

Effect of High Pressure Heat Treatment on Hardness and Electrical Conductivity of a Copper-Based Multiple Alloy

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Abstract: A copper-based multiple alloy was treated at different high pressure and 850 °C for 15 min, and the effect of high pressure heat treatment on the hardness and electrical conductivity of copper-based multiple alloy were studied by electric conductivity instrument and hardness tester. The results show that high pressure heat treatment can increase the hardness and decrease electrical conductivity of the copper-based multiple alloy. After high pressure heat treatment and 500 °C aging for 2 h, its electrical conductivity can be greatly improved, and the improving is obvious with the pressure increasing.

Key words: A copper-based multiple alloy, high pressure heat treatment, hardness, electrical conductivity.

1. Introduction

Cu-based alloys have been widely used as conducting wire of integrate circuit, electrode of resistance welding, generator sets and commutator of electric hand tool and so on due to high strength, good electric conductivity [1-3]. With the development of science and technology, based on the premise that the requirement for strength is met, the electrical conductivity is needed to improve as far as possible. Because of the contradiction between strength and conductivity of the copper alloy, generally [4], high-strength is obtained at the expense of conductivity. How to resolve this contradiction is the key issue for copper alloys with high strength and conductivity. In recent years, the research results have shown that high pressure heat treatment can improve the microstructure and properties of Cu-based alloys [5-7]. Therefore, effects of high pressure heat treatment on hardness and electrical conductivity of

copper-based multiple alloy were investigated.

2. Experiment

The experimental material was an as-cast copper-based multiple alloy, with chemical composition (mass percent, %) of 96.72 Cu, 0.37 Cr, 0.61 Ag, 1.27 Se, 1.03 Te. High pressure experiment was carried out on a CS-IIB tester. The samples with dimension of $\Phi 8 \times 10 \text{ mm}^2$ were heated up to 850 °C and held for 15 min under the pressures of 1, 2, 4 and 6 Gpa, respectively. Then the electricity (kept pressure) was shut off and the samples were cooled to room temperature. The specimens before and after high pressure were aging treated at 500 °C for 2 h in a SX-4-10 furnace. Hardness and electrical conductivity of the specimens were tested with a THV-5 Vickers hardness tester and a WD-Z type eddy electrical conductivity instrument, respectively. All of the data were taken the average of three measurements. The microstructures were analyzed by Axiovert200MAT metallographic microscope and S-3400N scanning electron microscope (SEM-BSE).

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3. Results and Discussion

3.1 Microstructure

Fig. 1 shows microstructures of the copper-based multiple alloy before and after high pressure. It can be seen that the microstructure after 6 GPa pressure treatment is composed of basis and irregular-shaped particles. Analysis proves that the basis is $\alpha(\text{Cu})$ solid solution and the irregular-shaped particles are Cu-Se (Te) compound.

High pressure heat treatment doesn't have a large effect on the microstructural characteristics. The images of SEM-BSE (Fig. 2) indicate that the micropores in the alloy after 6 GPa pressure treatment are less than in as-cast alloy and the structure is more compact.

3.2 Influence of High Pressure Heat Treatment on the Hardness

Fig. 3 shows the hardness of the copper-based

multiple alloy under different pressures. The sample of 0 GPa indicates that it is as-cast. It can be seen that high pressure heat treatment can increase the hardness of copper-based multiple alloy, and the hardness increases with pressure increasing. When the pressures are 1 GPa and 6 GPa, the values of hardness are 118.54 HV and 127.16 HV, respectively, which increase by 26.61% and 34.75%, respectively, compared with that of as-cast samples (94.37 HV). The reason for it may lie in that the high strain, generated in the specimen at high pressure, leads to the increase in internal dislocation density. This sub-structure can cause the hardening of the alloy. So high pressure heat treatment can increase the hardness of alloy. By aging treatment after high pressure heat treatment, the hardness of copper-based multiple alloy is still higher than that of the as-cast sample by the same aging treatment. The hardness of the sample aging treated at 500 °C for 2 h after 6 GPa pressure treatment is 125.03 HV, while that of the as-cast sample

