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Effects of Gd addition on the microstructure, mechanical properties and shape memory effect of polycrystalline Cu-Al-Ni shape memory alloy

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ABSTRACT

The effects of Gd addition on the microstructure, mechanical properties and shape memory effect of (Cu-13.0Al-4.0Ni)-*x*Gd ($x=0$, 0.3, 0.9, 1.5 and 6) (wt%) alloys were investigated. The results showed that the grain of (Cu-13.0Al-4.0Ni)-*x*Gd alloys was refined by the Gd addition. The 18R martensite and a small amount of 2 h martensite were present for $x<0.9$ wt%, and dual phases containing 18R martensite and hexagonal structured $AlCu_4Gd$ phase were observed for $x\geq0.9$ wt%. In addition, Gd addition significantly enhanced the mechanical and shape memory properties. The compressive fracture strain of 15.3% and reversible strain of 6.6% were obtained in (Cu-13.0Al-4.0Ni)-0.3Gd alloy.

1. Introduction

To date, high-temperature shape memory alloys (HTSMAs) have attracted more and more attentions [1,2]. Cu-Al-Ni HTSMAs have been widely investigated due to its lower cost [3–6] in comparison with some well studied HTSMAs, such as Ti-Ni-Pd, Ti-Ta and Ni-Mn-Ga [7–15], etc. However, polycrystalline Cu-Al-Ni alloys suffer from high brittleness, which is associated with large elastic anisotropy, intergranular cracking and large grain size [16,17]. Some methods were adopted to improve the mechanical properties of polycrystalline Cu-Al-Ni, including grain refinement [18] and fourth element addition [3, 19–21]. Published results showed that rare earth Gd addition can tailor the microstructure and mechanical properties of shape memory alloys [22–24], and accordingly, Gd is added into Cu-13.0Al-4.0Ni HTSMA to improve its plastic in the present work. The effect of Gd content on the microstructure, mechanical properties and shape memory effect (SME) of (Cu-13.0Al-4.0Ni)-*x*Gd alloy is investigated in detail.

2. Material and methods

The nominal composition of studied alloys were (Cu-13.0Al-4.0Ni)-*x*Gd ($x=0$, 0.3, 0.9, 1.5 and 6) (wt%), and they were marked as Cu0, Cu1, Cu2, Cu3 and Cu4, respectively. Copper, aluminum, nickel and gadolinium with high purity ($\geq$99.97 wt%) were melted in a non-consumed vacuum arc furnace to prepare polycrystalline button ingots. The ingots were remelted eight times to ensure homogeneity. The ingots were annealed in a vacuum quartz tubes at 850 °C for 24 h, and subsequently quenched into ice water.

The microstructures were observed by optical microscopy and Quanta 200FEG scanning electron microscopy (SEM). X-ray diffraction (XRD) measurements were performed by Rigaku D/max-rB with Cu K_α radiation. The phase transformation temperatures were determined by Perkin-Elmer Diamond differential scanning calorimetry (DSC) with heating and cooling rate of 20 °C/min. The martensitic transformation temperatures are listed in Table 1. The compression and SME tests were performed at room temperature on Instron 5569 testing system at a crosshead displacement speed of 0.2 mm/min, and the size of the sample was Φ 3 × 5 mm. The

Table 1
The transformation temperatures of (Cu-13.0Al-4.0Ni)-xGd alloys (°C).

