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EFFECT OF AGING TREATMENT PARAMETERS ON MICROSTRUCTURE AND PROPERTIES OF Cu-Ni-Si ALLOY

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ABSTRACT

In this paper, effect of cold pre-deformation and sequent aging time and temperature on microstructure and properties of Cu-2.8Ni-1.0Si alloy are reported. The results shown that, hardness and electrical conductivity of alloy increase with increasing cold deformation degree after quenching and subsequent aging. With undeformed specimens after quenching, hardness and electrical conductivity of alloy reach maximum values with subsequent aging at 425 and 475 ^{o}C, respectively. Alloy attains maximum hardness of 255 HV5 with aging at 425 ^{o}C for 4.5 hours, while maximum electrical conductivity of 38.5 %IACS with aging at 475 ^{o}C for 8 hours. In the case of deformed specimens after quenching and subsequent aging, this rule is still preserved. Especially, at 70 % cold pre-deformation degree, alloy attains the maximum hardness of 274.3 HV5 with aging at 425 ^{o}C for 3.5 h, while maximum electrical conductivity reaches 42.4 % IACS with aging at 475 ^{o}C for 6 h.

Keywords: Cu-2.8Ni-1.0Si alloy, cold pre-deformation, deformation degree, aging, Vickers hardness, electrical conductivity.

1. INTRODUCTION

In all of the copper alloys used in electrical engineering, Cu-Ni-Si alloy have been considerable interest in the applications of leadframe, electrical contacts, bus conductor, electrodes... due to its high strength and good electrical conductivity [1 - 4]. Recently, the studies of Cu-Ni-Si alloy still continue to develop in many different priorities. Most studies about this alloy system aim to improve the mechanical properties, especially combination of high strength and good electrical conductivity [5 - 9].

In this work, the effect of thermomechanical treatment, consisting cold deformation after quenching and subsequent artificial aging on microstructure and properties of Cu-2.8Ni-1.0Si (*wt* %) alloy, which can be used in manufacturing of leadframes, busbars, and electrodes… are explored.

2. EXPERIMENTAL

The Cu-2.8Ni-1.0Si (*wt* %) alloy was produced by the classical method of melting in the electrical furnace Nabertherm (Germany). Chemical composition of an experimental alloy is given in Table 1.

Table 1. Chemical composition of an experimental alloy.

Chemical composition, wt %									
Ni	Si	Zn	Pb	Sn	Fe	Cr	Al	Ti	Cu
2.77	1.02	0.021	0.012	0.005	0.03	0.003	0.035	0.006	96.098

Cylindrical ingot of dimension of Φ50x150 (mm) was homogenized at 925 for 4 hours, cooled with furnace. Cylindrical ingot was cut into specimens with dimension of Φ50×δ6 (mm), then these specimen were hot rolled to the thickness of 3 mm at 900 ^{o}C. Rolled specimens were reheated to 850 ^{o}C, held at this temperature for 1 hour and then supersaturated in water. Supersaturated specimens were cut into flat specimens with dimension of 60x6x3 (mm) (length x thickness x width). They were used as a starting material for further studies about effect of cold deformation degree and aging temperature on hardness (HV5) and electrical conductivity (%IACS) of Cu-2.8Ni-1.0Si alloy.

The thermomechanical treatments were divided into four processes and are expressed as follows:

(1) Solution treatment (ST) at 850 ^{o}C for 1 h and then water quench + cold rolling (CR) to 0 % reduction + aging at 425, 475 and 525 ^{o}C for different times (ST + CR + aging).

(2) Solution treatment at 850 ^{o}C for 1 h and then water quench + cold rolling to 30 % reduction + aging at 425, 475 and 525 ^{o}C for different times (ST + CR + aging).

(3) Solution treatment at 850 ^{o}C for 1 h and then water quench + cold rolling to 45 % reduction + aging at 425, 475 and 525 ^{o}C for different times (ST + CR + aging).

