated after casting, cold rolling and annealing. X-ray diffractometry (XRD), field emission scanning electron microscope (FE-SEM), vibrating sample magnetometer (VSM), and also tensile tests were used to evaluate phase formation, microstructure, magnetic behavior and tensile properties of the samples, respectively. The results showed that as the indices of x value increase to 0.6, crystallographic structures transform from FCC to FCC + BCC. This in turn decreased the magnetic saturation of $FeCoNi(MnAl)_{0.6}$ from 151 to 36 emu/g. Increasing x to 0.6, also raised the values of Hc from 3 to 16 Oe. This behavior was also observed in annealed and cold rolled alloys. Annealing treatment also released the residual stresses and resulted in reduction of Hc values. However, the highest values of Hc was observed in cold rolled samples which ranged from 5 to 25 Oe. The tensile strength of cold rolled and annealed alloys for x values of 0, 0.2, and 0.4, were 510, 635, and 910 Mpa, respectively. Furthermore, the electrical resistance augmented monotonously with an increasing value of x. It is therefore concluded that cold rolled and annealed high entropy alloys of FeCoNi(AlMn)x can present a variety combinations of tensile, magnetic, and electrical behavior when compared to other soft magnetic materials.

Mechanical properties

3.4.1. Tensile properties

Mechanical properties with an elongation of more than 75 %, the yield stress (YS) of about 220 MPa, and ultimate stress (UTS) of about 510 MPa, are shown in Fig. 11. With further increase in x values, the grains undergo supercooling and reduce the properties of the alloy. After cold-rolling and annealing, the deformation resistance of the alloy is improved, and the mechanical properties of all alloys are significantly modified.

By increasing x value, lattice distortion is more intense, so the overall mechanical properties of $FeCoNiMn_{0.2}Al_{0.2}$ alloy are improved by solid solution strengthening. The YS, UTS, and elongation of $FeCoNiMn_{0.4}Al_{0.4}$ are 750 MPa, 910 MPa, and 30 %, respectively which show that the increase of Al and Mn contents is conducive to improving the comprehensive mechanical properties of HEAs.

Actually, by increasing the x value, the structure changes from FCC to FCC + BCC. It is reported that the BCC structure has less flexibility as compared to the FCC structure [47]. When x reaches the value of 0.6, the ductility of the alloy decrease and the sample became quite brittle. Table 7 shows the mechanical parameters of the cold rolled samples with 80 % reduction in thickness and subsequent heat treatment at 900 °C for 1 h.

It is reported that the formation and stabilization of BCC solid solution in the CoNiMnCrAl system can be related to high structural distortion of FCC structure due to the presence of Al [48]. Zhang et al. [20], stated that by increasing the amount of Al to CoCrFeNiTiAlx system, the stability of BCC phase rises and the mechanical properties of final alloy is enhanced [20].