Sample	A_s	A_f	M_s	M_f
Cu0	325.27	376.57	228.59	210.10
Cu1	307.70	362.22	202.72	149.60
Cu2	319.19	353.25	228.19	211.73
Cu3	319.08	360.75	189.16	177.92
Cu4	315.43	364.37	234.78	205.31

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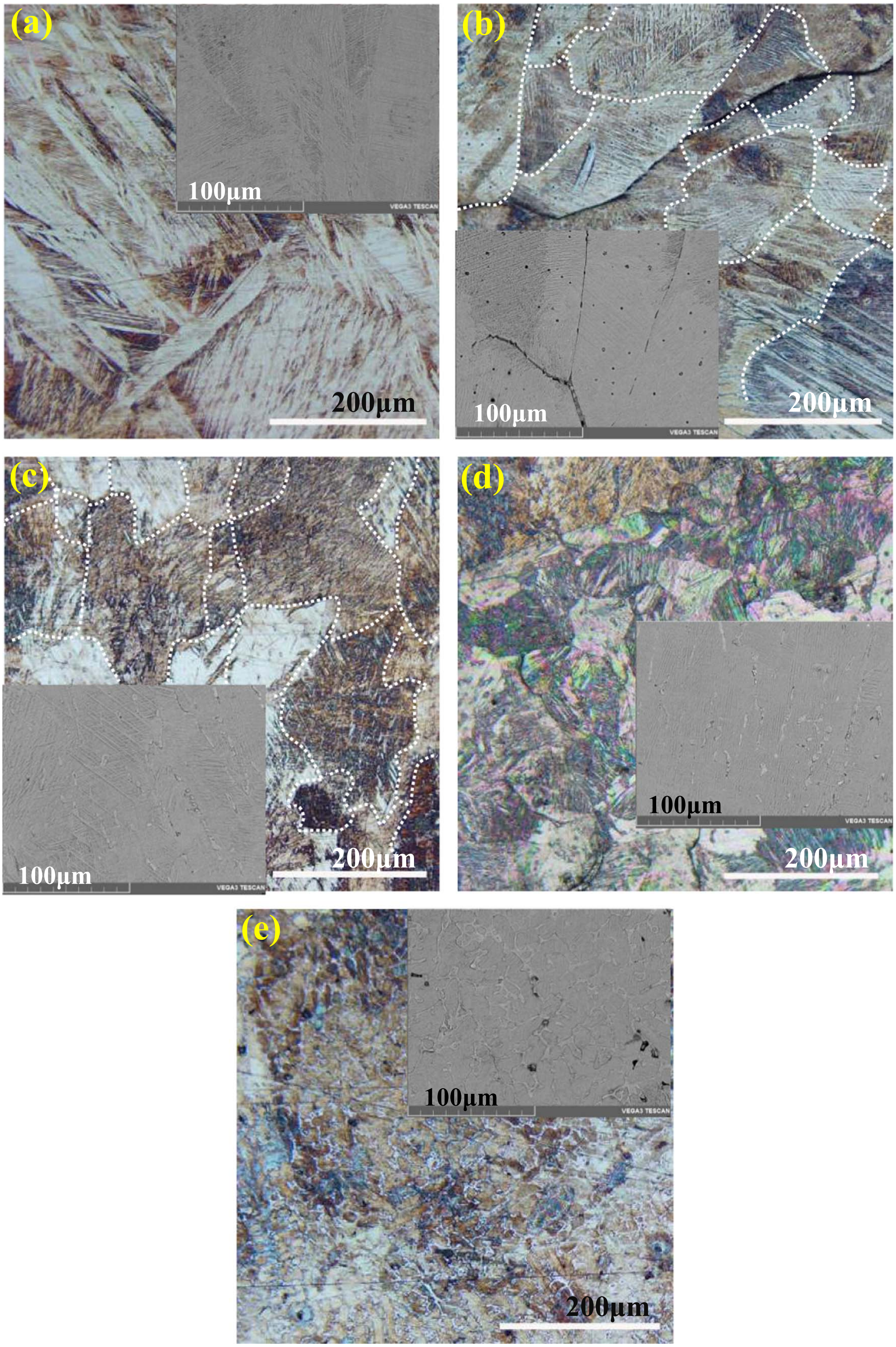

Fig. 1. Optical and SEM micrographs of solution treated (Cu-13.0Al-4.0Ni)-xGd alloys, (a) x=0; (b) x=0.3; (c) x=0.9; (d) x=1.5; (e) x=6.