Journal of Zhejiang University SCIENCE A
ISSN 1009-3095 (Print); ISSN 1862-1775 (Online)
www.zju.edu.cn/jzus; www.springerlink.com
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Study on the failure mechanism of Ag-Ce contacts in DC level

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Received Dec. 19, 2006; revision accepted Jan. 5, 2007

Abstract: Nominal contact resistance, minimum erosion and material transfer are required with low cost materials working in a wide currents range for DC relays. Ag-Ni contact materials have low contact resistance, but the erosion and material transfer are large at high current level. Ag-SnO_2 contact materials have good anti-welding properties and resistance to arc erosion, but they have large contact resistance during working and are easily block SnO_2 from flocking together on the surface at low current level. In this paper, the failure mechanisms of Ag-Ce contact material were studied. The surface morphologies of the contacts after electrical endurance test for Ag-Ce contact material were compared with that of Ag-Ni and Ag-SnO_2 contact materials. The effect of Ce on the surface morphologies of the contacts after electrical endurance test was analyzed.

Key words: Relays, Electric contact, Failure analysis
doi:10.1631/jzus.2007.A0449 **Document code:** A **CLC number:** TB114.3; O224; O211.6

INTRODUCTION

Electrical contact materials are very important and act as a vital part in various of applications, such as electrical switches, contactors, circuit breakers, voltage regulators, arcing tips, switch gears and relays. Materials used as electrical contacts in these applications must have a good combination of electrical conductivity, wearing qualities, and resistance to erosion and welding (Cristian, 1993). Otherwise, the contacts will erode, causing poor contact and arcing. Investigations were conducted to define the electrical and mechanical performances of many contact materials. Nominal contact resistance, minimum erosion and material transfer are required with low cost materials working in a wide currents range for DC relays (Erbay, 1988; Rieder, 1988).

Ag-Ni contact materials are used widely for relays because they have low contact resistance and are easy to machine. But the erosion and material transfer are large in DC level. The early failures resulted from material transfer are the main fail character at large surge current at DC load for Ag-Ni contact materials.

Silver-based refractory contact materials produced by powder metallurgy are used extensively as contact materials due to their high conductivity, good resistance to welding, corrosion properties, high melting temperature and hardness.

As a pollution-free contact material, Ag-SnO_2 has been gradually replacing toxic Ag-CdO materials in the last two decades. SnO_2 has higher thermal stability and is more difficult to be wetted by liquid silver than CdO (Michal and Saeger, 1989). Consequently, SnO_2 can easily aggregate to the interface between Ag and SnO_2. Furthermore, the mixture of Ag and SnO_2 can deposit from the silver melt onto the contact surface by the arc reaction. As a consequence, Ag-SnO_2 materials exhibit less favorable high temperature behavior than Ag-CdO materials. Generally, the high temperature properties of Ag-SnO_2 materials produced by powder metallurgical (PM) method can be improved by the addition of some metal oxides such as WO, MoO_3, Bi_2O_3, TeO_2, etc. (Huck *et al.*, 1990; Lu *et al.*, 2002; Jemaa, 2002; Myers, 1993), but this method increases the brittleness of Ag-SnO_2 and makes it difficult to machine in practice. Therefore, it is necessary to develop new methods to enhance the wettability between Ag and SnO_2 while keeping the good properties of Ag-SnO_2.

In this paper, the failure mechanisms of Ag-Ce contact materials were studied. The surface morphologies of the contacts after electrical endurance test for Ag-Ce contact material were compared with those of Ag-Ni and Ag-SnO_2 contact materials. The effect of Ce on the surface morphologies of the contacts after electrical endurance test was analyzed.

EXPERIMENTAL METHODS

The compositions of four type contact materials used in this experiment were as follows: Ag-$SnO_2$11.7, Ag-Ni10, Ag-Ni0.15, Ag-Ce0.5. The conditions of the electrical endurance test for those contacts are shown in Table 1. The current waveform for lamp load is shown in Fig.1.

Rivets with contact material bonded to the copper shank were metallographically examined by polishing. The surface morphology of the contacts was examined by OLYMPUS SZX12 photics microscope. The failure characteristics of the contact materials were investigated by Scanning Electron Microscopy (SEM).

