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Letter

500 °C Isothermal section of the Ag–Cu–Nd (0–34 at.% neodymium) phase diagram

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Abstract

The 500 °C isothermal section of the Ag–Cu–Nd ternary phase diagram containing 0–34 at.% neodymium was determined by X-ray diffraction analysis and optical microscopy. The section consists of seven single-phase regions, eleven bi-phase regions and five tri-phase regions. No ternary intermetallic compounds are found.

1. Introduction

The Ag–Nd binary phase diagram has already been studied by some authors [1–4]. Recently, Gschneidner and Calderwood [5] summed up the previous works, and obtained a more complete Ag–Nd binary phase diagram with three intermetallic compounds: $Ag_{51}Nd_{14}$, Ag_2Nd and AgNd. Carnasciali *et al.* [6] studied the Cu–Nd binary system comprehensively. They reported a complete Cu–Nd binary phase diagram with six intermetallic compounds: Cu_6Nd, Cu_5Nd, Cu_4Nd, Cu_7Nd_2, Cu_2Nd and CuNd. The phase Cu_7Nd_2 forms at 825 ± 5 °C by a peritectic reaction, with subsequent decomposition at 785 ± 5 °C. Much literature on the Ag–Cu binary alloy system has been published. An Ag–Cu binary eutectic phase diagram is given in ref. 7.

Until now, no investigation of the Ag–Cu–Nd ternary system has been reported. Proceeding from the requirement of developing new alloys, this work studied the Ag–Cu–Nd ternary system containing 0–34 at.% neodymium, based on the corrected conclusions of refs. 5–7.

2. Experimental details

All the alloys were prepared from silver (99.99% pure), copper (99.99% pure) and neodymium (99.9% pure). For degassing, first the stoichiometric mixtures of silver and copper were refined in vacuum using an induction furnace. Then corresponding amounts of neodymium were added. The alloys were melted in boron nitride crucibles under pure argon atmosphere. After being remelted at least twice, the melts were cooled quickly, and homogeneous lumps of alloys were obtained.

Wrapped in tantalum foils, all samples were sealed in silica tubes filled with argon. To determine the isothermal section at 500 °C the specimens were homogenized at 500 °C for 30 days, and then quenched.

It was determined by chemical analysis that a little silver, copper and neodymium in the alloys was lost during the melting and heat treatment. Usually the loss of silver is more than that of copper and neodymium, so the composition of the alloys was shifted to the Cu–Nd side. The maximum shift of composition in all samples was less than 1 at.% in this work, and the results of the experiments were corrected correspondingly.

The X-ray diffraction experiments were performed in a Rigaku (RV-200 model) diffractometer, using Cu Kα radiation ($\lambda=0.15405$ nm). Diffraction data were corrected with silicon powder as an internal standard.

3. Results and discussion

The solid solubility of neodymium in silver at 500 °C is less than 0.1 at.%, and that of neodymium in copper is negligible according to the lattice parameter measurements; these results agree with those reported previously [5, 6].

It was determined from lattice parameter measurements that the solid solubility of silver in Cu_5Nd (hexagonal $CaCu_5$-type structure) is about 38.5 at.% at 500 °C. Figure 1 shows the lattice parameters of (Cu_5Nd) in the alloys $Nd_{16.7}Cu_{83.3-x}Ag_x$ as a function of silver content at 500 °C. The solid solubility of silver in Cu_6Nd at 500 °C is less than 1 at.% and that of silver in Cu_4Nd at 500 °C is negligible. The solid solubility of copper in $Ag_{51}Nd_{14}$ at 500 °C is about 5 at.%.

