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The Properties of Cu-Cr Alloy Prepared by the Horizontal Continuous Casting

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Effects of the solid solution and aging treatment on microstructure, hardness and electrical conductivity of the Cu alloy containing 1.1wt% Cr were investigated. The Cu-Cr alloy contains Mn as an alloying element. The horizontal continuous casting process was applied to obtain the unidirectionally solidified billets. The solid solution treatment of the alloy was carried out at 990 °C and the aging treatment was performed in the range 420-520 °C. The electrical conductivity generally increased as the aging temperature increased from 420 °C to 520 °C.

Keywords: Copper alloys, continuous casting, Chromium, electrical conductivity

1. INTRODUCTION

Copper alloys containing more than 0.1% chromium can be made to precipitation harden. Such alloys are of interest because of their excellent combination of high electrical conductivity and high strength. Many studies have been made on age hardenable Cu-Cr alloys, and have found their applications in developing welding machine in automobile, lead frame and plasma facing components [1-7].

It has been known that if Cu-Cr alloys were properly alloyed or heat-treated, their electrical conductivity exceeding 75%IACS could be attained in the aged condition. With increasing chromium content, the strength increases, whereas the electrical and thermal conductivity decreases so that a compromised condition should be found when both properties are needed.

In case of most precipitation hardenable alloys, a high strength is attained if the alloys are properly solution-treated and aged. Experimental works has been primarily done on Cu-Cr binary systems in laboratory scale [8-11] and thus scare literature exists regarding the continuously cast alloys and the multi-alloying element system.

The aim of the present study is to give a contribution to the understanding of effects of the solid solution and aging treatment on, hardness and electrical conductivity of the Cu-Cr-x alloys prepared by horizontal continuous casting. The present investigation includes: (a) influence of heat treatment on hardness; (b) influence of heat treatment on electrical conductivity; and (c) effects of microstructure.

2. EXPERIMENTAL

The Cu-1.1wt% Cr alloy was prepared in order to investigate effects of the solid solution and aging treatment on their hardness and electrical conductivity. The Cu-Cr alloys contain Mn, Si, Zn and Te as an alloying element (Table 1). The horizontal continuous casting process was applied to obtain the unidirectionally solidified billets. XRD analysis confirmed that the billets were unidirectionally solidified. The solid solution treatment of the sample was carried out at 990 °C for 1 h and the aging treatment was performed at 420 °C, 470 °C and 520 °C for 10 min, 20 min, 30 min, 60 min, 120 min, and 180 min, respectively.

Table 1 Chemical composition of the present specimens (wt%)

Alloy/ Element	Cr	Mn	Zn	Te	Si	Cu
Cu-Cr	1.1	0.03	<0.01	<0.01	<0.01	Bal.

The metallographic samples of the chromium copper alloys were first mechanically wet ground using a #1200 SiC grit paper, then polished with Al_2O_3 powder of 3㎛ diameter, followed by etching in a mixture of nitric acid and hydrogen peroxide(5ml HNO_3 + 15ml H_2O_2 at 25°C). After etching, the specimen was cleaned with distilled water, and then dried in air. Subsequently, the specimen was examined in scanning electron microscope (SEM). The samples for hardness measurement were wet ground using #1200 SiC grit paper, then tested by Rockwell hardness B and C scale, and finally converted to Vickers hardness value for comparison. Electrical conductivity was measured according to ASTM E 1004 with FISCHER's SMP-1 model.

3. RESULTS AND DISCUSSION

Fig. 1 shows the changes of electrical conductivity of

Cu-1.1wt% Cr alloy as a function of aging temperature and time. In general, the electrical conductivity of specimens increased as the aging time increased. The initial electrical conductivity was 41%IACS and this value was enhanced to 72 %IACS after aging at temperature 420 °C for 60 min. Further aging up to 180 min at this temperature increased the electrical conductivity up to 79 %IACS. The aging at 470 °C showed the similar results to that at 420 °C as shown in Fig. 1. At this temperature, the maximum conductivity 84%IACS was attained. For the aging at 520 °C, the electrical conductivity increased to 81%IACS even for the 10-min aging time and the further aging slightly increased the value to 85%IACS. It is to be noted that the electrical conductivity of the specimen aged at higher temperature showed the higher values at the same aging times.

