Research on the Influence of Different Oxide Particles on Properties of AgCdO Contact Material

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Abstract. AgCdO electric contact material is widely used in low voltage industries, such as contactors, electric relays, switches and miniature circuit breaker, therefore it is called “the universal material”. This material is mainly prepared by internal oxidization and it has good machining properties and anti-welding resistance. In this paper, AgCdO(12) electrical contact materials with different oxide particle sizes (0.8, 1.2, 1.5μm) will be prepared. Besides, the microstructure, mechanical properties and electrical properties of different AgCdO(12) materials will be investigated. It is expected to provide reference for research and design of electrical contact materials.

1. Introduction

In last decades, researchers who were in the electric contact material industry had made lots of investigations on AgCdO[1-9].

Paper [1] researched on using the solid state diffusion to produce AgCdO contact material, which had good performance and low cost. Meanwhile, small size of alloy powders prepared by this method were internal oxidized in the lower temperature and the time of internal oxidization was shortened comparing with the traditional internal oxidization and this technique was a good energy-saving technique. Paper [2] investigated on the influence of different adding elements on the performance of AgCdO(12) wires and it showed that small amount of Ni and Cu had little effect on mechanical properties of AgCdO(12) wires and the AgCdO(12) wires which were added Sn had more broken wires when they were made wiredrawing. Besides, the AgCdO(12) wires which were added small amount of Bi could not finish regular processing. Bimetal rivets of the AgCdO(12) wires which were added small amount of Sn had longer electrical life, lower value of electrical wearing. Paper [3] focused on researching high oxide content of AgCdO which was applicated in GMC AC contactor, showing that electrical life of AgCdO(19) in AC4 was more excellent.

However, little literature was reported about the influence of different oxide particles on properties of AgCdO contact material. In this paper, AgCdO(12) electrical contact materials with different oxide particle sizes (0.8, 1.2, 1.5μm) will be prepared. Besides, the microstructure, mechanical properties and electrical properties of different AgCdO(12) materials will be investigated, hoping to provide an important reference for the research and design of the electric contact materials.
2. Experiment method
This paper prepared AgCdO(12) with different particle sizes of oxides. The detailed elements were listed in table 1. The contents of Ag, CdO and addition were 86 wt.%, 12 wt.% and 2 wt.% respectively. The AgCdO(12) electrical contact material with different particle sizes of oxides was required by the adjustment of internal oxidization.

Manufacturing processes of AgCdO(12) was as follows:
Smelting → surface treatment → extruding → AgCd drawing → internal oxidization → compacting → sintering → extruding → drawing → finished products.

| No. | Ag%  | CdO% | Additives% | Average particle sizes of oxides (μm) |
|-----|------|------|------------|---------------------------------------|
| 1   | 86   | 12   | 2          | 0.8                                   |
| 2   | 1.2  |      |            |                                       |
| 3   | 1.5  |      |            |                                       |

The microscopic structure of AgCdO (12) was examined and analyzed with SEM and the density was tested with water displacement method and hardness was tested with MICROHARDNESS MHV2000 hardness tester and the tensile strength and the elongation were tested with LJ-1000 material testing machine and the resistivity was tested with TH2512B intelligent DC resistance tester.

Meanwhile, the electrical properties were tested with electrical life simulation tester of contact material which was developed with a China’s university. The simulation electrical properties tester of new model was showed in the following figure: mainly including XYZ three axes displacement sliders, driving system composed of direct acting electromagnet and push rod, electromagnetic stroke positioning linkage and relay seat. The system could adjust the working point of the push rod by adjusting displacement sliders of Z axis and Y axis, and could adjust displacement slider of X axis of electromagnetic stroke positioning linkage to control the limiting stopper so as to adjust the idle stroke and excess of stroke of the push rod. The adjusting precision of the position is 10μm. The device can easily replace the contact spring system of different relays for simulation test, and can simultaneously measure the contact voltage, current and welding force. The electrical performance test requirements are 220VDC, 20A, 1s on, 1s off, resistance load.
3. Experiment result and analysis
This paper prepared different oxide particle sizes (0.8, 1.2, 1.5 μm) of AgCdO(12) electrical contact materials. Table 3 shows the comparison of mechanical and physical properties among the different materials. It can be seen that the densities of AgCdO(12) with different oxide particle sizes were almost the same. In addition, as the increase of the oxide particle sizes, the resistivity, hardness, and tensile strength of the materials gradually decreased, while the elongation presented a gradually increasing trend.

It should be noted that as the increase of the oxide particle sizes, the number of oxide particles was decreased in a unit length and the distance that hindered the movement of electrons was reduced, so the resistivity presented a declining trend. As the increase of the oxide particle sizes, the specific surface area of the oxide particles was greatly reduced, which resulted in the decrease of strengthening effect, therefore the hardness and tensile strength presented a declining trend, but the elongation presented an increasing trend.

