Preparation and Performances Analysis of a New $Ag\text{-}CuO\text{-}La_2O_3$ Electrical Contact Material

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Abstract: A new electrical contact material, Ag-CuO-La_2O_3, was produced by chemical coating and powder metallurgy method, and its microstructure and performance were investigated. The results show that fine oxides of CuO and La_2O_3 have a uniform distribution in the silver matrix. Its density, resistivity and micro-hardness($Hv_{0.2}$) is 9.77 g·cm^{-3}, 2.36 μΩ·cm and 113 respectively. Compared with convenient Ag-SnO_2 electrical contact materials prepared by the same process, the new material has superior room temperature processing performance, better ability of anti-arc erosion and longer service life. The Ag-CuO-La_2O_3 material may be substitute for Ag-SnO_2 as a new electrical contact material.
Key words: electrical contact material; Ag-CuO-La_2O_3; microstructure; performance; service life
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新型 Ag-CuO-La_2O_3 电接触材料的制备及其性能分析

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摘 要：采用化学包覆和粉末冶金法制备了新型 Ag-CuO-La_2O_3 电接触材料，研究了新材料的微观结构和性能。结果表明，细小的 CuO 和 La_2O_3 颗粒高度弥散地分布于银基体中，新材料的密度为 9.77 g·cm^{-3}，电阻率为 2.36 μΩ·cm，显微硬度($Hv_{0.2}$)为 113。与相同工艺制备的 Ag-SnO_2 传统电接触材料比较，新材料具有更好的室温加工性能、更优异的耐电弧侵蚀能力以及更长的电寿命。Ag-CuO-La_2O_3 新材料有望成为一种替代传统 Ag-SnO_2 的新型电接触材料。
关键词：电接触材料；Ag-CuO-La_2O_3；微观结构；性能；电寿命

Silver-metal oxide electrical contact materials, including Ag-CdO, Ag-In_2O_3, Ag-CuO and Ag-ZnO, are widely used in low voltage apparatus such as relays, contactors, circuit breakers, and motor starters[1-6]. They 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[7-10]. The oxides with high stability cannot decompose and sublimate rapidly and suspend in the Ag pool to increase the viscosity of Ag liquid in order to prevent the splash erosion. Therefore the arc erosion may be reduced and service life of the contact may be prolonged. Ag-CdO contact material is one of the best among these silver-metal oxide electrical contact materials for its good ability of anti-arc

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erosion and low contact resistance. The Ag-CdO contact material has been replaced gradually by some new contact materials such as Ag-SnO_2 because of its damages to the human health and environment[11-16].

The rare earth oxides are stable compounds that have high decomposition temperature and formation heat. In recent years, rare earth oxides have been used as an addition to optimize the mechanical and contact properties of the silver-metal oxide electrical contact material[17-18]. In this work, La_2O_3 is used as a stable oxide and the Ag-CuO-La_2O_3 electrical contact materials were fabricated by chemical coating and powder metallurgy method. The microstructure and performance of the material were also comparatively investigated. The purpose of this paper is to develop a new kind of silver-multi metal oxide electrical contact material with good combined performances.

1 Experiment

1.1 Ag-CuO-La_2O_3 material preparation

The chemical coating method was adopted to obtain Ag-CuO-La_2O_3 compound powder. Its composition is Ag-8%CuO-2%La_2O_3 (mass fraction). The specific chemical coating process was as follows: CuO and La_2O_3 were mixed together according to a certain component ratio then put into a reactor containing deionized water, combined with mechanical agitation and ultrasonic vibration to form suspension liquid. The $AgNO_3$ and ammonia were added into the suspension liquid to form silver-ammonia complex, then slowly doped with hydrazine hydrate, which reduced Ag from the solution and coated Ag on the surface of the oxide particles. Finally, the coating mixed powders were washed, filtrated and was dried to obtain Ag-CuO-La_2O_3 compound powders.

The Ag-CuO-La_2O_3 compound powders were mixed in a ball mill for 24 h, and then moulded with cold extrusion press (100 MPa) to obtain the ingot. The ingot was sintered at 850 ℃ for 2 h, and then it was made to a wire of 8mm in diameter by hot extrusion press, which was further made to a wire of 1.36 mm in diameter with cold drawing. The contact sample was made into the shape of a rivet shape. The comparative study material Ag-10%SnO_2 (mass fraction) was prepared by the same process.

1.2 Characterization method

Microstructure observations were carried out by Hitachi S-3400N scanning electron microscope. The tensile test was performed by AG-IC10 kV tester at room temperature with a crosshead speed of 2 mm/min. The micro-hardness was determined using HMV-FA2 micro Vickers hardness tester with a load of 1.961 N, a holding time of 10 s and each sample was measured five times to obtain the value. The electrical conductivity was determined by measuring the alloy samples using FD101 metal conductivity tester, and every sample was tested for two times. The electrical contact experiment was held by JF04C. The arc erosion experimental parameters are showed in Tab.1. The arc erosion was determined by the mass loss of the contacts.

