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Testing results analysis of contact materials' electrical contact performance*

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Abstract: Because of the different ways in which contact materials work, the basic requirements for silver metal oxide contact materials are different. They are anti-welded and anti-erosion when closed, anti-erosion when broken, and arc easily moved and have smaller contact resistance. In this paper, La_2O_3 is used as a stable oxide in contact material to replace CdO. A new type of Ag/SnO_2-La_2O_3-Bi_2O_3 contact material is first obtained through using powder metallurgical method. Then electrical contact material parameter tester is used to test the electrical contact performance of the contact material. Through experiments, the arcing voltage and current curves, arcing energy curves, fusion power curves while broken and contact resistance while closed were obtained. Analysis of the results showed that the addition of La_2O_3 makes the contact material have the following advantages: smaller electrical wear, smaller arc energy, smaller contact resistance and arc is more easily extinguished.

Key words: Ag/SnO_2-La_2O_3-Bi_2O_3, Contact materials, Electrical contact performance
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INTRODUCTION

The advantages of the present low-voltage electrical switch are high reliability and long life span. The electrical switch contact, particularly the contact materials, is the key to ensure high reliability and long life of the low-voltage electrical switch.

Electrical switch contact generally has three working modes:

(1) Closure process. The flexible moving contact rebounds after it contacts the fixed contact. If the contact bounce exceeds the amount of deformation, an arc will be generated when the moving contact and the fixed contact separate. The arc's heat melts the contact surface material, vaporizes and splashes, and causes contact closing erosion. The arc is extinguished when the contact bounce stops, the molten metal of the contact surface cools and solidifies, the contact surface tends to weld, commonly called moving welding. The switch contact will be useless permanently if the contact welding strength exceeds the breaking power.

(2) The closure conductive state. Because of the contact resistance, when current passes through the contact, the heat of the contact resistance increases the contact temperature, which makes the contact surface material fuse and weld or the contact resistance becomes infinitely large. This is commonly called static welding. In addition, the contact resistance and temperature increase because of the surface erosion deformation under the heating effect.

(3) Breaking process. An arc will be generated when the moving contact separates from the fixed contact. The arc will stay on the surface of the contact awhile and erode the surface because the arc cannot be driven by the magnetic field at the initial separated period. The arc can be driven by the magnetic field when the separation distance between the contacts exceeds a certain amount. The arc extinguishes when it leaves the contact.

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Because of the different ways contact material works, the basic requirements for silver metal oxide contact materials are different. They are anti-welded and anti-erosion when closed, anti-erosion when broken, arc easily moved and have smaller contact resistance (Shao, 1999; Ohta, 1994; Wan, 1998; Mayer and Michal, 1988).

Silver-metal oxide contact materials generally contain two components. One is pure silver which can provide high electrical conductivity and has antioxidant and anti-nitride properties. The other is metal oxides, which can decide arc breaking performance and improve electrical contact performance of the contact materials. When the oxide stability is high, it cannot decompose and sublimate rapidly and suspend in the Ag pool to increase the viscosity of Ag liquid in order to prevent the Ag's splash erosion (Jeannot and Pinard, 1994; Weng, 1995). Therefore the contact material-wear may be reduced and service life of the contact may be prolonged. In this work, La_2O_3 is used as a stable oxide in contact material to replace CdO (Clark, 1991). A new type of Ag/SnO_2-La_2O_3-Bi_2O_3 contact material was obtained through using powder metallurgical method. Then, electrical contact material parameter tester was used to test electrical contact performance of the Ag/SnO_2-La_2O_3-Bi_2O_3 (Wang *et al.*, 2005; Wang and Lu, 2001; Lu and Wang, 2002).

PREPARATION OF SPECIMEN

The chemical coprecipitation method was adopted to obtain Ag/SnO_2-La_2O_3-Bi_2O_3 compound powder. The composition is shown in Table 1.

Table 1 Composition of specimen

Element or oxide	Mass fraction (%)
Ag	88.0
SnO_2	7.0
La_2O_3	3.5
Bi_2O_3	1.5

The chemical coprecipitation method was as follows: Ag, La, Sn and Bi were mixed together according to certain component ratio, then they were dissolved with HNO_3. The mixture of $AgNO_3$, $La(NO_3)_3$, SnO_2 ($Sn(NO_3)_4$ decomposes into SnO_2+N_2+O_2 directly because of instability) and $Bi(NO_3)_3$ was obtained. After filtering, Na_2CO_3 was used as coprecipitation dissolvent, coprecipitation occurs in the mixture and the coprecipitation of Ag_2CO_3, $La_2(CO_3)_3$ and $Bi_2(CO_3)_3$ which were uniformly distributed can be obtained. The coprecipitation product was filtered by deionized water and washed in order to remove Na^+ and NO_3^-. Finally, the coprecipitation product was dried and torrefied at 420 °C to obtain Ag/La_2O_3+SnO_2+Bi_2O_3 compound powder.

