L-J Phase in a Cu-14Al-4Ni Alloy

J. Tan(譚澤安) and T. F. Liu(劉增豐)
Department of Materials Science and Engineering
National Chiao Tung University
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Abstract

The as-quenched microstructure of the Cu-14.6Al-4.3Ni alloy is $D0_3$ phase containing extremely fine precipitates. Transmission electron microscopy examinations indicated that the extremely fine precipitates should belong to the L-J phase, rather than 2H phase. The L-J phase has an orthorhombic structure with lattice parameters a=0.413 nm, b=0.254 nm and c=0.728 nm. This result is quite different from that reported by Otsuka et al.
Keywords: Cu-14.6Al-4.3Ni alloy, Microstructure, 2H phase, L-J phase

I. Introduction

According to the Cu-Al binary alloy phase diagram [1-4], it is seen that when a Cu-14Al alloy was heated at a point in the single disordered bcc β phase region and then quenched rapidly, a $\beta \rightarrow \beta_1(D0_3\text{-type}) \rightarrow \gamma'$(orthorhombic) phase transition would occur during quenching by an ordering transition and a martensitic transformation, respectively [5-10]. In order to suppress the martensitic transformation temperature, nickel was added to the Cu-Al binary alloys [11-14]. In 1966, P. R. Swann reported that the addition of 2.0 wt pct nickel in a Cu-14.6Al alloy did not introduce any new phases, but could prevent the martensitic transformation of the high temperature β phase on quenching to room temperature [11]. It means that the as-quenched microstructure of the Cu-14.6 pct Al-2.0 pct Ni alloy was single $D0_3$ phase. However, when the nickel content was increased to 4 wt. pct, a high density of extremely fine precipitates could be observed within the $D0_3$ matrix in the as-quenched alloy [13-14]. By using electron diffraction method, the crystal structure of the extremely fine precipitates was determined to be 2H phase [13]. The 2H phase has an orthorhombic structure with lattice parameters a=0.4274 nm, b=0.5393 nm and c=0.4127 nm [13].

Recently, we have also made transmission electron microscopy examinations on an as-quenched microstructure of the Cu-14Al-4Ni alloy. Based on our present study, it is found that the extremely fine precipitates formed within the $D0_3$ matrix belong to the L-J phase, rather than 2H phase. The L-J phase was firstly found and identified by the present workers in an as-quenched $Cu_{2.2}Mn_{0.8}Al$ alloy [15].

II. Experimental procedure

The alloy examined in the present study was prepared in a vacuum induction furnace under a controlled protective argon atmosphere by using 99.9 pct. copper, 99.9 pct. aluminum and 99.9 pct. nickel. The melt was chill cast into a 30x50x200-mm-copper mold. After being homogenized at 1000°C for 72 hours, the ingot was sectioned into 2-mm-thick slices. These slices were subsequently heat-treated at 1000°C (in the single β-phase state) for 1 hour and then quenched into iced brine rapidly.

Electron microscopy specimens were prepared by means of a double-jet electropolisher with an electrolyte of 70 pct. methanol and 30 pct. nitric acid. Electron microscopy was performed on a JEOL 2000FX scanning transmission electron microscope operating at 200 kV. This microscope was equipped with a Link ISIS 300 energy-dispersive X-ray spectrometer (EDS) for chemical analysis. Quantitative analyses of elemental concentrations for Cu, Al and Ni were made with the aid of a Cliff-Lorimer Ratio Thin Section method.

III. Results and discussion

Figure 1 represents a typical EDS spectrum of the present alloy in the as-quenched condition. The quantitative analysis indicated that the average chemical composition was Cu-14 wt pct Al-4 wt pct Ni.

Figure 2(a) is a bright-field (BF) electron micrograph of the as-quenched alloy, exhibiting the presence of the extremely fine precipitates with a mottled structure within the matrix. This feature is similar to that observed by other workers [13]. Figures 2(b) through (i) demonstrate eight different selected-area diffraction patterns (SADPs) of the as-quenched alloy. In these figures, it is seen that in addition to the reflection spots corresponding to the $D0_3$ phase [14,16-19], the diffraction patterns also consist of extra spots caused by the presence of the extremely fine precipitates. Compared to the previous study [13], it is found that the positions and streak behaviors of the extra spots in Figures 2(b), (c), (d), and (e) are the same as those observed by other workers in the Cu-14.2Al-4.3Ni alloy [13]. In their study, these four different SADPs were used to determine the crystal structure of the extremely fine precipitates. They pointed out that the extra spots in Figures 2(d) and (e) could be explained by both the ω structure and the 2H type structure; while the extra spots in Figures 2(b) and (c) could not be accounted for by the ω structure, but by the 2H type structure. Consequently, they concluded that the 2H type structure was more appropriate than the ω structure for accounting for these extra

