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Effects of Annealing Temperature on the Electrical Conductivity and Mechanical Property of Cu-Te Alloys

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Abstract: The effects of annealing temperatre on the electrical conducitivity and mechanical property of Cu-Te alloys were studied via an AG-10TA electronic universal machine, an SB2230 digital electric bridge, SEM, EDS and XPS. The results show the electrical conductivity increases while the tensile strength fluctuates when the annealing temperature becomes higher because the recrystallization occurs during the annealing process, leading to the density of dislocation decreasing, grain size growing up, but the second phase precipitating sufficiently and simultaneously.

Key words: Cu-Te alloys; annealing temperature; recrystallization

1 Introduction

Pure copper and copper alloys are widely used due to high electrical conductivity, high heat transfer, corrosion resistance and excellent formability[1-3]. However, the strength of pure copper is low and the strength gained during cold working will decrease quickly after annealing. So development high strength and high conductivity copper alloys with not only have a high plasticity but also a high conductivity simultaneously is necessary[4-7]. Presently, the main research concentrates on Cu-Cr, Cu-Fe and Cu-Ag alloys, a few of study on new copper alloys[8-10]. The previous research showed that the conductivity of Cu-Te alloy can reach 94%-103% IACS and Cu-Te alloy has special properties, *e g*, anti-electric corrosion simultaneously[11-12]. In order to get a high strength, high conductivity and high ductibility, study on the annealing process is necessary. No report about the annealing process of Cu-Te alloy is found presently, so the influence of annealing temperature on the electrical conductivity and mechanical properties of Cu-Te alloys was investigated in the paper.

2 Experimental

A ZG-25A vacuum induction furnace was used to melt Cu-Te alloys by adding different amount of pure tellurium into industrial copper in an argon protective atmosphere. The tellurium content in different areas of Cu-Te alloy ingots was detected by an ICAP9000(N+M) plasma spectrometer according to ICP-AES analysis method. The content of tellurium for design and measurement is shown in Table 1.

Then the ingots were forged and hot-rolled to copper stick with a diameter of 8 mm and the copper sticks were cold drawn to wires with a diameter of 2 mm. At last, the copper wires were annealed in the vacuum resistance furnace. The tensile strength was measured by an AG-10TA electronic universal machine, the conductivity was measured by an SB2230 digital electric bridge and the microstructure was investigated by a JSM-5900LV SEM. The binding energy of surface electron was measured by XPS.

Table 1 The content of tellurium for design and measurement in Cu-Te alloys /wt%

No.	Te content for design	Te content for measurement
1	0.00	0.00
2	0.20	0.19
3	0.35	0.32
4	0.50	0.39

3 Results and Discussion

3.1 Influence of annealing temperature

The pure copper and Cu-Tealloy wires were separately annealed at 360 ℃, 390 ℃,420 ℃,450 ℃,480 ℃ for 2 hours. Then the conductivity and the tensile strength were measured . The results are shown in Fig.1 and Fig.2.

It can be seen from Fig.1 and Fig.2 that the electrical conductivity increases, while the tensile strength of copper wires fluctuates after annealing at different temperatre. When the annealing temperature is higher, the recrystallization and precipitation occur, grains grow up, the precipitated phase increases and arranges more dispersively, following the rising of

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electrical conductivity. With the increase of Te content, the electrical conductivity declines but the tensile strength of copper wires rises.

3.2 Influence of annealing

Fig.3 presents the variety of binding energy of surface electrons of copper between hardened wire and annealing wire at different temperature. After annealed for two hours, the binding energy of surface electrons decreased with the rise of annealing temperature. Because the lattice deformation recovered, even disappeared and grains grew up with annealing temperature being higher, the restriction to electrons reduced, leading to the decrease of binding energy.

3.3 Effect of annealing on the microstructure of Cu-Te alloys

The microstructure of sample 3 after annealed for 2 h at different temperature was observed by an XJP-6 metallograph, as shown in Fig.4.

It can be confirmed that the recrystallization begins to occur after annealed for 2 h at 390 ℃, but the recrystallization is incomplete. Along with the rise of annealing temperature, the recrystallization finishes and grains start to grow up.