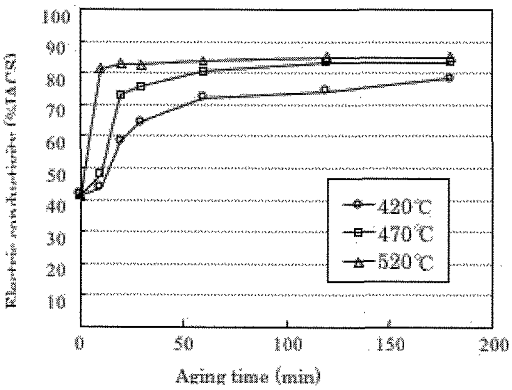

Fig. 1 Changes of electrical conductivity of Cu-1.1wt%Cr alloys

Fig. 2 represents the variation of hardness of Cu-1.1wt% Cr alloys as a function of aging temperature and time. The hardness of the specimen slightly increased from 50 Hv to 53 Hv after aging at 420 °C for 10 min. However, further aging up to 180 min increased the value to 99 Hv. Similarly, the hardness of the specimens aged at 470℃ was enhanced up to 119 Hv after 180 minute aging. For the aging at 520 °C, the hardness increased up to 30-min aging. However, further aging to 180 min decreased the hardness from 119 Hv to 95 Hv. The softening temperature of Cu-Cr alloys is known to be around 500 °C. Thus the hardness of the present specimen deceased as aging time increased at 520 °C.

Fig. 3 shows the SEM micrographs of the non-aged and the aged specimens at 420 and 450 °C. It can be seen that the second phase particles were precipitated along grain boundaries indicated as point A and were also uniformly distributed within grains indicated as point B in Fig. 3.

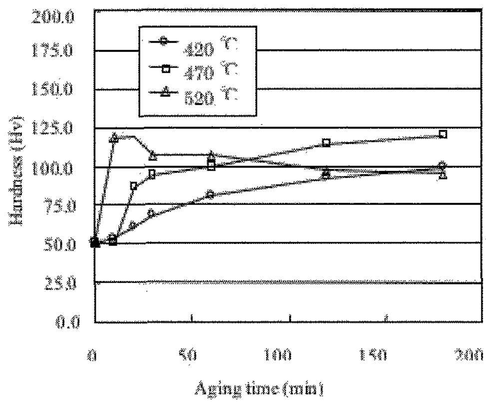

Fig. 2 Changes of hardness of Cu-1.1wt%Cr alloys

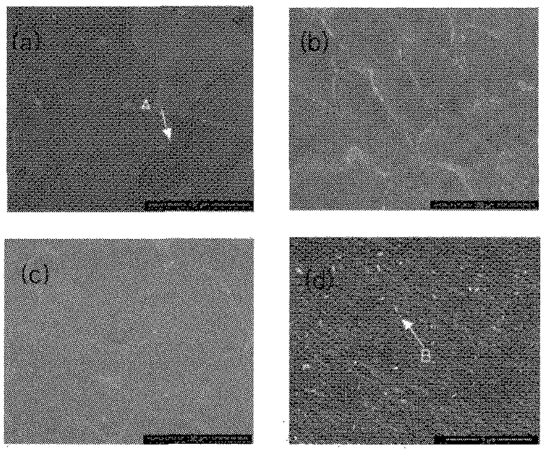

Fig. 3 SEM micrographs of the non-aged and the aged specimens at 420 and 450 °C
(a) non-aged (b) aged at 420 °C (c) aged at 470 °C (d) aged at 420 °C

From EDS analysis, it was found that the precipitate was composed of copper, chromium and manganese. The composition ranges of Cr and Mn were 5-11 wt% and 0.3-0.7 wt%, respectively. Comparing to the non-aged specimens, the aged ones had larger amount of precipitates within the grains and along the grain boundaries. These precipitated particles were thought to be the reason for the increases in hardness of the present specimens.

4. CONCLUSIONS

For the Cu-1.1 wt%Cr alloys, the electrical conductivity generally increased as the aging temperature increased in the range of 420-520 °C and as the aging time increased in the range of 10-180 min. Accordingly, the highest electrical conductivity of 85%IACS could be obtained by the aging at 520 °C for 180 min. When the Cu-1.1 wt%Cr specimens were aged for 60 min, the hardness was higher when the aging temperature was higher. However, the hardness decreased as the aging time increased at 520 °C after 10-min aging.

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