TEST

Test method

Electrical contact material parameter tester was used for testing the electrical contact performance of the Ag/SnO_2-La_2O_3-Bi_2O_3. The hardware structure of the tester is shown in Fig.1. The core is a computer. The contact was installed in a specially designed fixture. Step/breaking devices regulate the breaking and contact pressure of the contact. The parameter changes were measured by pressure sensors. The contact resistance was measured by constant current source and the corresponding amplifying circuit. Through computer adapter card and monitoring software, the data of testing and controlling signals were exchanged. The functions of detection system, signal amplification processing and driving can be achieved by the hardware.

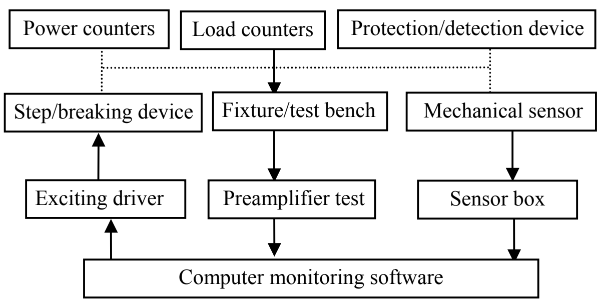


Fig.1 Hardware structure of the electrical contact material parameter tester

The parameter tester can simulate the closing and breaking process of the contact under the condition of closure pressure, contact distance, frequency action and breaking ratio. The changes of the arc current, arc voltage, arc time, arc energy, welding power, contact resistance and contact bounce, can determine the effect of the contact materials composition, arc, ambient gas, shape, hardness and circuit conditions affecting the electric contact characteristics can be detected by parameter tester.

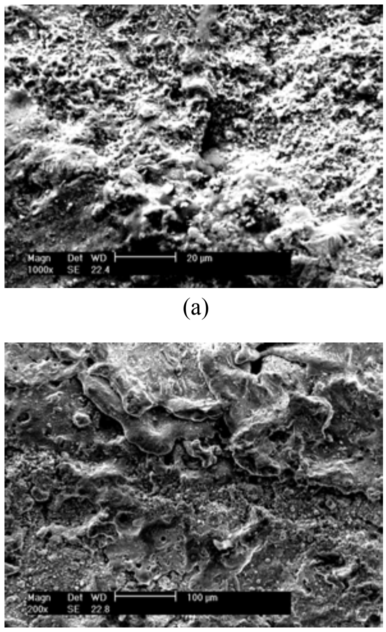
The contact material sample was made into the shape of a rivet shape with shank diameter of 5 mm. The test parameters were 17 V and 30 A DC, contact pressure was 80 cN and the space was 2.0 mm.

Testing results and analysis

The photo of the contact surface after tests is shown in Fig.2 showing that the erosion of the contact starts from the edge. There was fresh material on the surface of the anode contact. On the surface of the cathode contact, there was no metal material covered with black material. The black material should be metal oxide that is difficult to decompose. The metal oxide increases the viscosity of Ag liquid and prevents Ag splash erosion so that contact material-wear may be reduced. The microstructure of the anode surface and the cathode surface is shown in Figs.3a and 3b, respectively.

Fig.2 Photo of the contact

Contact quality before and after tests are shown in Table 2. The basic properties of metal oxides are shown in Table 3. The contact material erosion is tiny as shown in Table 2. The main reason for the tiny erosion is that the decomposition temperature of La_2O_3 is higher than that of SnO_2 and Bi_2O_3. The performance of La_2O_3 is relatively stable as it cannot decompose and sublimate rapidly. The non-decomposition oxide can suspend in the Ag pool to increase the viscosity of the Ag liquid in order to prevent Ag jet erosion, so that the contact material-wear may be reduced and the service life of the contact may be prolonged.