reflections. The 2H phase has an orthorhombic structure with lattice parameters a=0.4274 nm, b=0.5393 nm and c=0.4127 nm [13]. Therefore, it may be deduced that the extremely fine precipitates formed in the present alloy were of the 2H type phase. However, a further analysis indicated that the extra spots in Figures 2(f) through (i) could not be indexed completely in terms of the lattice parameters of the 2H phase. Furthermore, a detailed dark-field (DF) electron microscopy examination indicated that all of the extra spots in Figure 2 should come from the same type of precipitates. A typical example is shown in Figure 3. Figures 3(a) and (b) are two DF electron micrographs, which were taken with the reflection spots marked as 1 and 2 in Figures 2(b) and (f), respectively. It is obvious that the precipitates presented in Figures 3(a) and (b) are completely identical. However, the reflection spot marked as 1 in Figure 2(b) can be indexed as 2H phase, but not the reflection spot marked as 2 in Figure 2(f). Therefore, it is reasonable to suggest that the extremely fine precipitates should not be of the 2H-type phase. However, when compared with the previous study of the present workers in the $Cu_{2.2}Mn_{0.8}Al$ alloy [15], it is clear that the positions and streak behaviors of the extra spots in Figures 2(b) through (i) are the same as those of the L-J phase. The L-J phase has an orthorhombic structure with lattice parameters a=0.413 nm, b=0.254 nm and c=0.728 nm. Accordingly, it is proposed that the extremely fine precipitates should belong to the L-J phase, rather than 2H phase. Figure 4 shows a 111 $D0_3$ DF electron micrograph of the as-quenched alloy, clearly reveals the presence of the $D0_3$ domains. In this figure, it is also seen that a high density of the extremely fine L-J precipitates (dark contrast) was present within the $D0_3$ domains. Based on the above observations, it is concluded that the as-quenched microstructure of the present alloy is $D0_3$ phase containing extremely fine L-J precipitates.

IV. Conclusion

The as-quenched microstructure of the Cu-14Al-4Ni alloy is $D0_3$ phase containing extremely fine precipitates. Transmission electron microscopy examinations revealed that the extremely fine precipitates were of L-J phase. The L-J phase has an orthorhombic structure with lattice parameters a=0.413 nm, b=0.254 nm and c=0.728 nm.

V. Acknowledgement

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VI. References

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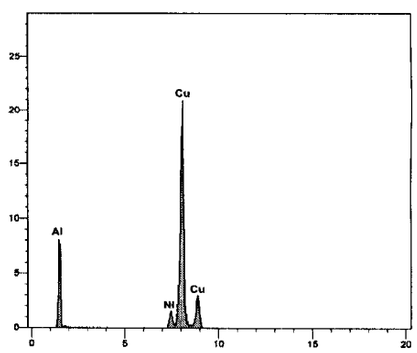
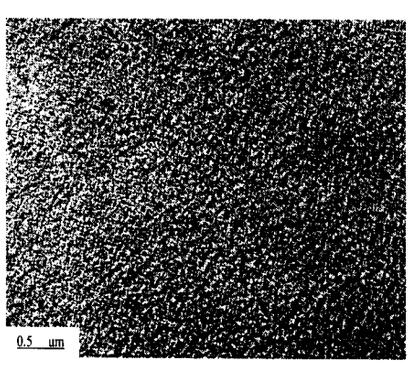
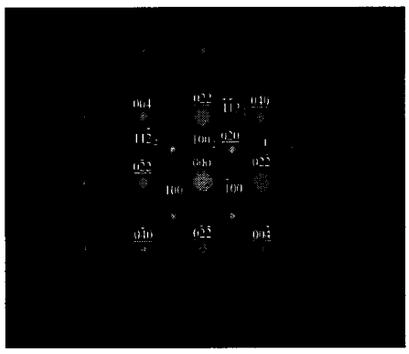


Fig. 1. A typical EDS profile of the present alloy in the as-quenched condition.



