The Influence of Different Particles on the Coating Material with High Thermal Conductivity and Insulation for Busbar

Yue-ju ZHAO¹,², *, Jian-hui WANG¹,², Liu-suo WU¹,², Ji-lin TENG¹,², Jing-jing MU¹,², Peng WU¹,² and Xu-hui WANG³

¹Nari Group Corporation (State Grid Electric Power Search Institute), Beijing, 100070, China
²Beijing Guodian Futong Science and Technology Development Corporation, Ltd, Beijing, 100070, China
³Shenhua Shanxi Guohua Jinjie Energy corporation, Ltd, Shanxi, 719319, China

*Corresponding author

Keywords: Thermal conductive silicone rubber, Thermal conductive particles, Thermal conductivity, Mechanical property.

Abstract. In this study, the coating material with high thermal conductivity and insulation for busbar has been synthesized based on Polymethylvinylsiloxane rubber using aluminum oxide and aluminum nitride as the thermal conductive filler, and its mechanical property, thermal conductivity, morphology, dielectric property were measured. The results revealed that the mechanical property and thermal conductivity of the coating material with high thermal conductivity and insulation for busbar filled with aluminum nitride is better than the material filled with aluminum oxide. The dielectric properties of the materials have little difference.

Introduction

The material with high thermal conductivity is the key material for electrical products. The material with high thermal conductivity can provide a safe and reliable way of cooling for electrical equipment, which also can play the role of insulation and Shock absorption [1-3]. The material with high thermal conductivity is mainly used for power busbar insulation protection in the power transmission system. The power busbar is used in the high and low voltage switch cabinet, transformer, electric screen and other infrastructure, which plays a vital role in the power supply system. Thus insulation protection of the bus is the key to ensure the safe and stable operation of power system [4-7].

To obtain high thermal conductivity for the insulating materials, the key is the choice of thermal particles and thermal compatibility between the particles [8-10]. Only when the thermal network chain is formed with the thermal particles in the matrix, the high degree of thermal conductivity can be achieved. If the thermal network chain is not formed, it will form thermal resistance in the heat flow direction, resulting in material performance degradation.

In this paper, Al₂O₃ and AlN were used as thermal conductive particles. The mechanical properties, thermal conductivity, dielectric properties and SEM were investigated to study of the different thermal particles on the thermal conductivity and dielectric properties of the materials.

Experimental

Materials

Polymethylvinylsiloxane rubber (Mn 5.8×10⁵; mole content of vinyl group, 0.15%) was provided by Hesheng Zhejiang. The fumed silica (TS-530) with the specific surface area of 220 m²/g was purchased from Cabort. Al₂O₃ (with particle size of 5µm, 10µm, 40µm ) and Aluminum nitride (AlN) (with particle size of 5µm, 10µm, 40µm ) was supplied by Sanhe Beijing, China.
2,5-Bis(tert-butylperoxy)-2,5-dimethylhexane (DBPMH) was obtained from Akzo Nobel Peroxide, Tianjin, China.

**Characterization**

Thermal conductivity of silicone rubber was measured with a thermally conductive probe instrument RTC-C (Ron-ghua Electronic Instrument Manufacture, Jiangsu, China) under the stable state method. The size of the specimen is 13.0 cm in diameter and 0.20 cm in thickness.

Mechanical properties of silicone rubber, including tensile strength, hardness, and elongation at break were measured according to ASTM D412 and D624 procedures at a crosshead speed of 500 mm/min using dumbbell-shaped test pieces in an electronic rubber tension tester (XLD-A, Second Experimental Machine Factory, Changchun, China) at room temperature. Testing of hardness was carried out using a Shore type A Durometer in accordance with ASTM D2240.

**Preparation of the Material with High Thermal Conductivity and Insulation for Busbar**

First, the thermal particle surface was treated with using of A-172. Then the polymethylvinyl siloxane rubber was mixed with the silica TS-530 and aluminum nitride using a two-roll mill (SK-160, Shanghai Technical Research Institute of Light IndustryMachinery, China) at room temperature, then the curing agent DBPMH was added. The gross silicone rubber mixture was compression-molded at 160°C at the pressure of 10 MPa for 25 min. Then, the silicone rubbers were hung in the oven at 180°C for 2 h to post-cure.