Tab.1 Parameters of arc erosion experiment

表 1 电弧侵蚀实验参数

Variables	Magnitude
Voltage /V	20~25
Current/A	10~15
Distance between the contacts/mm	1.0
Contact pressure/cN	70
Contact frequency/(times/min)	60

2 Results and discussion

2.1 Surface morphology

Fig.1 shows the surface morphology and EDS pattern of the Ag-CuO-La_2O_3 electrical contact material specimen. It can be found that the CuO and La_2O_3 oxides with nearly spherical particles are uniformly distributed in the silver matrix. For the oxide particles reinforced silver matrix electrical contact materials, it is very important to obtain homogeneous reinforcements in the silver matrix in order to enhance mechanical and electrical contact properties. Moreover, it can be seen from Fig.1, there are no clear visible pores on the surfaces of the sample, and the Ag matrix phase and oxide particles do not show interfacial debonding, indicating the good wettability between oxide particles and the Ag phase. This proves that the chemical coating-powder metallurgy method is a very promising technique for uniformity and full densification of Ag-CuO-La$_2$O$_3$ electrical contact material.

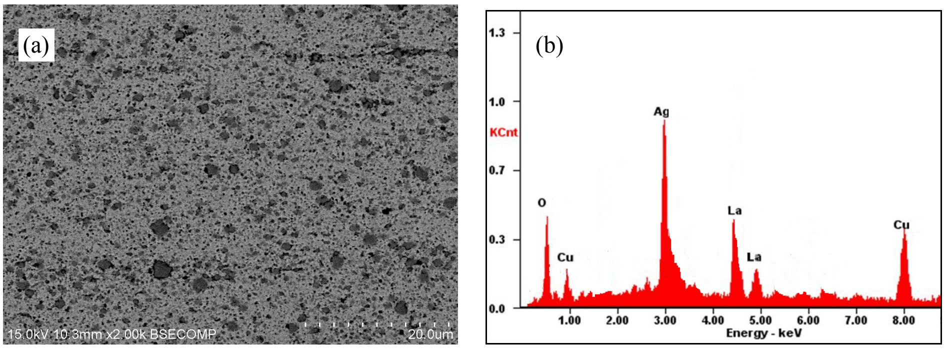

Fig.1 Microstructure of Ag-CuO-La$_2$O$_3$ material (a) and EDS pattern (b)

图 1 Ag-CuO-La$_2$O$_3$ 材料的(a)微观组织及其(b)ESD 图谱

2.2 Physical properties

The physical properties of the electrical contact materials listed in Tab.2. The relative density of the Ag-CuO-La$_2$O$_3$ material is higher than that of Ag-SnO$_2$ material prepared by the same method. The electrical conductivity of Ag-CuO-La$_2$O$_3$ material is 2.36 μΩ·cm, which decreases by 0.13 μΩ·cm compared with that of Ag-SnO$_2$ material. The electrical resistivity is a very important property for the electrical contact materials. The lower the electrical resistivity is, the better the electrical contact properties such as contact resistance, anti-welding and anti-arc erosion are. The micro-hardness of the Ag-CuO-La$_2$O$_3$ material is also higher than that of Ag-SnO$_2$, which may be contributed to the dispersion strengthening of fine CuO and La$_2$O$_3$ particles.

Tab.2 Physical properties of the samples

表 2 试验样品的物理性能

Material	Density /g·cm^{-3}	Relative density/%	Electrical resistivity /μΩ·cm	Hv$_{0.2}$
Ag-SnO$_2$	9.72	97.6	2.49	95
Ag-CuO-La$_2$O$_3$	9.77	98.8	2.36	113

2.3 Processing performance

Fig.2 shows the relationship between tensile strength and drawing deformation of Ag-SnO$_2$ and Ag-CuO-La$_2$O$_3$ material at room temperature. All wire samples were annealed at 400 ℃ for 2 h before cold drawing. The tensile strength of Ag-CuO-La$_2$O$_3$ wire is 262 MPa, which increases by 26 MPa compared with that of Ag-SnO$_2$ wire. It can be found form Fig.2 that the tensile strength gradually increases with the increasing deformation. When the deformation reach to 18%, the tensile strength of the Ag-CuO-La$_2$O$_3$ comes reach to 352 MPa, which is higher than that of Ag-SnO$_2$. This proves that the ability resistant to deformation of Ag-CuO-La$_2$O$_3$ is better than that of Ag-SnO$_2$ at room temperature.

