Effect of Powder Form and SPS Process Sintering on CuCr50 Alloy Powder

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Abstract — This paper introduces the technology of activating CuCr50 alloy powder by MA(Mechanical Alloying) and sintering CuCr50 powder by SPS(Spark Plasma Sintering). It analyzes the effect on electrical conductivity and hardness of CuCr50 alloy when Cu powder in different morphology. The results indicate that the CuCr50 powder sintered by SPS takes a good sintering shape, whose electrical conductivity and hardness get improved. At the same time, CuCr50 alloy density has been improved. The flake morphology Cu powder improves the electrical conductivity of 32.7% than the pine morphology needle Cu powder. And the bigger flake Cu powder is, the better CuCr50 alloy electrical conductivity is. Adding 1% of the mass fraction of graphite powder and carbon nanotubes into CuCr50 alloy, whose effect of improving the electrical conductivity is not obvious. CuCr contact material has excellent mechanical and electrical properties and is widely used in vacuum switchgear[1]. As contact materials, CuCr50 alloy can play such an important role in the actual production and application.Improving the mechanical properties and electrical performance are the main trend for development of high performance CuCr alloy.

Keywords: spark plasma sintering;electrical conductivity;hardness;scanning electron microscope morphology;microstructure and properties

I. INTRODUCTION

In the CuCr alloy, one component Cu has lower melting point, higher conductivity and better plasticity than Cr. The other component Cr has higher melting point, higher mechanical strength and lower chopping current than Cu. The solubility of Cr in Cu is low so that CuCr alloy material has a superior performance, such as high breaking current capacity, high voltage withstanding stress and less burnt loss. At present, with the development of switch apparatus aiming to high voltage and large power, contact material is required to have a higher conductivity and mechanical properties. Therefore, CuCr alloy is widespread adoption in the electrical contact materials when it comes to manufacturing high power vacuum circuit breakers, and it plays a decisive role in the switching performance.[2-4]

At present, the melt infiltration method and the mixed powder sintering process are mainly adopted as traditional manufacturing process in production of CuCr contact materials. Contact materials manufactured by the melt infiltration method has better mechanical strength, but they are easy to form macro porosity and composition segregation. Contact materials manufactured by the mixed powder sintering process has a uniform metallographic structure, low mechanical strength, and they are difficult to realize densification[5-6]. In this paper,we adopt MA to activate CuCr50 alloy powder so that the powder can be mixed uniformly. Then, we make a research into the microstructure of CuCr alloy powder. And then we Sintering CuCr50 alloy powder by SPS. It effectively resolves the problems above. At the same time, it greatly improves the comprehensive performance of the contact materials.

II. MATERIALS and METHODS

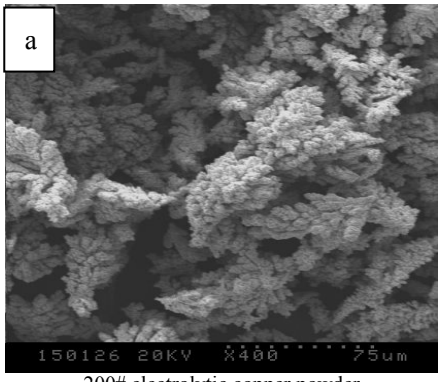
Operation of MA is in the machine the QM-1SP2-CL planetary ball mill,at the speed of 250r/min for 5.5 hour. The grain size of the the original Cu powder and Cr powder used in the experiment is nearly 300#(300 mesh) and 200#(200mesh) respectively. The powder mixture put in the stainless steel ball-milling jar comprises Cu powder and Cr powder in the mass percent of 1:1. The milling media consists of acemented carbide balls. Evacuate the ball-milling jar to -0.1 Pa before ball-milling, then dry the milled MA powder for 3 hour under vacuum after the ball milling. The quality of added graphite powder and carbon nanotubes powder is 1%,mixing in the

grinding device.And Then sintering the dried MA powder in the SPS320MK Ⅱ under the heating rate of 100℃/min with 50 Mpa pressure and 900℃, thermal insulating for 5 minute. View the microtopography of the powder sample under the scanning electron microscope whose type is QUANTA200. Measure electrical conductivity with the SB2230 Digital direct current resistance measuring instrument. Measure the hardness with the HVA -10 vickers hardness tester.Test density by drainage method.