The microscopic structure of AgCdO (12) with different oxide particle sizes was shown in figure 3. It can be seen that the mean values of the oxide particle sizes were 0.8, 1.2, and 1.5μm, respectively. Besides, the interface between CdO particles and silver was metallurgical bond.

The above-mentioned electrical contact materials with different oxide particle sizes were made into wires, and then were cold-headed into rivet contacts by a rivet machine. After that, electrical contact material life test were carried out by a simulation tester. Each material was tested in 5 groups. The electrical life of AgCdO(12) with different oxide particle sizes was shown in figure 3. From the figure
3, we could know when the oxide particle sizes were 0.8μm, 1.2μm and 1.5μm, the number of electrical life in confidence interval of 95% were 57,000, 68,000 and 52,000 respectively, among which, when the oxide particle size was 1.2μm, the number of electrical life in confidence interval of 95% was the highest.

Table 2 Electric life times with different oxide particle sizes

| Number | Oxide Particle size(μm) | Electric life times | Remarks |
|--------|--------------------------|---------------------|---------|
| 1      | 0.8                      | 57126               |         |
| 2      | 1.2                      | 67589               |         |
| 3      | 1.5                      | 52156               |         |

Table 3 shows the comparison of the average arc energy, arc duration and welding force of AgCdO (12) with different oxide particle sizes. From figure 4 we could know that with the increase of the sizes of oxide particles, the arc energy presented a tendency of decreasing first and increasing next. When the particle size was 1.2μm, the arc energy was the lowest with the value of 1196mJ. Besides, as the increase of the oxide particle sizes, the arc duration presented a tendency of decreasing first and increasing next. When the particle size was 1.2μm, the arc duration was lowest with 3.85ms. It can be seen from the table 3 that as the increase of the oxide particle sizes, the welding force presented a tendency of decreasing first and increasing next. When the particle size was 1.2μm, the welding force was lowest with 0.01N.

Table 3 Analog electrical performance data

| Number | Oxide Particle size(μm) | Arc energy (mJ) | Arcing time(ms) | Welding force(N) | Remarks |
|--------|--------------------------|-----------------|-----------------|------------------|---------|
| 1      | 0.8                      | 1491            | 3.88            | 0.012            |         |
| 2      | 1.2                      | 1196            | 3.85            | 0.01             |         |
| 3      | 1.5                      | 1305            | 4.07            | 0.016            |         |

Figure 4 shows the surface morphology pictures of AgCdO (12) with different oxide particle sizes after the simulation electrical properties test (SEM). From pictures (a)(b), we could know when the oxide particle size was 0.8 μm, the way of burning loss was from upper-right side to lower-left side with the upper-right side was burnt severely and sizes of spatters on the riveted copper sheet were bigger; from pictures (c)(d), we could know when the oxide particle size was 1.2 μm, the way of burning loss was from the edges to the center of the contact with the slightest burning loss and sizes of spatters on the riveted copper sheet were smaller; from pictures (e)(f), we could know when the oxide particle size was 1.5μm, the way of burning loss was from the edge of one side to the other side of the contact with burning loss of one side was worse and sizes of spatters on the riveted copper sheet were bigger.
Figure 4 The surface morphology pictures of AgCdO (12) with different oxide particle sizes after the simulation electrical properties test (SEM)

(a) Particle size 0.8 μm, moving contact; (b) Particle size 0.8 μm, stationary contact; (c) Particle size 1.2 μm, moving contact; (d) Particle size 1.2 μm, stationary contact; (e) Particle size 1.5 μm, moving contact; (f) Particle size 1.5 μm, stationary contact;

It should be noted that as the increase of the oxide particle sizes, the electrical life of AgCdO (12) presented a tendency of increasing first and decreasing next. When the oxide particle size was 1.2μm, the number of electrical life was highest. When the oxide particle size was smaller (0.8 μm), the arc
energy of the contact material was large and the arc duration was long. Therefore, the welding resistance of the material was bad and its electrical life was the lowest.

When the oxide particle size was 1.2μm, the arc energy of the contact material was small and the arc duration was short, and its welding force was low. Therefore, its welding resistance was excellent and its electrical life was the highest. With the size of the oxide particle size increased to 1.5μm, the arc energy, arc duration and welding force presented an increasing tendency. Therefore, the welding resistance of the material was decreased a bit.

4. Conclusion

4.1 As the increase of CdO particle sizes (0.8μm, 1.2μm, 1.5μm), the resistivity, hardness and tensile strength of AgCdO (12) gradually decreased, but their elongation presented a tendency of gradual increase.

4.2 As the increase of the oxide particle sizes, the number of oxide particles decreased in a unit length and the distance which hindered the movement of electrons was reduced, therefore the resistivity presented a declining trend;

4.3 As the increase of the oxide particle sizes, the electrical life of AgCdO (12) presented a tendency of increasing first and then decreasing. When the oxide particle size was 1.2μm, the welding force of AgCdO(12) was the smallest and the welding resistance was the best, thus the electrical life was the highest with 68,000 times.

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