*Journal of Ceramic Processing Research. Vol. 8, No. 3, pp. 164~166 (2007)*

JOURNAL OF
Ceramic
Processing Research

# An investigation of the properties of Cu-Be-x alloys prepared by horizontal continuous casting

**Hyun Seon Hong[a,*], Man Sik Kong[a], Neung-Mo Sung[b], Seung Yun Lee[b] and Kyung Min Kim[c]**
[a]*Plant Engineering Center, Institute for Advanced Engineering (IAE), Yongin 449-863, Korea*
[b]*Jungjin Metal Co., Ltd, Pocheon 487-881, Korea*
[c]*Dept. of Materials Science, Hanyang Univ, Seoul 133-791, Korea*

**The effects of the solid solution and aging treatment on the microstructure, hardness and electrical conductivity of Cu alloys containing 0.7 wt% and 1.8 wt% Be were investigated. These Cu-Be alloys contain Co, Si, Ni and Mn as alloying elements. An horizontal continuous casting process was applied to obtain unidirectionally solidified billets. A solid solution treatment of the sample was carried out at 865 °C and aging treatments were performed in the range 270-550 °C. For the Cu-1.8 wt% Be alloys, the electrical conductivity generally increased as the aging temperature increased in the range of 270-370 °C. For the Cu-0.7 wt% Be alloys, the electrical conductivity increased as the aging time increased in the range of 10-180 min.**

**Key words: Copper alloys, continuous casting, beryllium, hardness, electrical conductivity.**

## Introduction

Copper alloys containing beryllium have attracted considerable interest because of their excellent combination of high electrical conductivity and high strength. Many studies have been made on age hardenable Cu-Be alloys, which have found their application in developing electrical and electronic components, high strength springs, diaphragms and forming tools [1-7]. It has been known that if Cu-Be alloys were properly alloyed or heat-treated, a yield strength exceeding 700 MPa could be attained in the hardened condition. Two types of Cu-Be alloys have been commercially developed, described as high strength and high conductivity alloys. With increasing beryllium 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 the case of most precipitation hardenable alloys, a high strength is attained if the alloys are properly solution-treated and aged. Experimental studies have been primarily made on Cu-Be binary systems on a laboratory scale and thus scare literature exists regarding multi-alloying element systems and continuously cast alloys [8-10]. The aim of the present study is to give a contribution to the understanding of the effects of the solid solution and aging treatment on the hardness and electrical conductivity of the Cu-Be-x alloys prepared by horizontal continuous casting. The present investigation includes: (a) the influence of heat treatment on hardness; (b) the influence of heat treatment on electrical conductivity; and (c) the effects of the beryllium content.

## Experimental

The Cu-0.7 wt%Be alloy and Cu-1.8 wt%Be alloy were prepared in order to investigate the effects of the solid solution and aging treatment on their hardness and electrical conductivity. These Cu-Be alloys contain Co, Si, Ni and Mn as alloying elements. An horizontal continuous casting process was applied to obtain unidirectionally solidified billets. XRD analysis confirmed that the billets were unidirectionally solidified. The solid solution treatment of the samples was carried out at 865 °C for 1 h and the aging treatments for Cu-0.7 wt%Be alloy were performed at 450 °C, 500 °C and 550 °C for 10 min, 30 min, 60 min, and 180 min because the temperature for the maximum age hardening is known to be 500 °C. The Cu-1.8 wt%Be alloy was aged at 270 °C, 320 °C and 370 °C for the same time intervals. For this alloy, the temperature for the maximum age hardening is known to be 315-345 °C.

The metallographic samples of the beryllium copper alloys were first mechanically wet ground using a #1200 SiC grit paper, then polished with 3 μm diameter $Al_2O_3$ powder, followed by etching in a mixture of nitric acid and hydrogen peroxide (5 ml $HNO_3$ + 15 ml $H_2O_2$ at 25 °C). After etching, the specimens were cleaned with distilled water, and then dried in air. Subsequently, the specimen was examined in a scanning electron microscope (SEM). The samples for hardness

*Corresponding author:
Tel : +82-31-330-7481
Fax: +82-31-330-7113
E-mail: hshong@iae.re.kr