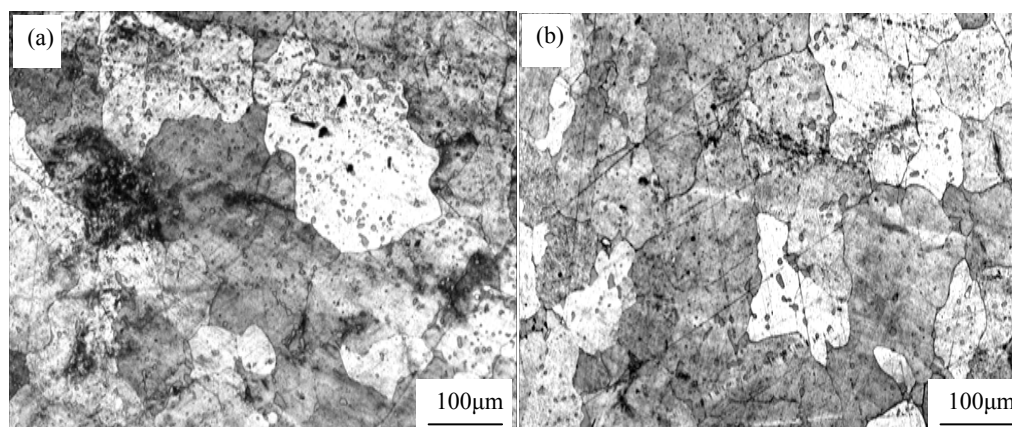


Fig. 1 Microstructures of copper-based multiple alloy: (a) as-cast and (b) 6 GPa treatment.

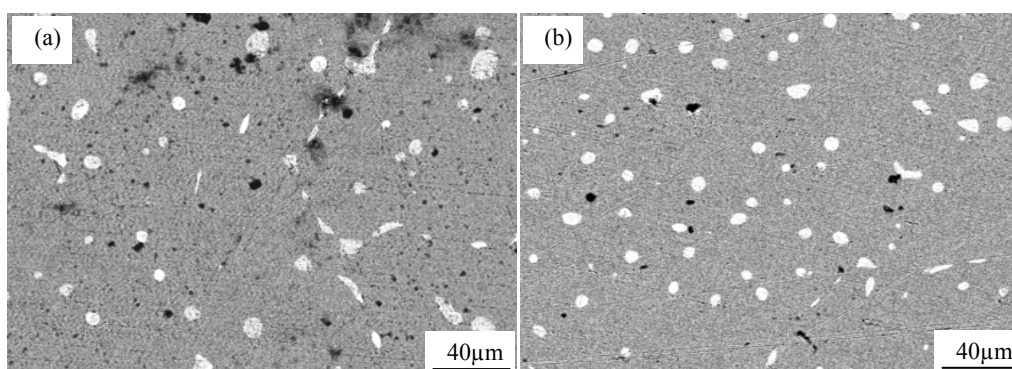


Fig. 2 SEM-BSE images of copper-based multiple alloy: (a) as-cast and (b) 6 GPa treatment.

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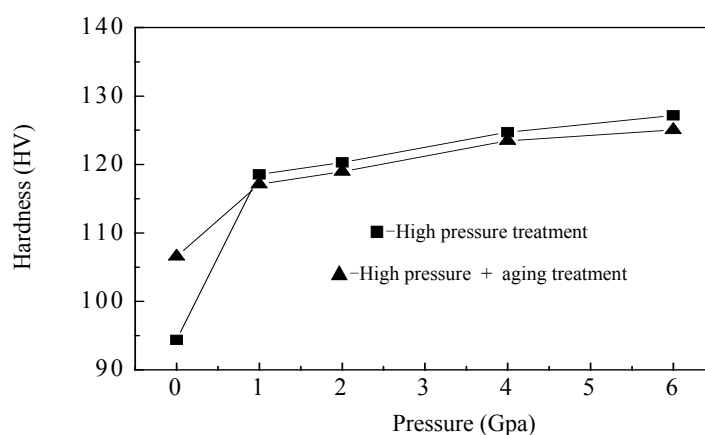


Fig. 3 Effect of pressure on hardness of copper-based multiple alloy.