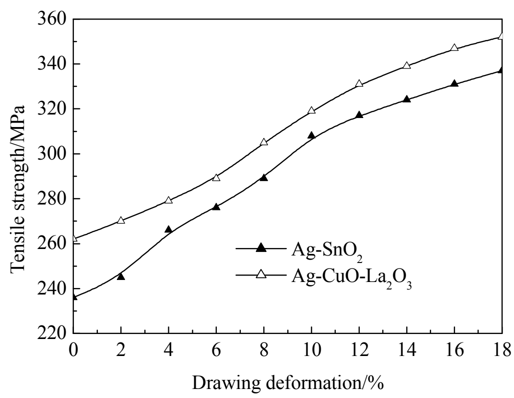

Fig.2 Relationship between tensile strength and drawing deformation

图 2 抗拉强度与拉拔变形量的关系曲线

Fig.3 shows the relationship between elongation and drawing deformation of Ag-SnO$_2$ and Ag-CuO-

La_2O_3 at room temperature.

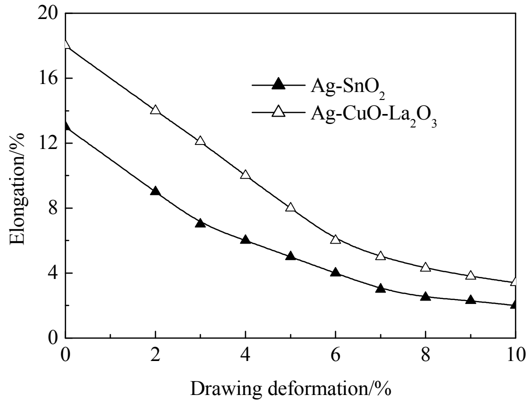

Fig.3 Relationship between elongation and drawing deformation

图 3 伸长率与拉拔变形量的关系曲线

It can be seen that the elongation of the two kinds of electrical contact materials decreases rapidly with the increasing deformation. However, under the same deformation condition, the elongations of the Ag-CuO-La_2O_3 are higher than that of Ag-SnO_2. The elongation of Ag-CuO-La_2O_3 is 18%, while 13% of Ag-SnO_2.

2.4 Electrical contact performance

Tab.3 shows the mass changes of Ag-SnO_2 and Ag-CuO-La_2O_3 contacts over 50000 times break operations under DC 25 V/15 A. As listed in Tab.3, there is a net transfer of material from the anode to the cathode and weight loss to the environment. The weight of transfer and weight loss to the environment of Ag-CuO-La_2O_3 contacts is only 5 mg and 3 mg, respectively, which is lower than that of Ag-SnO_2 contacts. The result indicates that the new material, Ag-CuO-La_2O_3, has better ability of anti-arc erosion. This is because the stable La_2O_3 particles increase the viscosity of molten pool of silver and thus reduce the splatter erosion of liquid silver.

Tab.3 Mass change of the contacts over 50000 times breaks

表 3 50000 次分段后触头质量变化

Contacts	Weight of anode/mg		Weight of cathode/mg		Weight of transfer/mg	Weight loss/mg
	Before erosion	After erosion	Before erosion	After erosion		
Ag-SnO_2	5101	5087	5112	5122	10	4
Ag-CuO-La_2O_3	5129	5121	5134	5139	5	3

In this study, the break operation times of the first welding was defined as the service life of the material. The service life testing results of Ag-SnO_2 and Ag-CuO-La_2O_3 contacts are given in Tab.4.

Tab.4 Service life test comparison of the contacts

表 4 触头电寿命测试结果比较

Contacts	Service life under DC resistance load			
	20 V/10 A	20 V/15 A	25 V/10 A	25 V/15 A
Ag-SnO_2	42114	40096	39914	38825
Ag-CuO-La_2O_3	84071	80202	79817	77498

According to Tab.4, the service life of the Ag-CuO-La_2O_3 is twice as long as that of the Ag-SnO_2 made by same process under DC testing. The Ag-CuO-La_2O_3 electrical contact material has fine microstructure, good comprehensive mechanical properties and low electrical resistivity, which is the reason of better service life for the material.

3 Conclusions

(1) A new Ag-CuO-La_2O_3 electrical contact material has been successfully produced by chemical coating and powder metallurgy method. The oxides are uniformly distributed in the silver matrix.

(2) The new material has good physical properties, its density, resistivity and micro-hardness($Hv_{0.2}$) are 9.77 $g\cdot cm^{-3}$, 2.36 $\mu\Omega\cdot cm$ and 113, respectively.

(3) Compared with convenient Ag-SnO_2 material, the new material has superior room temperature processing performance, better ability of anti-arc erosion and longer service life.

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