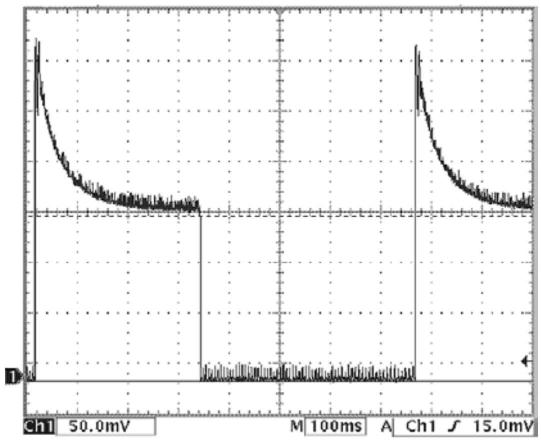


Fig.1 The current waveform for lamp load

RESULTS AND DISCUSSION

The surface morphologies of the Ag-Ni0.15, Ag-Ni10 and Ag-SnO_2 contacts after electrical endurance test at Condition 1 are shown in Fig.2 indicating that the contact surfaces have different shape varied from different composition. Ag-Ni0.15 contacts are easily melted by arc and have obvious materials transfer from anode to cathode. Ag-Ni10 contacts have better resistance to erosion than Ag-Ni0.15. But the melting and material transfer of Ag-Ni10

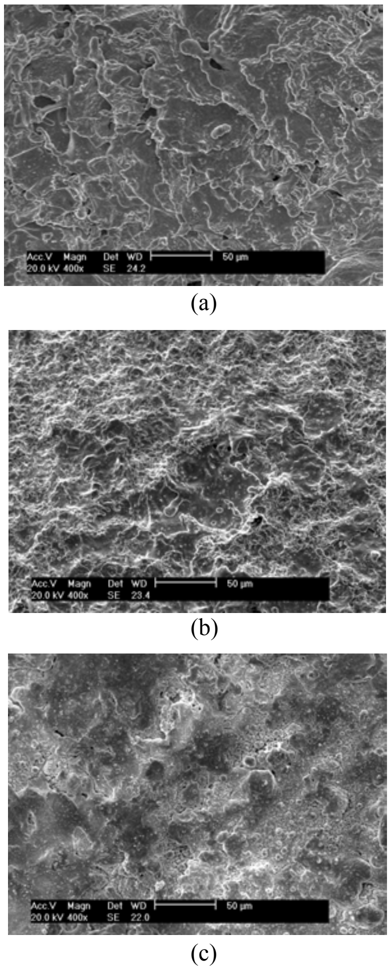


Fig.2 The surface morphologies of (a) Ag-Ni0.15, (b) Ag-Ni10 and (c) Ag-SnO_2 contacts after electrical endurance test at Condition 1

Table 1 The conditions of the electrical endurance test

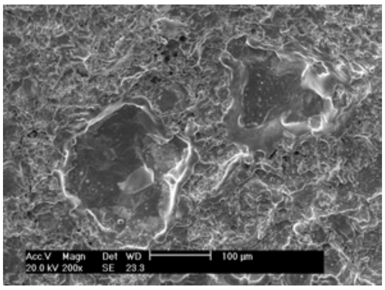
	Load	Current (A)	Voltage	Ambient temperature	Operation frequency (ops/min)	Operation number
Condition 1	Resistance	60	14 V DC	RT	30	1×10^4
Condition 2	Lamp	15^*	12 V DC	RT	30	2×10^5

*Surge current is 33.5 A

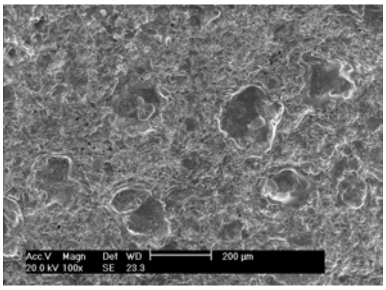
contacts are larger than Ag-SnO_2 contacts at this test condition. Ag-SnO_2 contacts have good resistance to erosion. But SnO_2 can easily aggregate on the surface of contact, which will result in high resistance or block.

The surface morphology of contacts revealed that the material transfer was by metal vapor mainly at Condition 1 for Ag-Ni0.15 and Ag-Ni10 contacts. The Ag-SnO_2 contacts have good resistance to material transfer, with it being mainly by melt metal bridge.

Fig.3 shows the surface morphology of Ag-Ce0.5 contact observed by SEM after electrical endurance test at Condition 1. Many concave holes were found on the contact surface.



(a)



(b)

Fig.3 The surface morphology of Ag-Ce0.5 contact after electrical endurance test. (a) 200×; (b) 100×

Ce is an active rare earth metal and easily burns. When Ce and Ag are compounded to Ag-Ce alloy embedded in Ag, the arc energy is enough to gasify the Ag-Ce alloy. If the arc duration is long enough, it could gasify the Ag-Ce alloy completely in a short time and the blowing out of the melted Ag can result in formation of concave holes. Fig.4 is the metallograph of Ag-Ce0.5 contact showing the distribution of Ag-Ce alloy in Ag. It can be found that the distribution of Ag-Ce alloy is similar to the distribution of concave holes. Following the previous discussion, it can be concluded that the gasification of Ag-Ce alloy results in concave holes.