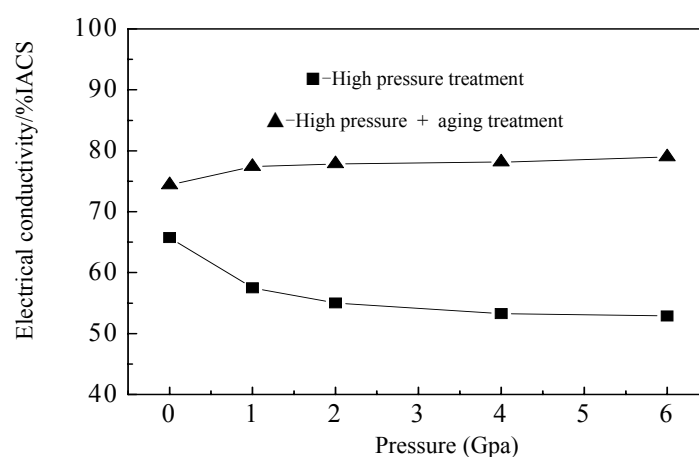


Fig. 4 Effect of pressure on electrical conductivity of copper-based multiple alloy.

subjected to the same aging treatment is 106.55 HV. It can also be seen from Fig. 3 that the hardness increases for the as-cast sample after aging treatment, while the hardness decreases for the as-cast sample by aging treatment after high pressure heat treatment, but the decrease is not significant. For example, the hardness difference between before and after aging is $\Delta 2.13$ HV for the sample treated under 6 Gpa pressure, which increase by 32.49%, compared with that of as-cast samples. In the aging process of copper-based multiple alloy, the supersaturated solid solution Cr atoms in the Cu matrix precipitate in the form of secondary phases, enhancing the effect of aging treatment and increasing the hardness of the

alloy [8], and high pressure increases defects, such as a number of dislocation, providing more sites for the segregation and precipitation of solute atoms [9]. These sites make the segregating phase more dispersive, and thus enhance the strengthening effect. Meanwhile, high pressure improves the density of the alloy. As a result, under the same aging treatment condition, the hardness of samples after high pressure heat treatment is higher than that of the as-cast samples. The fact that the hardness decreases for the samples aging treated after high pressure heat treatment may be related to the recovery, reduced lattice distortion and disappearance of dislocation.

3.3 Influence of High Pressure Heat Treatment on the Electrical Conductivity

Fig. 4 shows the electrical conductivity of copper-based multiple alloy under different pressures. It can be seen that high pressure heat treatment can reduce the electrical conductivity of copper-based multiple alloy, and the electrical conductivity decreases with pressure increasing. The electrical conductivity of the samples aging treated at 500 °C for 2 h after high pressure heat treatment increases, and the greater the pressure, the higher the electrical conductivity. The electrical conductivity is higher than that of the as-cast samples after the same aging treatment. When the alloy is aging treated at 500 °C for 2 h after 6 Gpa pressure treatment, the electrical conductivity is 78.97 IACS, which increases by 20.12% and 6.12%, respectively, compared with that of as-cast samples (65.74 IACS) and as-cast samples after the same aging treatment (74.41 IACS).

As for the electrical conductivity of Cu-based alloys, it is mainly affected by scattering effect to electrons by solid-solution atoms, vacancies, impurities, distortion, dislocations and grain boundaries [10, 11]. Lattice distortion caused by high pressure blocks the electron mobility and leads the electron to scatter, resulting in low electrical conductivity. Therefore, the electrical conductivity of copper-based multiple alloys decreases by high pressure heat treatment. In the subsequent aging process, dislocations and other defects, produced by high pressure, offer favorable conditions for the nucleation and growth of precipitation phase, so the precipitation phase segregates more fully. At the same time, crystal defects can be eliminated. Furthermore, the high pressure heat treatment can increase the density of the alloy, reduce the number of microscopic pores of the matrix, and thereby reduce the scattering effect to electrons. The electrical conductivity of the samples after high pressure processing and aging treatment is higher than that of the as-cast samples.

4. Conclusions

High pressure heat treatment can increase the hardness and decrease electrical conductivity of the copper-based multiple alloy, and it is obvious with the pressure increasing, and high pressure heat treatment combined with appropriate aging treatment can increase electrical conductivity of the copper-based multiple alloy.

Higher hardness (125.03 HV) and electrical conductivity (78.97 IACS) are obtained when the copper-based multiple alloy is subjected to aging treatment at 500 °C for 2 h after 6 Gpa pressure treatment, which increase by 32.49% and 20.12%, respectively, compared with that of as-cast samples.

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