(4) Solution treatment at 850 ^{o}C for 1 h and then water quench + cold rolling to 70 % reduction + aging at 425, 475 and 525 ^{o}C for different times (ST + CR + aging).

Hardness is determined by Wilson Wolpert Vickers hardness Tester (China), and electrical conductivity is calculated through resistance R, which determined by Megger Digital Microhmmeter DLRO-10 (Great Britain).

3. RESULTS AND DISCUSSIONS

The as-cast microstrucure of Cu-2.8Ni-1.0Si alloy is shown in Figure 1. It can be seen that cast alloy has a dendritic structure with average hardness of 115 HV5. After homogenization at 925 ^{o}C, average hardness of alloy decreased to 75 HV5.

Hot-rolled alloy specimens were reheated to 850 ^{o}C for 1 hour, then cooled by quenching in water. The microstructure of alloy after solution treatment and quenching is supersaturated copper solid solution with average hardness of (92-94) HV5 (Figure 2).

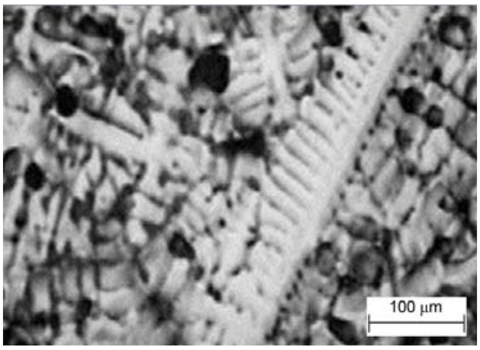

Figure 1. As-cast microstructure of Cu-2.8Ni-1.0Si alloy.

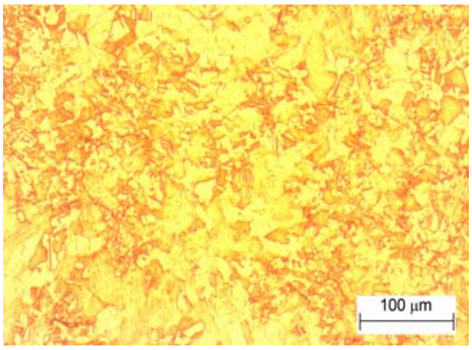

Figure 2. Microstructure of Cu-2.8Ni-1.0Si alloy after solution treatment and quenching.

After the cold rolling process of supersaturated flat specimens, hardness of alloy specimens increases with increasing of deformation degree. Effect of cold deformation degree on hardness of Cu-2.8Ni-1.0Si supersaturated alloy is shown in Figure 3. The alloy can be subjected to cold rolling with degree of deformation up to 80 %.

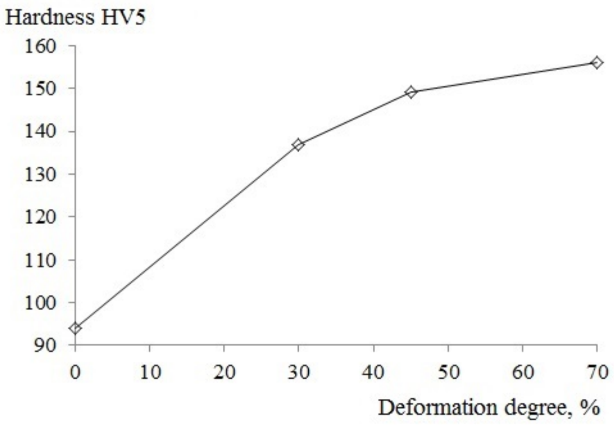

Figure 3. Effect of cold deformation degree on hardness of Cu-2.8Ni-1.0Si supersaturated alloy.