**Result and Discussion**

**Influence of Different Thermal Conductive Particles on the Mechanical Properties of Thermal Conductive Insulating Coated Busbars**

Figure 1 shows the effect of the different thermal conductive particles on the mechanical properties of the thermal conductivity busbar materials. It can be seen from the Figure 1, with the increasing of thermal conductive particles, the tensile strength and hardness of the two kinds of thermal insulation coated busbar materials are relatively increased and the elongation is decreased. In addition, the tensile strength and hardness of the AlN particle filled thermally conductive coated busbar material is relatively higher than that of the Al₂O₃-filled. This is due to This is because the sphericity of the AlN particles is relatively low and arranged more compact in the matrix with respect to the Al₂O₃ particles. The compatibility of AlN particles with matrix is better than that of Al₂O₃, so it can improve the tensile strength and hardness of the heat-conductive insulation busbar material.
Influence of Different Thermal Conductive Particles on the Thermal Conductivity Properties of Thermal Conductive Insulating Coated Busbars

Figure 2 shows the different thermal conductive particles on the thermal conductivity of the insulation material. As can be seen from the Figure 2, with the thermal particle content increases, the two thermal conductivity of the thermal conductivity of the insulation material covered busbars are increased. With the low number of the Al$_2$O$_3$ in filled parts, the thermal conductivity increases slowly. Because in the pre-filled with fewer parts, the thermal particles independent of each other, the formation of heat flow direction of the thermal network chain was increased slowly. And with the increasing of the number of filled particles in the matrix, the thermal network chain was formed on the heat flow direction. Thus the thermal conductivity was increased rapidly. The thermal conductivity of AlN filled particles is significantly higher than that of the materials filled with Al$_2$O$_3$ particles because the thermal conductivity of AlN particles is higher than that of Al$_2$O$_3$ particles. Furthermore, AlN particles have lower sphericity than Al$_2$O$_3$, so contact area is larger than Al$_2$O$_3$ contact area in contact with each other in the matrix. The formation of the number of thermal conduction channels is greater than the number of Al$_2$O$_3$ with the contact probability is relatively large.
The Influence of Different Heat Conductive Particles on the Dielectric properties of Thermal Conductive Insulating Coated Busbars

Figure 3 shows the different thermal conductive particles on the dielectric properties of the insulating material covered busbar. It can be seen from the Figure 3, with the thermal particle content increases, the dielectric loss increases, while the dielectric strength decreased. And the two kinds of thermal insulation coated busbar material dielectric properties of the difference are not significant. The reason for the decrease of the dielectric strength is that the micropores in the silicone rubber increase with the increase of the thermal conductive particles. The residual air in the micropores decreases the density of the material, which leads to the decrease of the dielectric strength of the thermal conductive material.

Figure 3. The Influence of Different Heat Conductive Particles on the Dielectric properties of Thermal Conductive Insulating Coated Busbars.

SEM Analysis of Thermal Conductive Insulated Coated Busbars with Different Conductive Particles

The SEM analysis was tested with the same number of filled parts for the two thermal insulation coated busbar material. As show in Figure 4, the AlN particles in the matrix are more compact than the Al₂O₃ particles, and the contact area is larger with the same number of filled parts. Thus the thermal conductivity is better than that of the Al₂O₃ particles.

Figure 4. SEM Analysis of Thermal Conductive Insulated Coated Busbars with Different Conductive Particles, (a) Al₂O₃, (b) AlN.

Summary

In this paper, the thermal insulation coated busbar material was prepared with Al₂O₃ and AlN used as
thermal conductive particles respectively. The mechanical properties, thermal conductivity, dielectric properties and SEM were investigated to study of the different thermal particles on the thermal conductivity and dielectric properties of the materials.

It can be seen that the thermal conductivity and mechanical properties of AlN filled thermally insulated busbars are better than that of Al₂O₃ filled busbars because the packing arrangement of AlN particles in matrix is better than that of Al₂O₃ particles. Thus the thermal conduction path can be formed easier and the compatibility with the substrate was better for AlN comparing to Al₂O₃. In addition, the dielectric properties of the thermal insulation coated busbar material formed with Al₂O₃ and AlN are not different.

Acknowledgement

In this paper, the research was sponsored by the State Grid Science Foundation (52467O140004, Study on the development and the testing technology of the hybrid composite functional material for power transmission and transformation equipment) and Guodian Futong Corporation Fund of Science and Technology Project (Project No. FTZY 201601).

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