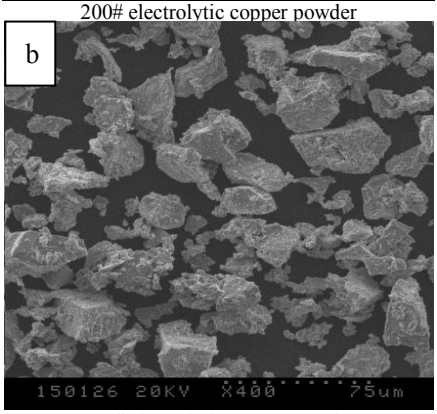
III. EXPERIMENTAL RESULTS and ANALYSIS

A. SEM Analysis of Metal Powder

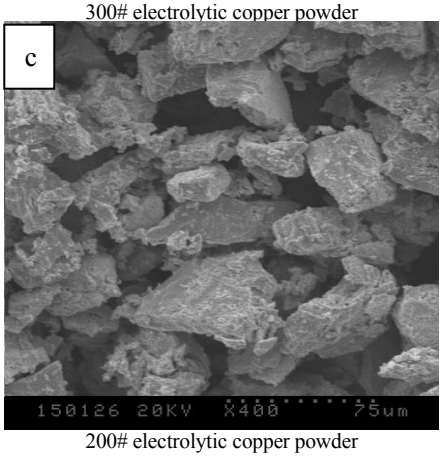
The original powder morphology is shown in Figure1a, b, c, d. 1a is 200# electrolytic copper powder,whose morphology is the pine needle. 1b is 300# electrolytic copper powder; 1c is 200# electrolytic copper powder, whose morphology is flake. 1d is 200# electrolytic Cr powder,whose morphology is irregular granular.



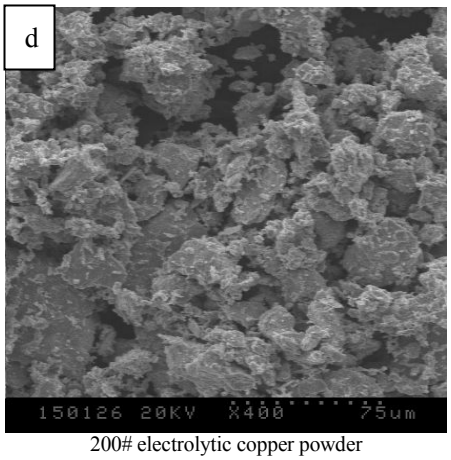
200# electrolytic copper powder



300# electrolytic copper powder

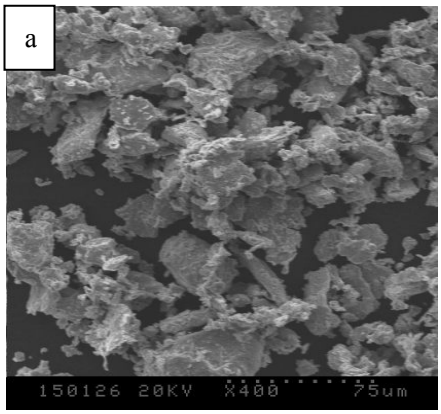


200# electrolytic copper powder



200# electrolytic copper powder

Figure 1. SEM micrographs milled Cu powder and Cr powder



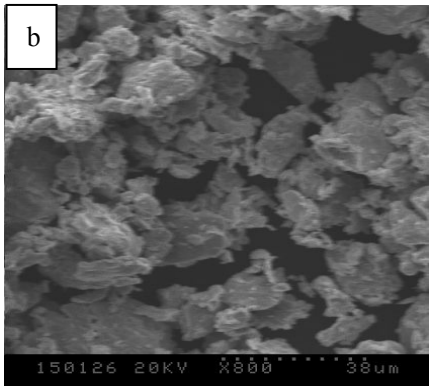


Figure 2. SEM micrographs milled Cu powder and Cr powder for MA 5.5 hour

After dealing with MA process, powder particle morphology is shown in the Figure 2. 2a is the alloy powders include 300# flake Cu powder and 200# Cr powder afer MA. During the MA, alloy powder occurs frequent collision among ball mill medium, ball mill and medium tank wall ,which leads to work hardening and the circulation of the rupture process.[7] Since Cu powder has a good plasticity and ductility and Cr powder has a large brittleness,Cr powder's fracture and broken is more significant than Cu powder during the process of MA. Which lead to the final powder particle size refined than the original size of Cr powder. As is shown in the Figure 2,2a and 2b reflects that the mixed powder formed flake Cu and Cr composite particles.That is to say,alloy powder mixed uniformity.