After initial cold rolling, the flat specimens are artificially aged. The hardness of aged alloy specimens rapidly increases after aging for only 1 hour. The dependence between hardness and deformation degree, aging time for alloy at 425 ^{o}C, 475 ^{o}C and 525 ^{o}C are illustrated in Figure 4, 5, 6 and 7. With the undeformed specimens (0 % cold work), hardness is reached maximum value of 255 HV5 at aging temperature of 425 ^{o}C for 4.5 hours. When increasing aging temperature, time to reach a peak hardness is shorter but maximum value of hardness is lower with the value of 223.4 HV5 and 195.6 HV5 at 475 ^{o}C for 4 hours and 525 ^{o}C for 2 hours, respectively. This rule is still preserved when study on the change of hardness of cold rolling specimens after quenching with deformation degree of 30, 45 and 70 % and subsequent aging at the same temperature (see Figure 4, 5 and 6). At the same aging temperature, when increasing deformation degree, the peak hardness also increases, but time to reach maximum hardness is shorter, and the softening process of alloy also easily occurs. With 70 % cold pre-deformation degree, alloy reaches the highest hardness of 274.3 HV5 at aging temperature of 425 °C for 3.5 hours (see Figure 7).

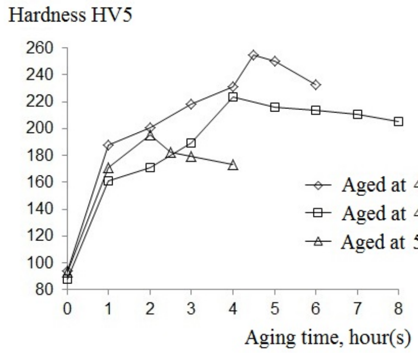

Figure 4. The changes in hardness of specimens after ST + CR 0 % + aging.

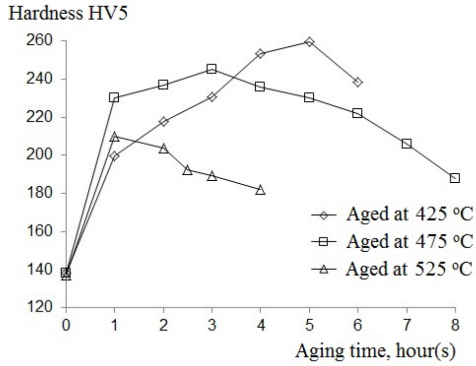

Figure 5. The changes in hardness of specimens after ST + CR 30 % + aging.

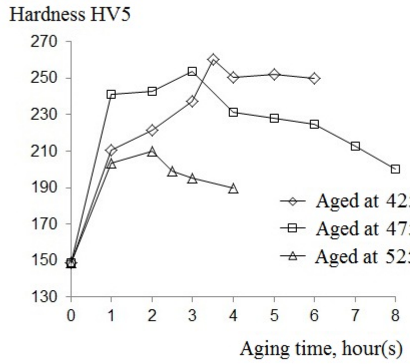

Figure 6. The changes in hardness of specimens after ST + CR 45 % + aging.

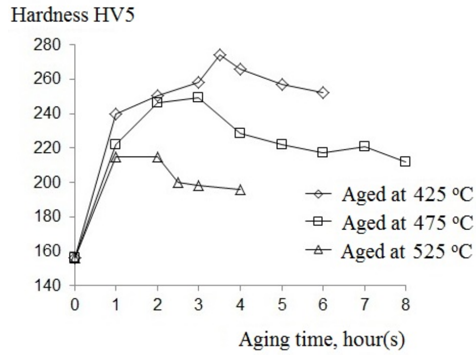

Figure 7. The changes in hardness of specimens after ST + CR 70 % + aging.

Next, the electric conductivity of Cu-2.8Ni-1.0Si alloy is also studied. The results show that, the electrical conductivity of alloy reaches maximum value at aging temperature of 475 ^{o}C. In the case of cold undeformed specimens, the electrical conductivity reaches maximum value of 38.5% IACS after aging for 5 hours. The maximum value of electrical conductivity increases with increasing degree of cold deformation before aging, as shown in Figure 8, 9, 10 and 11. With 70 % cold pre-deformed specimens, the electrical conductivity reaches the highest value of 42.4% IACS at subsequent aging at 475 ^{o}C for 6 hours (see Figure 11).