2(a)



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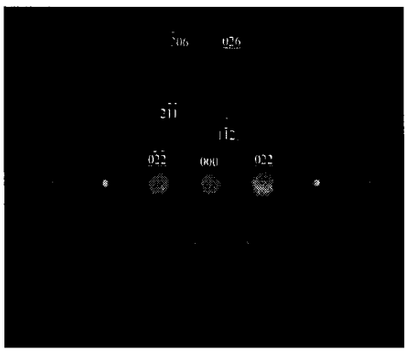

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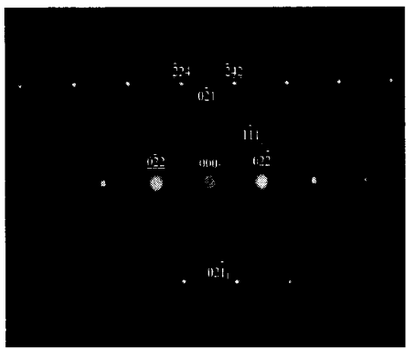
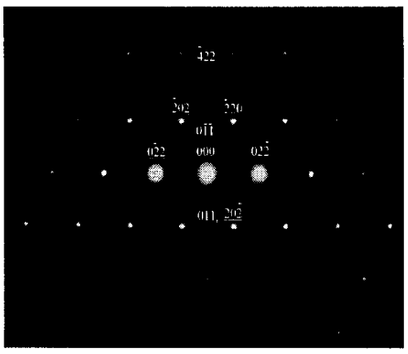
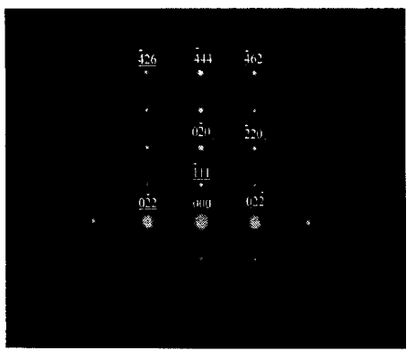


2(c)



2(g)



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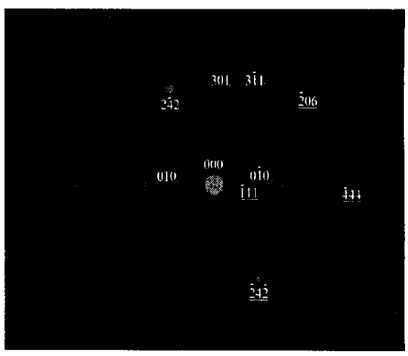

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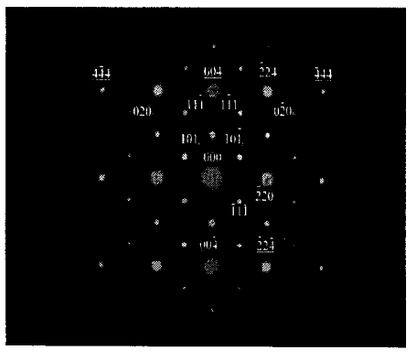
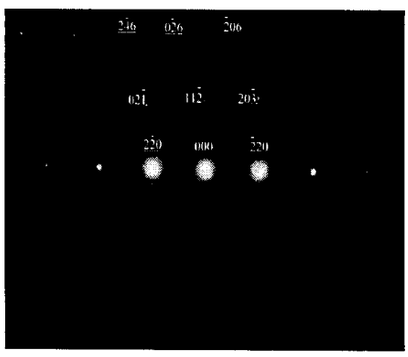


2(e)



2(i)

Fig. 2. Electron micrographs of the as-quenched alloy. (a) BF, and (b) through (i) eight SADPs. The zone axes of the $D0_3$ phase are (b) [100], (c) [311], (d) [211], (e) [110], (f) $[3\bar{3}1]$, (g) [111], (h) [321] and (i) [331], respectively. ($\underline{hkl}$ = $D0_3$ phase, $hkl_{1,\text{ or }2}$ = L-J phase, 1: variant 1; 2: variant 2)

3(a)

3(b)

Fig. 3. (a)-(b) Two DF electron micrographs, which were taken with the reflection spots marked as 1 and 2 in Figs. 2(b) and (f), respectively.

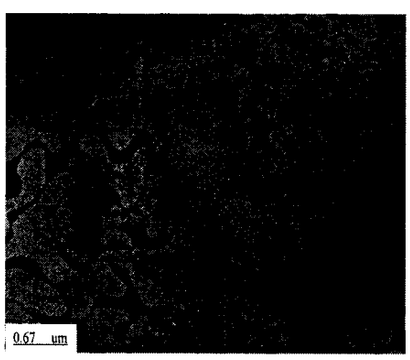


Fig. 4. 111 $D0_3$ DF electron micrograph of the same area as in Fig. 2(a).