Fig.5 shows the SEM morphologies of sample 3 annealed for 2 h. It can be seen that second phase precipitated as linear arrangement along with the deformation direction after annealed for 2 hours at 420 ℃. With annealing temperature rising, the recrystallized grains grew up and more second phase precipitated more dispersively.

To ascertain the composition of precipitation, EDS analysis was conducted. According to EDS, the compositions of precipitations are given in Table 2. Combining with Cu-Te alloy phase diagram, the precipitated phase is concluded to be Cu_2Te.

Because precipitations occur at dislocations and subgrain boundaries primarily, the bigger precipitation grains grow up but the smaller ones dissolve during annealing, blocking dislocations rearrangement and subgrain boundaries movement[13,14]. Then the precipitated phase arranges linearly along with the deformation direction. Under the condition of higher annealing temperature, the recrystallization and precipitation of Cu-Te alloys continue. Meanwhile, rains grow up, the precipitated phase increases and arranges more dispersively, so the dislocation density declines. At the same time, bigger grains make line

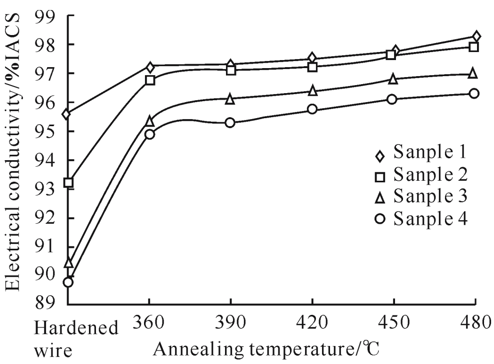


Fig.1 Effect of annealing temperature on the electrical conductivity of Cu-Te alloys

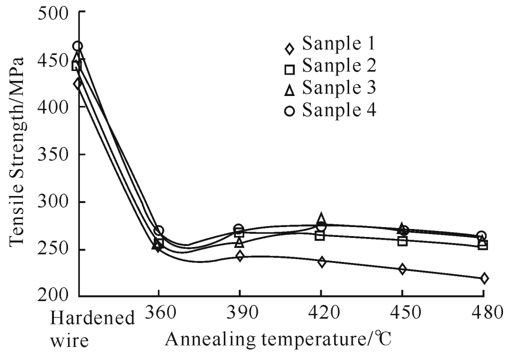
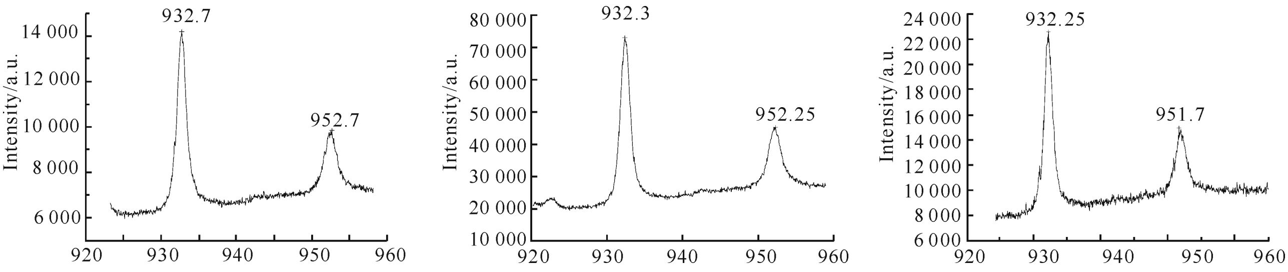