B. Metallographic Structure

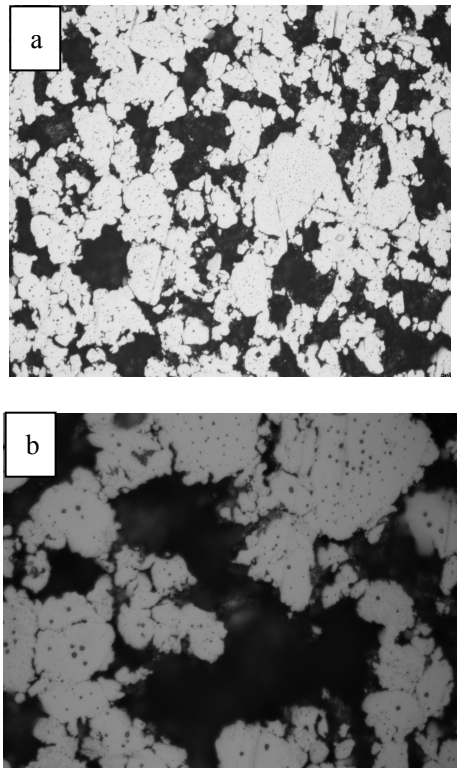


Figure 3. metallographic structure of CuCr50 alloy in different magnification

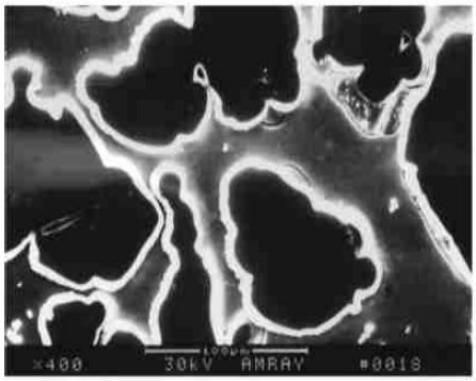


Fig .4 SEM of CuCr50

As is shown in the figure 3, 3a is the metallographic in 200 times magnification,3b is the the metallographic in 500 times magnification .the white structure is Cu and the black structure is Cr. In the Fig. 4[8], the continuous phase is the Cu phase and the isolated phase is the Cr phase. Cr phase is the precipitate on the Cu matrix. Cr is random distribution in irregular block on Cu the substrates.[9] Cu and Cr present uniform mixing.

As is shown in the figure 5, 5a is the metallographic in 200 times magnification added graphite powder, 5b is the the metallographic in 500 times magnification added graphite powder.In the figure 6, 6a is the metallographic in 200 times magnification added carbon nanotube graphite powder, 6b is the the metallographic in 500 times magnification added carbon nanotube graphite powder.the white structure is Cu and the black structure is Cr.Cr phase is the precipitate on the Cu matrix.Cu and Cr present uniform mixing.The appearance of graphite and carbon nanotubes is not obvious under the metallurgical microscope.

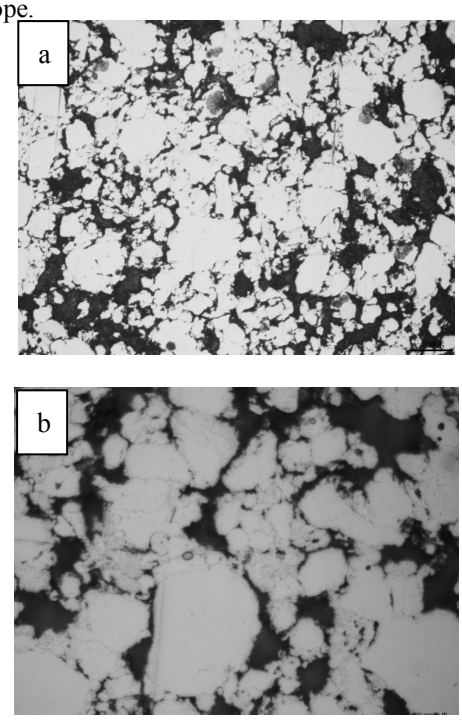


Figure 5. metallographic structure of CuCr50 alloy added graphite powder in different magnification