(a)

(b)

Fig.3 Microstructure of the anode surface (a) and the cathode surface (b)

Table 2 Contact quality

	Contact quality before test (mg)	Contact quality after test (mg)	Quality change (mg)
Cathode contact	691.15	693.15	2.00
Anode contact	675.55	669.50	6.05

Table 3 Basic properties of metal oxides

Oxide's type	Heat (kcal/mol)	Decomposition temperature (°C)	Boiling point (°C)	Heat [cal/(g·°C)]	Density (g/cm^3)
CdO	66.4	1000	1385	–	7.28
SnO_2	135.8	1625	2250	0.0931	7.01
CeO_2	233.0	1930	–	–	7.35
La_2O_3	543.0	2315	4200	0.0749	6.75
Y_2O_3	440.0	2400	4300	0.1170	5.05
Bi_2O_3	136.8	>1750	–	0.0620	8.20

The broken and closed arcing waves are recorded once every 2000 times. One group of broken and closed curves is shown in Figs.4a and 4b. No. 1 is the current (A)-time (ms) curve. No. 2 is the voltage (V)-time (ms) curve. It can be seen from the voltage and current curves that there was no arcing platform in the process of breaking and closing. So, the arc extinguishes rapidly.

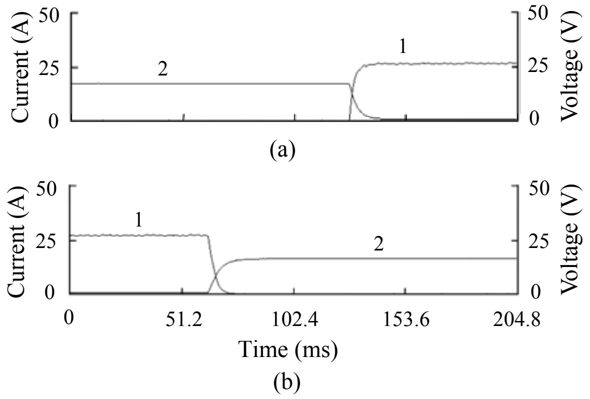


Fig.4 Arcing voltage and current wave. (a) Closing process; (b) Opening process

The wave of arcing energy and time is shown in Fig.5. No. 1 is arcing time (ms)-testing time curve. No. 2 is arcing energy (mJ)-testing time curve. It can be seen form the curves that the arcing peak energy mainly depends on the arcing time; longer arcing time results in larger arcing energy. The average arcing energy of every 200 tests was less than 1400 mJ shown in Fig.6. Such a low arcing energy helps to extinguish the arc.

The waves of the contact resistances and contact pressures are shown in Fig.7. No. 1 is the contact resistance (mΩ) and testing time curve. No. 2 is the welding power (cN) and testing time curve, showing

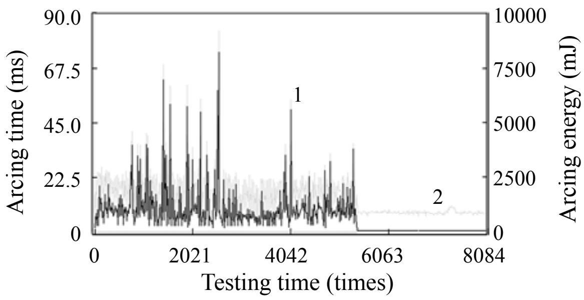


Fig.5 Wave of the arcing energy and time

that the contact resistance is about 10 mΩ. The contact resistance peak follows the decreasing of the welding power.

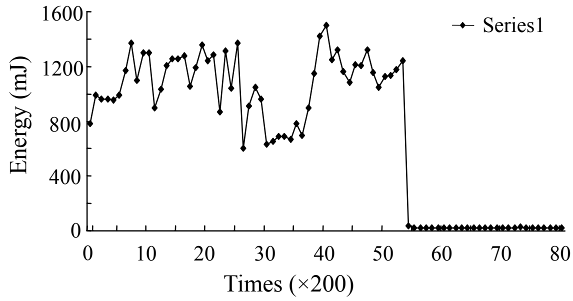


Fig.6 The mean of the arcing energy

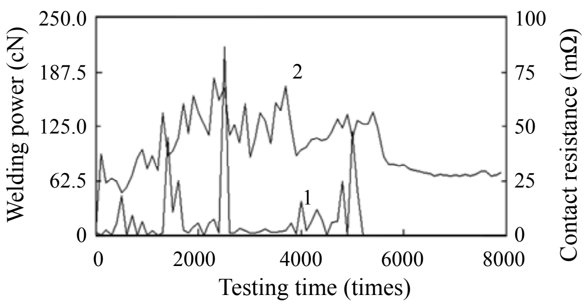


Fig.7 The waves of the contact resistance and welding power

CONCLUSION

Electrical contact performance test results showed that the addition of La_2O_3 reduces the Ag liquid splash erosion, the amount of material-wear and make splash erosion more difficult to form. The arcing energy is smaller and more easily extinguished. The contact resistance of the material is smaller too. Further electrical contact performance tests compared with widely used Ag/CdO will be needed for the wide application of Ag/SnO_2-La_2O_3-Bi_2O_3 in the production of contact material.

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