Fig.2 Effect of annealing temperature on the tensile strength of Cu-Te alloys



a) hardened wire b) annealed for 2 h at 390 ℃ c) anneaed for 2 h at 420 ℃

Fig.3 Effect of annealing temperature on binding energy of sample 3

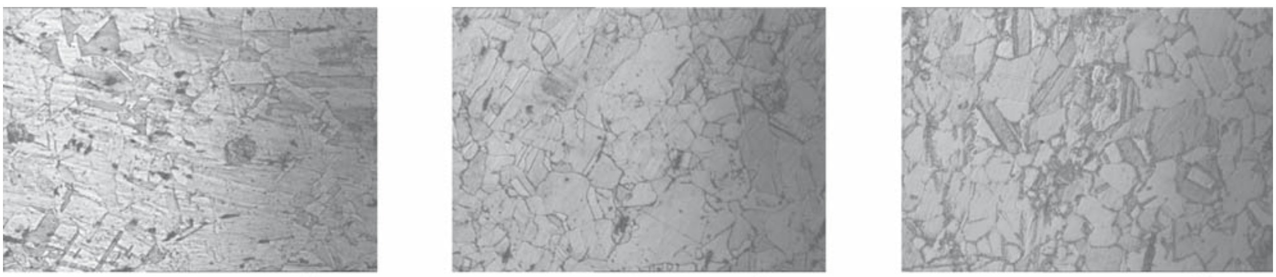

a) annealed for 2 h at 390 ℃ b) annealed for 2 h at 420 ℃ c) annedled for 2 h at 450 ℃

Fig.4 Electric metallograph of sample after annealed for 2 h

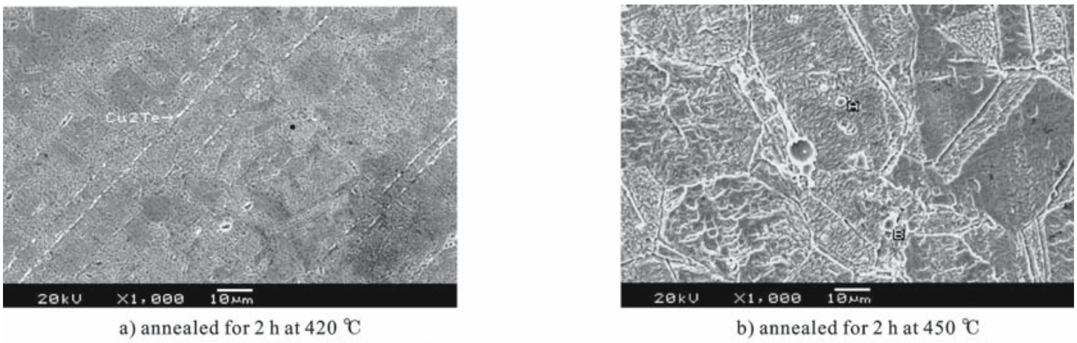


Fig.5 SEM morphologies of sample 3 after annealed for 2 h

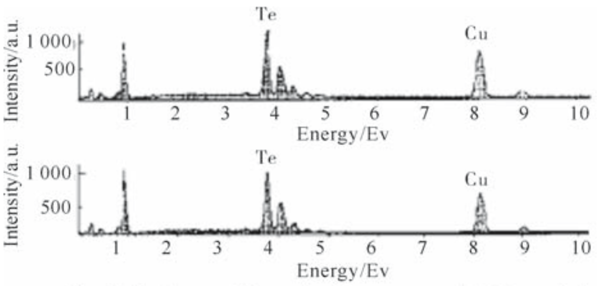


Fig.6 The Energy Dispersion Spectrocopy (EDS) analysis of precipitation phase

Table 2 Analysis of precipitation composition

	Element	Atom/%	Element Weight/%
3-A	Te-L	30.61	46.97
	Cu-K	69.39	53.03
	Total	100	100
3-B	Te-L	33.93	50.77
	Cu-K	66.07	49.23
	Total	100	100

defects and plane defects decrease, so the scattering to electrons decreases, resulting in the rising of electrical conductivity. However, the tensile strength should decrease dramatically in theory. But the co-existing annealing makes Te precipitate as Cu_2Te from copper solid solution. Then the solid solubility and the electrical resistance fall, yet the precipitated second phase strengthens Cu-Te alloys[15]. So the tensile strength fluctuates. There exits an optimum value after annealed at 420 ℃.

4 Conclusions

Under the interaction of precipitation and recrystallization, the density of dislocations exiting in Cu-Te alloys decreased after annealing, grains grew up and more second phase precipitated sufficiently with temperature being higher, so the electrical resistance declined monotonously, meanwhile the tensile strength fluctuated. There exits an optimum value after annealed at 420 ℃.

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