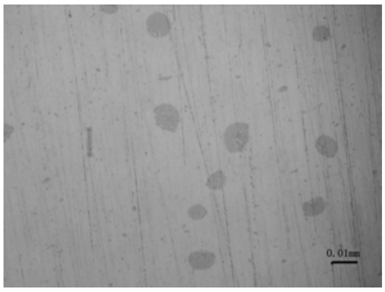


Fig.4 The metallograph of Ag-Ce0.5 contact

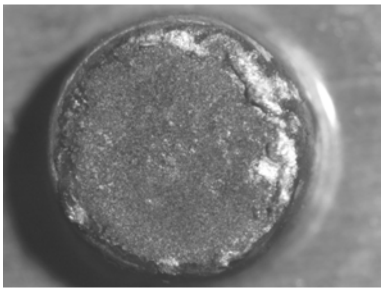
The melting and material transfer of Ag-Ce0.5 contacts are equal to those of Ag-Ni0.15. It means that Ag-Ce0.5 contacts were not adaptable for application to the test Condition 1. The mass of volatile matter found around the contact would result in defective insulation.

Contacts material asymmetrical pairs testing was conducted under Condition 2. The anode contacts material was Ag-SnO_2. The surface morphologies of the cathode contacts Ag-Ce0.5, Ag-Ni0.15 and Ag-Ni10 after electrical endurance test are shown in Fig.5.

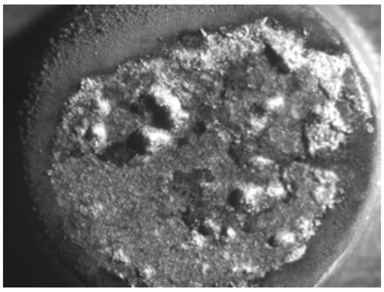
It could be found that the materials transfer from anode to cathode varied with cathode contact material under the same anode material. When the cathode material was Ag-Ce0.5, the materials transfer was slight. When the cathode material was Ag-Ni0.15 or Ag-Ni10 the materials transfer was obvious as shown in Figs.5b and 5c after 2×10^5 operations.

Usually, in asymmetrical pairs testing under Condition 2, the anode material was the most important determinant of material transfer from anode to cathode. Because the material transfer was by bridge the unwelted anode material determines the quantity of transfer under this condition. In this experiment, the cathode material had the function to resist the transfer of materials.

The amplified morphology of Ag-Ce0.5 contact surface after electrical endurance test is shown in Fig.6. There were no concave holes as mentioned in previous contents on the surface of contacts. It means that the arc energy could not lead Ag-Ce alloy gasification completely in short time at Condition 2.



(a)



(b)

(c)

Fig.5 The surface morphologies of the cathode contacts (a) Ag-Ce0.5, (b) Ag-Ni0.15 and (c) Ag-Ni10 after electrical endurance test

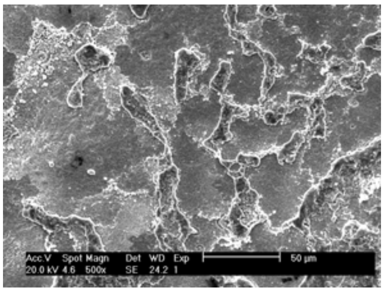


Fig.6 The amplificatory morphology of Ag-Ce0.5 contact surface after electrical endurance test

But the gasification of Ag-Ce alloy is easier than that of Ag. The gasification of Ag-Ce alloy surface prevents the metal melted bridge from coming into being.

CONCLUSION

The Ag-Ni0.15, Ag-Ni10, AgCe0.5 and Ag-SnO_2 contacts have different surface morphology after electrical endurance test. Many concave holes were found on the Ag-Ce0.5 contact surface at the testing Condition 1.

The Ag-Ce alloy in Ag-Ce0.5 contact material was easier gasifiable than Ag. When the arc energy was high enough, the Ag-Ce alloy would be gasified completely in short time and the melted Ag was blown out on the contact surface the concave holes were formed. The materials transfer of Ag-Ce0.5 contact was like that of Ag-Ni0.15 under testing Condition 1.

Contacts material asymmetrical pairs testing showed that when the cathode material was Ag-Ce0.5 and the anode material was Ag-SnO_2, the materials transfer was slight. When the cathode material was Ag-Ni0.15 or Ag-Ni10 the materials transfer was obvious.

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