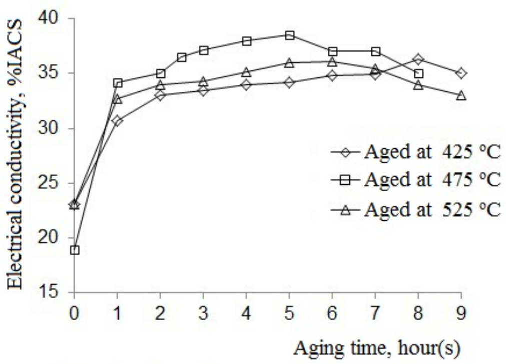

Figure 8. The changes in electrical conductivity of specimens after ST + CR 0 % + aging.

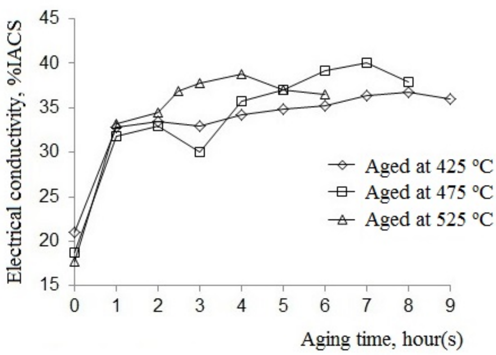

Figure 9. The changes in electrical conductivity of specimens after ST + CR 30 % + aging.

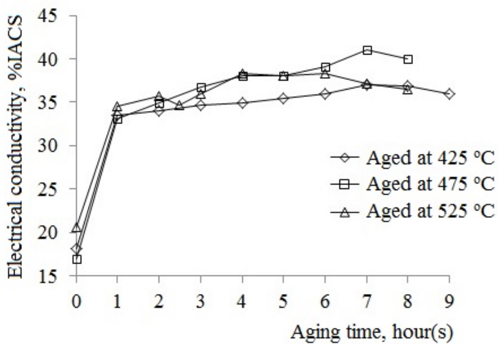

Figure 10. The changes in electrical conductivity of specimens after ST + CR 45 % + aging.

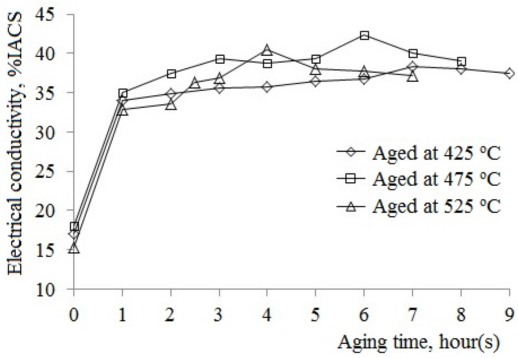

Figure 11. The changes in electrical conductivity of specimens after ST + CR 70 % + aging.

The microstructure of alloy specimens after quenching, cold rolling and aging at 425, 475 and 525 ^{o}C are shown in Figures 12, 13 and 14. The recrystallization behaviour of particles in alloy increases with increasing artificial aging temperature.

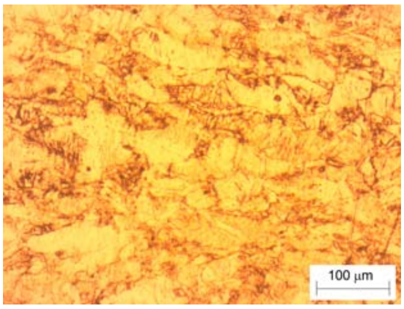

Figure 12. Microstructure of alloy specimen after aging at 425 ^{o}C for 8h with 70 % cold pre-deformation.