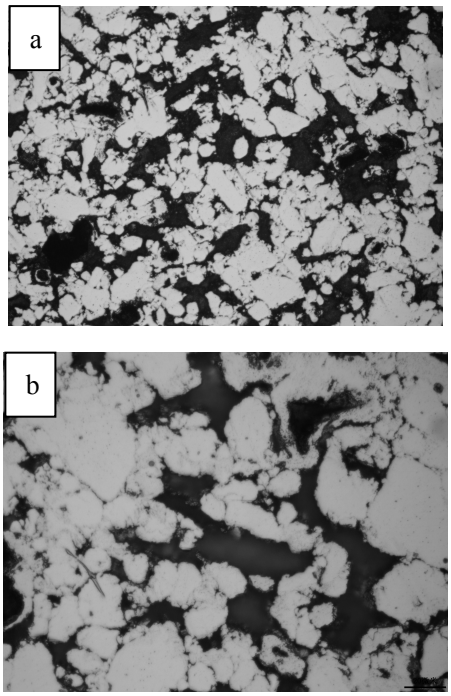


Figure 6. metallographic structure of CuCr50 alloy added carbon nanotube powder in different magnification

C. Conductivity and Micro-Hardness Analysis

We named the mixture of pine needle Cu powder and Cr powder NO.1, the mixture of 300# flake Cu powder and Cr powder NO.2,and the mixture of 200# flake Cu powder and Cr powder NO.3and the mixture of 300# flake Cu powder and Cr powder added graphite powder

NO.4,and the mixture of 300# flake Cu powder and Cr powder added carbon nanotube graphite powder NO.5.Their conductivity and hardness result in the Table 1 and Table 2.

TABLE 1. CONDUCTIVITY AND HARDNESS FOR EACH SAMPLE

NO.	1	2	3
Conductivity (Ms/m)	9.70	12.12	12.87
Electrical conductivity increase (Relative to No.1)	0	24.9%	32.7%
Microhardness (HV)	299.3	268.5	254.6
Relative density	98.02%	98.27%	98.10%

After dealing with MA process, the Cu atom and Cr atom is fine and homogeneous mixing, which makes it possible to produce the CuCr50 with balance organization and fine grains for lower temperature and shorter time. As is shown in the Table 1,after sintering of SPS by 5minute and 900℃, it can be seen that the flake Cu powder can get an increasing by 24.9% comparing to the pine needle Cu powder, and the larger flake ones can get an increasing by 32.7%. With the mixing of Cr powder, the strength and the hardness of the material is enhanced. Cr Separates out with tiny dot uniform dispersion in the Cu substrate.[10]According to the microtopography of Cu, the flake ones are softer than the pine needle ones and the larger size flake ones are softer than the smaller ones when they are mixed in the material.

TABLE 2. CONDUCTIVITY AND HARDNESS FOR ADDED GRAPHITE POWDER AND ADDED CARBON NANOTUBE POWDER

NO.	2	4	5
Conductivity (Ms/m)	12.12	10.87	12.7
Electrical conductivity increase (Relative to No.2)	24.9%	-10.16%	4.96%
Microhardness (HV)	268.5	354.2	346.6
Relative density	98.27%	98.20%	98.26%

As is shown in the Table 2, after adding graphite powder or carbon nanotube graphite powder,relative density is almost no changes, and the hardness rises with the adding of graphite powder or carbon nanotube graphite powder.while the electrical conductivity improves slightly, the electrical conductivity even gets declined due to the blocking effect of graphite powder.

IV. CONCLUSIONS

(1)The powder of Cu and Cr turn into supersaturated solid solution after 5.5h mechanical alloying, forming the flake Cu powder and Cr composite particles which are mixing uniformity.

(2)The CuCr50 lump which has fine particles and mixing uniformity powder can be produced by SPS with the parameter of 900 ℃ ,5mins, and the lump has higher conductivity and harder hardness.

(3)The morphology of the Cu powder is related to the conductivity and hardness of the CuCr50. The flake ones are better than the pine needle ones and the larger the flake powders are, the lower conductivity and harder hardness can be obtained.

(4)After adding graphite powder or carbon nanotubes powder into the flake Cu powder, the effect of improving the conductivity of CuCr50 alloy is not obvious. Graphite powder can reduce electrical conductivity, and carbon nanotubes powder improve the electrical conductivity slightly.

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