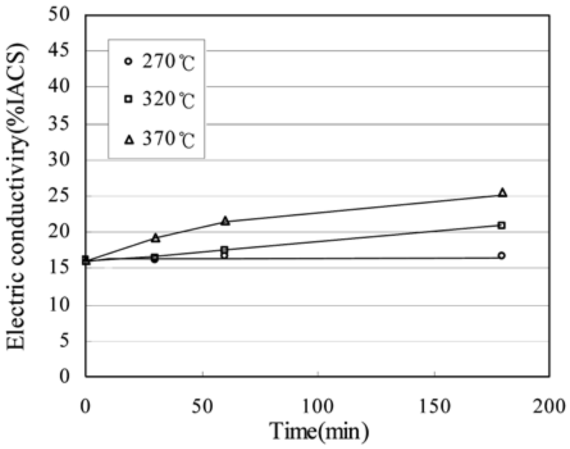


**Fig. 1.** Changes of electrical conductivity of Cu-1.8 wt%Be alloys.

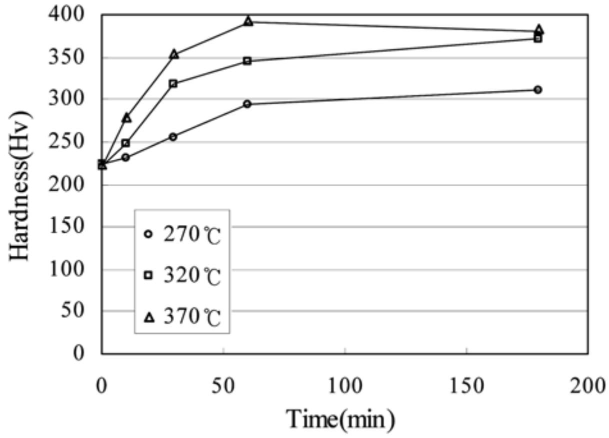


**Fig. 3.** Changes of hardness of Cu-1.8 wt%Be alloys.

measurements were wet ground using #1200 SiC grit paper, then tested on the Rockwell hardness B and C scales, and finally converted to Vickers hardness values for comparison. Electrical conductivity was measured according to ASTM E 1004 with a FISCHER's SMP-1 instrument.

## Results and Discussion

Figure 1 shows the changes of electrical conductivity of the Cu-1.8 wt%Be alloy as a function of aging temperature and time. The electrical conductivity of the initial specimen was 16%IACS. After aging at 320 °C and 370 °C for 180 min, the electrical conductivity increased to 21%IACS and 25%IACS, respectively. At these temperatures, the electrical conductivity increased almost linearly with the aging time. However, with aging at 270 °C, the electrical conductivity did not change even though the aging time increased. In the present aging temperature range of 270-370 °C, a higher electrical conductivity was attained at the higher aging temperature.

Figure 2 shows the changes of electrical conductivity of Cu-0.7 wt%Be alloys 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 31%IACS and this value was enhanced to 46%IACS after aging at temperatures 450 °C, 500 °C and 550 °C for 180 min. It is to be noted that the highest electrical conductivity value of Cu-0.7 wt%Be alloys was higher than that of Cu-1.8 wt%Be alloys by about 85%.

Figure 3 represents the variation of hardness of Cu-1.8 wt%Be alloys as a function of aging temperature and time. The hardness of the specimen slightly increased from 222 Hv to 230 Hv after aging at 270 °C for 10 min. However, further aging up to 180 min increased the value to 310 Hv. Similarly, the hardness of the specimens aged at 320 and 370 was enhanced up to 372 Hv and 382 Hv after 180 minute aging, respectively.

Figure 4 exhibits the relationship between hardness and aging time for the Cu-0.7 wt%Be alloys. For the aging at 450 °C, the hardness did not change up to 30-min aging. Further aging to 180 min increased the hardness from 74 Hv to 188 Hv. For the aging at 500