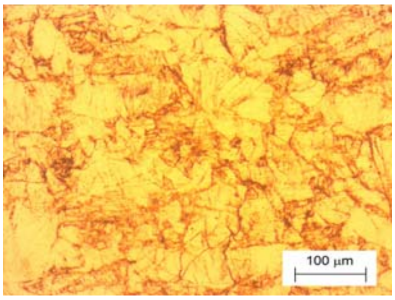

Figure 13. Microstructure of alloy specimen after aging at 475 ^{o}C for 6h with 70 % cold pre-deformation.

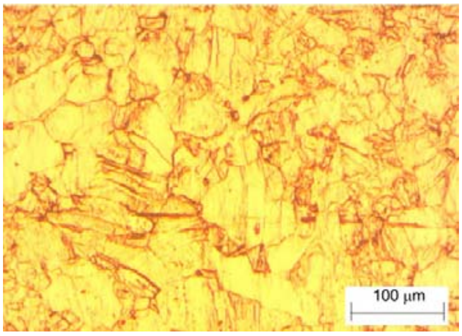

Figure 14. Microstructure of alloy specimen after aging at 525 ^{o}C for 4h with 70 % cold pre-deformation.

4. CONCLUSION

In conclusion, thermomechanical treatment, consisting cold deformation after quenching and subsequent artificial aging significantly affects on microstructure and properties of Cu-2.8Ni-1.0Si alloy. In the case of undeformed specimens after quenching, hardness and electrical conductivity of alloy reach maximum values with subsequent aging at 425 and 475 ^{o}C, respectively. The maximum hardness and electrical conductivity reach only 255 HV5 and 38.5 % IACS at the aging temperatures of 425 ^{o}C for 4.5 h and 475 ^{o}C for 8 h, respectively. In the case of deformed specimens after quenching and subsequent aging, this rule is still preserved. Especially, at 70 % cold pre-deformation degree, alloy attains the maximum hardness of 274.3 HV5 with aging at 425 ^{o}C for 3.5 h, while maximum electrical conductivity is 42.4 % IACS with aging at 475 ^{o}C for 6 h.

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TÓM TẮT

NGHIÊN CỨU ẢNH HƯỞNG CỦA CÁC THAM SỐ HÓA GIÀ ĐẾN TỔ CHỨC VÀ TÍNH CHẤT CỦA HỢP KIM Cu-Ni-Si

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Bài báo này nghiên cứu và đánh giá ảnh hưởng của nhiệt độ và thời gian hóa già nhân tạo kết hợp biến dạng nguội đến tổ chức và tính chất (độ cứng và độ dẫn điện) của hợp kim Cu-2,8Ni-1,0Si. Kết quả thực nghiệm cho thấy, độ cứng của hợp kim đạt cực đại khi hóa già ở 425 ^{o}C, còn độ dẫn điện đạt cực đại khi hóa già ở 475 ^{o}C. Khi được biến dạng nguội ngay sau tôi và hóa già nhân tạo tiếp theo, độ cứng và độ dẫn điện tăng theo mức độ biến dạng. Với các mẫu được biến dạng nguội 70 %, độ cứng đạt giá trị cao nhất 274,3 HV5 khi hóa già tiếp sau ở nhiệt độ 425 ^{o}C sau 3,5 giờ, độ dẫn điện đạt giá trị cao nhất 42,4 % IACS khi hóa già tiếp sau ở nhiệt độ 475 ^{o}C sau 6 giờ. Trong khi đó, với các mẫu không được biến dạng, độ cứng và độ dẫn điện đạt cực đại tương ứng là 255 HV5 sau 4,5 giờ và 38,5 % IACS sau 8 giờ với cùng nhiệt độ hóa già tương ứng.

Từ khóa: hợp kim Cu-2,8Ni-1,0Si, biến dạng nguội trước, mức độ biến dạng, hóa già nhân tạo, độ cứng Vickers, độ dẫn điện.