Cu_2Nd has an orthorhombic $CeCu_2$-type structure with $a=0.4387$ nm, $b=0.7001$ nm, $c=0.7418$ nm [6]. Mulokozi *et al.* [8] reported a polymophic phase transition in Ag_2Nd at about 620 °C; below this temperature α-Ag_2Nd also has an orthorhombic $CeCu_2$-type structure with $a=0.4772$ nm, $b=0.7027$ nm, $c=0.8153$ nm [9]. This work found that proportional solid solution is formed of Cu_2Nd and α-Ag_2Nd at 500 °C. Figure 2

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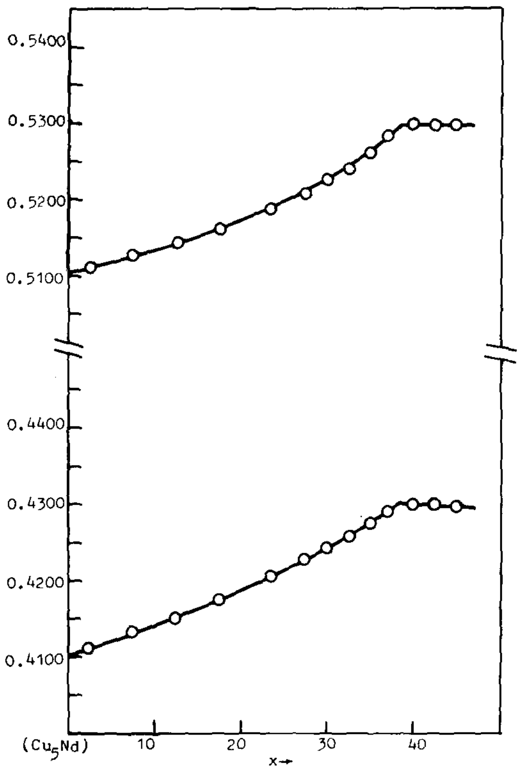

Fig. 1. Lattice parameters of the alloys $Nd_{16.7}Cu_{83.3-x}Ag_x$ *vs.* composition at 500 °C.

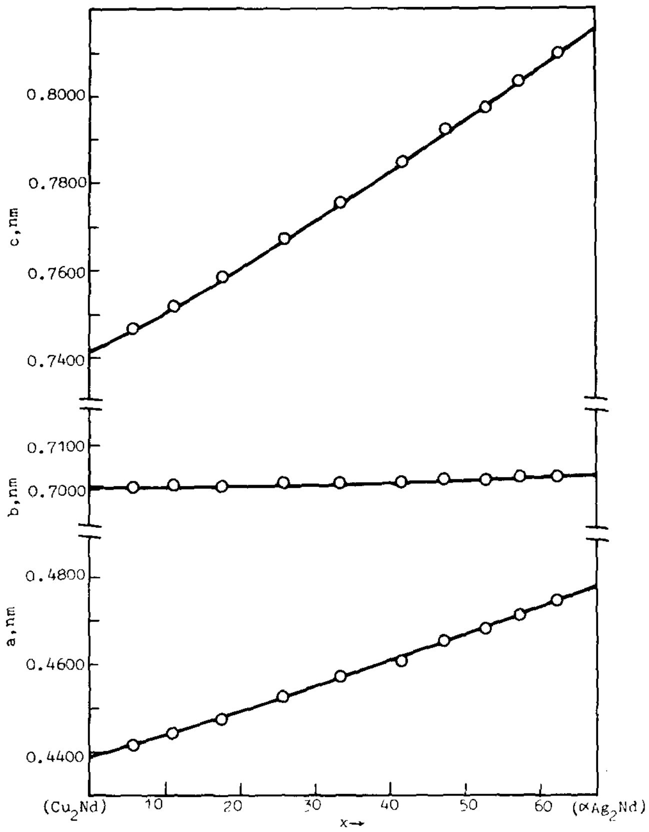

Fig. 2. Lattice parameters of the alloys $Nd_{33.3}Cu_{66.7-x}Ag_x$ *vs.* composition at 500 °C.