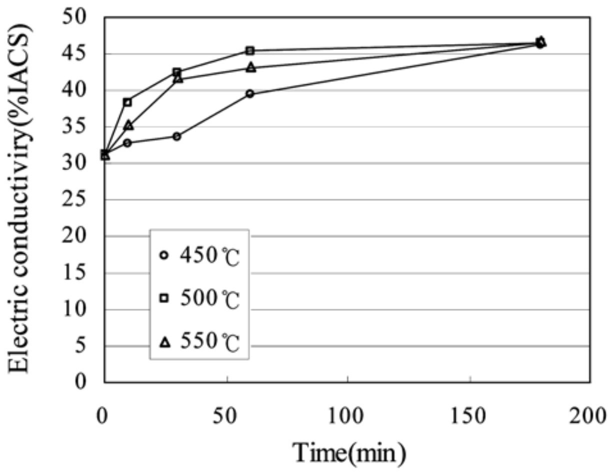


**Fig. 2.** Changes of electrical conductivity of Cu-0.7 wt%Be alloys.

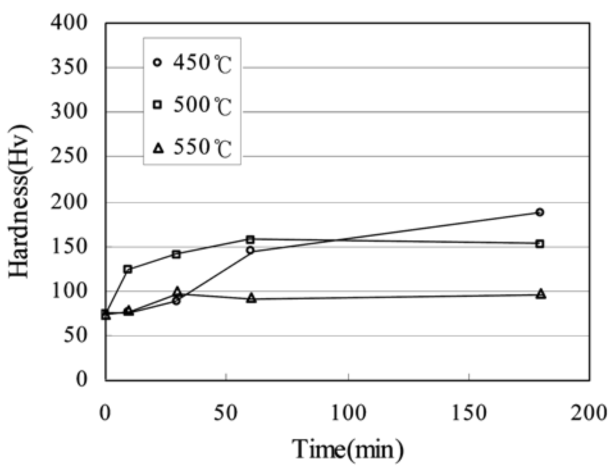


**Fig. 4.** Changes of hardness of Cu-0.7 wt%Be alloys.

**Table 1.** Chemical composition of the specimens (wt%)

| Alloy/ Element | Be | Co | Ni | Si | Mn | Cu |
|---|---|---|---|---|---|---|
| Cu-0.7Be | 0.71 | 1.72 | 0.08 | 0.03 | 0.07 | Bal. |
| Cu-1.8Be | 1.85 | 0.11 | 0.19 | 0.07 | 0.18 | Bal. |

°C, the hardness increased from 74 Hv to 151 Hv as the aging time increased. For the aging at 550 °C, the hardness remained the same even after 180 minute aging. The hardness value was 97 Hv after aging for 180 min.

## Conclusions

For the Cu-1.8 wt%Be alloys, the electrical conductivity generally increased as the aging temperature increased in the range 270-370 °C and as the aging time increased in the range of 10-180 min. Accordingly, the highest electrical conductivity of 25%IACS could be obtained by the aging at 370 °C for 180 min. For the Cu-0.7 wt%Be alloys, the electrical conductivity increased as the aging time increased in the range of 10-180 min. The electrical conductivities were higher when the alloy was aged at 500 °C than 550 °C up to 60 min, however, the electrical conductivity increased to the same value after 180-minute aging. When the Cu-1.8 wt%Be specimens were aged for 180 min, the hardness was higher when the aging temperature was higher. However, the hardness decreased as the aging temperature increased for the Cu-0.7 wt%Be specimens.

## References


1. W.F. Smith; Structure and properties of engineering alloys, McGraw-Hill, New York, USA, 1990, pp. 356-370.
2. A.S.M., Properties and Selection: Non-Ferrous Alloys and Pure Metals, Metal Handbook, 10th edition, Vol.2. ASM, Material Park, Ohio, USA, 1992, pp. 301-308.
3. K.G. Wikle; Beryllium Copper, an overview of heat treat techniques, Heat Treating, July (1981) 30.
4. US patent, 4,657,601, Apr. 14 (1987).
5. J. Su, Q. Dong, P. Liu, H. Li and B. Kang, Mater. Sci. Eng. A 392 (2005) 422-426.
6. Y. Karaki, Y. Koike, M. Kubota, and H. Ishimoto, Cryogenics 37[3] (1997) 171-172.
7. M.J. Saarivirta, Trans. Metall. Soc. AIME 218 (1960) 431-437.
8. A. Varschavsky and E. Donoso, Thermochimica Acta 266 (1995) 257-275.
9. G. Straffelini, L. Maines, M. Pellizzari, and P. Scardi, Wear 259 (2005) 506-511.
10. J. Lerner and C.J. McMahon Jr., Mater. Sci. Eng. A 336 (2002) 72-74.