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Effect of cold working on ordering of an equiatomic CuPt alloy

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Abstract

Effect of cold working on the ordering of an equiatomic CuPt alloy during continuous heating was studied by means of electrical resistivity measurements, hardness tests, differential scanning calorimetry, and X-ray diffraction. The ordering after cold working occurred in three stages with remarkable acceleration, namely, the migration and the annihilation of excess vacancies (I_a), those of secondary defects (I_b) and the migration of equilibrium vacancies (II) as well as that of quenched sample. The lattice defects introduced by cold working advanced the stages I_a and I_b, and therefore decreased the stage II. There existed two temperature regions with softening due to ordering enhanced recrystallization and normal recrystallization.

Keywords: Intermetallics; Metals; Point defects; X-ray diffraction; Calorimetry; Ordering; Cold working

1. Introduction

It is well known in CuPt [1,2], Ni_3Al [3], FeCo [4] and so on that the ordered state is destroyed by cold working. Because cold working introduces many lattice defects in alloys and makes some confusion on atomic arrangement. Effects of cold working on ordering have been studied in many alloys. Johnes and Sykes [5], Roessler et al. [6] and Mitsui et al. [7] have reported that the orderings are retarded by cold working. On the other hand, Arunachalam and Cahn [8], Ward and Mikkola [9], Feller-Kniepmeier and Ruckert [10], Buckley [4] and Blackford et al. [11] have concluded that subsequent annealing after cold working accelerates the ordering. However, their discussions are not concentrated in the reaction rate of disorder to order but that of antiphase domain (APD) growth. The APD growth may correspond to relatively later stage of ordering processes. Few studies have been known of effects of cold working on the early stage of ordering.

Though the ordering process in CuPt has been studied by many researchers [12–18], no study has been done about the effect of cold working on it. The object of the present work is to clarify the effects of cold working on the ordering of a disordered CuPt alloy during continuous heating.

2. Experimental procedures

Alloy was prepared by vacuum melting together 99.95 wt.% Pt and 99.99 wt.% Cu. The chemical analysis of the alloy showed 50.63 at.% Pt as compared to 50 at.% Pt for stoichiometric CuPt. We finally obtained a homogeneous wire specimen 1 mm in diameter by alternative annealing and drawing.

The alloy was disordered at 1223 K for 1800 s and then quenched into ice brine. Subsequently it was cold-rolled to various reductions in thickness. Thereafter, they were continuously annealed from room temperature to 1223 K at various heating rates, namely anisothermal annealing. The effect of cold working on the ordering of CuPt was investigated by means of electrical resistivity measurements, hardness tests, differential scanning calorimetry (DSC) and X-ray diffraction (XRD).

The electrical resistivity measurements were made in vacuum using a four-terminal potentiometric apparatus. The

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hardness tests were made using a diamond pyramid hardness indenter with 500 g load. The Vickers hardness results are the averages of at least five indentations. For the DSC, a powder sample was prepared from the cold-worked alloy by filing and measured with DuPont 990DSC. The XRD studies with nickel-filtered Cu Kα radiation were performed on the plate sample cold-worked.

3. Results and discussion

3.1. Cold working

Fig. 1 shows a hardness curve for cold working. Thickness of the specimen before or after cold rolling is referred to t_0 or t, respectively. As known generally, the remarkable hardening was obtained with increasing the degree of cold working. The arrows in the figure show the starting conditions of the specimen which were used for the hardness tests and the electrical resistivity measurements mentioned below.

3.2. Anisothermal resistivity curves

Fig. 2 shows the anisothermal resistivity curves (a) of the CuPt alloy as quenched (open circles) or 30% cold-worked after quenching (solid circles), and their temperature derivatives (b). A heating rate of 1.67 mK/s was employed. Each resistivity was normalized by that at 1223 K to eliminate the effect of the size difference between each specimen, where ρ_T and ρ_{1223} refer to the resistivity at T and 1223 K, respectively. It is noted that the ordering occurs in three stages, which are represented by a, b and c (or a′, b′ and c′) in Fig. 2(b), irrespective of the degree of cold working, and the resistivity in cold-worked specimen began to decrease at a lower temperature than that in quenched one. In the quenched CuPt, Hisatsune [15] has already reported that each stage corresponds

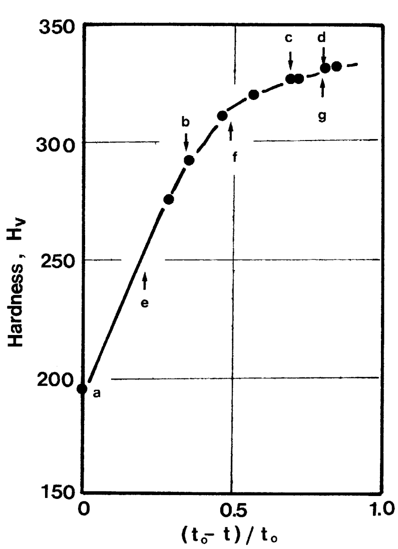

Fig. 1. Variation of hardnesses with the degree of cold working.

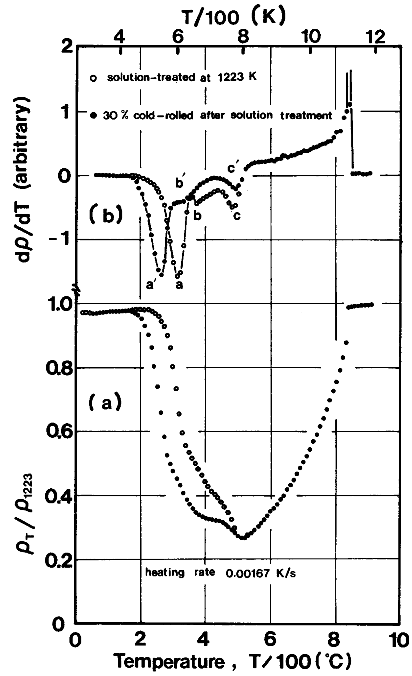

Fig. 2. Variation of resistivities (a) and their temperature derivatives (b) with temperature during a continuous heating of 1.67 mK/s.

to the ordering induced by the migration and the annihilation of quenched-in excess vacancies, those of secondary lattice defects and the migration of equilibrium vacancies from the lower temperature in turn. The ordering of the cold-worked specimen is very analogous to that of the quenched alloy except the temperature region and amount of the reaction in each stage. It is clear from the curves in Fig. 2 that the deformation produced considerable accelerating effect on ordering. In NiPt alloy, the resistometric analysis by Kuranov et al. [19] have shown that preliminary plastic deformation intensifies the ordering. Fig. 3 shows anisothermal resistivity curves (the lower part) and their temperature derivatives curves (the upper part) of the specimens with various degrees of cold

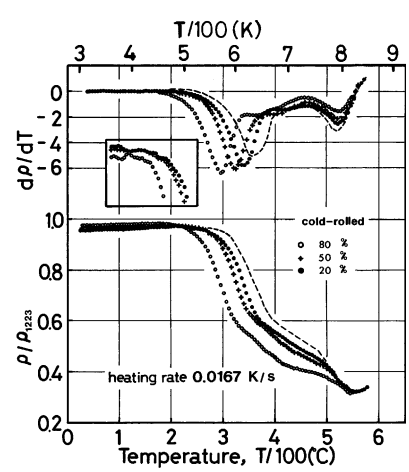

Fig. 3. Variation of the resistivity of specimens with various cold working during a continuous heating of 16.7 mK/s.