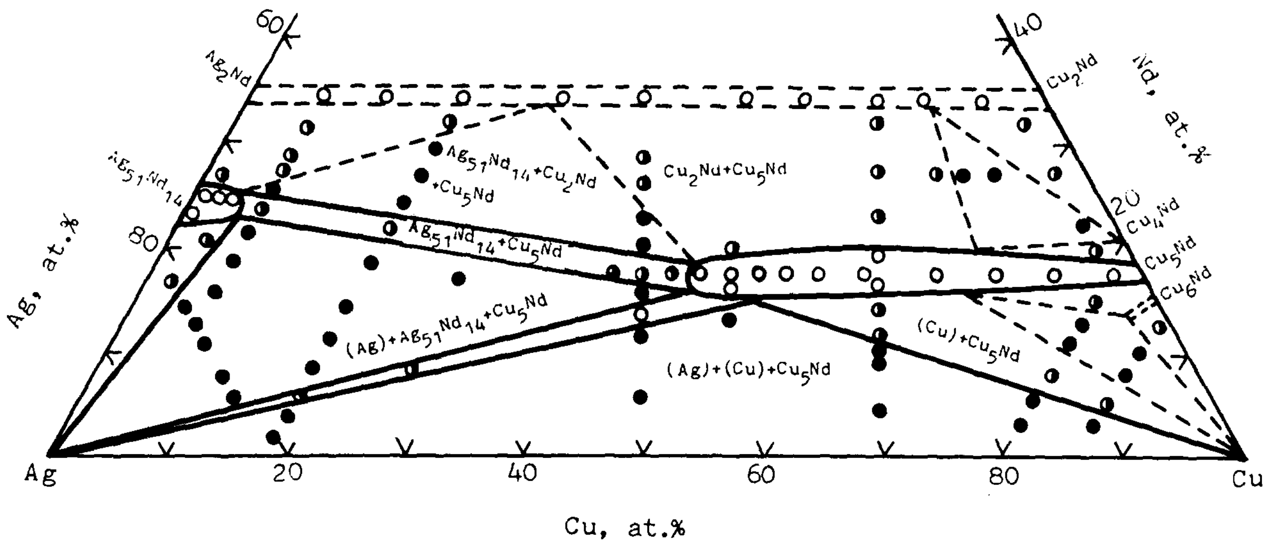

Fig. 3. 500 °C isothermal section of the Ag–Cu–Nd ternary system (0–34 at.% neodymium) phase diagram: ○ single phase, ◑ binary phase, ● ternary phase.

shows the lattice parameters of (Cu_2Nd) or (α-Ag_2Nd) in the alloys $Nd_{33.3}Cu_{66.7-x}Ag_x$ as a function of silver content at 500 °C.

The other boundaries of phase fields in the ternary phase diagram were determined by the X-ray diffraction disappearing-phase method, and checked by metallography. The compositions of the specimens are shown in Fig. 3 by the round symbols.

The experiments confirm that there is a wide ternary-phase region, (Ag) + (Cu) + Cu_5Nd, along the Ag–Cu binary system on the silver–copper-rich side of the Ag–Cu–Nd ternary phase diagram. In this region, the cold working properties of the alloys decrease rapidly with increasing neodymium content of the alloys.

To sum up, the isothermal section at 500 °C of the Ag–Cu–Nd (0–34 at.% neodymium) ternary phase diagram is shown in Fig. 3. The partial section consists of the following seven single-phase regions, solid solution (Ag), (Cu), Cu_6Nd, Cu_5Nd, Cu_4Nd, $Ag_{51}Nd_{14}$ and Cu_2Nd (Ag_2Nd); eleven binary-phase regions, (Ag) + (Cu), (Cu) + Cu_6Nd, (Cu) + Cu_5Nd, Cu_6Nd + Cu_5Nd, Cu_5Nd + Cu_4Nd, Cu_4Nd + Cu_2Nd, Cu_5Nd + Cu_2Nd, Cu_2Nd + $Ag_{51}Nd_{14}$, (Ag) + $Ag_{51}Nd_{14}$, Cu_5Nd + $Ag_{51}Nd_{14}$ and (Ag) + Cu_5Nd; five ternary-phase regions (Ag) + (Cu) + Cu_5Nd, (Cu) + Cu_5Nd + Cu_6Nd, Cu_5Nd + Cu_4Nd + Cu_2Nd, Cu_5Nd + Cu_2Nd + $Ag_{51}Nd_{14}$ and Cu_5Nd + $Ag_{51}Nd_{14}$ + (Ag). No new ternary intermetallic phase was found.

Acknowledgment

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