**Academic Journal of Science and Technology**
ISSN: 2771-3032 | Vol. 1, No. 3, 2022

# Development and Performance Analysis of High Thermal Conductivity Epoxy Resin for Dry-type Transformer Casting

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**Abstract:** The purpose of this paper is to provide a preparation method of epoxy resin with high thermal conductivity transformer casting. Adding metal oxide and nitride such as silicon nitride, boron nitride, aluminum nitride and so on into epoxy resin, so that the interface structure of the epoxy resin can be effectively changed, the thermal conductivity of the filling material is greatly improved. It greatly avoids the influence of temperature on its internal parameters, so that the transformer can works smoothly. However, the addition of thermal conductive fillers will affect its dielectric properties (such as Insulation strength, dielectric loss and conductivity characteristics) and mechanical stability. This paper solves the problem of how to improve the thermal conductivity and ensure the dielectric and mechanical properties.

**Keywords:** Epoxy resin, Thermal conductivity, Thermal conductivity filler.

## 1. Introduction

Epoxy resin is widely used as a casting material for dry-type transformer because of its excellent chemical resistance, electrical insulation, shrinkage. The internal temperature of dry type transformer will rise highly due to the heating of winding, ferromagnetic loss and dielectric loss during use. The increase of temperature will accelerate the aging of transformer insulation materials, thus it will reduce the life of transformers. The thermal conductivity of epoxy resin used for insulation in dry-type transformer directly affects its heat dissipation efficiency and service life. Using epoxy resin with high thermal conductivity is one of the effective ways to improve the heat dissipation efficiency of dry-type transformer. In This paper, In this paper, the thermal conductivity of dry-type transformer is improved by physical blending of high thermal conductivity filler(such as metal oxides, nitrides such as silicon nitride, boron nitride, aluminum nitride, etc.) and epoxy resin for casting. We text the conductivity, insulation strength, dielectric loss the thermal conductivity of it, and finally we provide a feasible method for improving insulation and thermal conductivity of dry-type transformer.

## 2. Research Background

The performance test of high thermal conductivity epoxy resin has been studied completely in China, and its application has increased in recent years. Zhang Xiaohui et al[1]The effect of SiC on epoxy resin was studied. ZHOU W Y et al.[2]The effects of particle size, concentration and dispersion of Si _ 3N _ 4 on the thermal conductivity and related dielectric properties of the composites were studied. Many scholars have studied metal powder materials, such as silver.[3]Copper[4]Aluminum[5]And so on, on the thermal conductivity of polymer materials.

However, the research on epoxy resin for dry-type transformer casting is relatively less at present, compared with other fields, the research on thermal conductivity of transformer is relatively less, its development is still in its infancy, and the production process and performance need to be improved. The results of this project will have more important significance and role for the long-term development of our country.

## 3. Research Content and Scheme

### 3.1. Experimental Process

1. Preparation of Epoxy Resin Composite

The experimental steps for preparing composite materials with glass fiber and basalt fiber as filling materials are as follows:

①Hydroxyl grafting: add short cut heat conducting filler into 5mol/l sodium hydroxide solution at 120 ℃ for 2 hours, then wash and filter with deionized water until the pH value is neutral, and dry the obtained hydroxyl grafted heat conducting filler at 80 ℃ for 5 hours.

②Coupling agent treatment: dissolve 1g of coupling agent KH-560 into 95% ethanol solution, add dilute hydrochloric acid to adjust the pH value to 5. Add 50g of chopped glass fiber treated with sodium oxide, heat and stir at 60 ℃ for 6h.

③Rinse and dry: cool to room temperature. Pass the solution through 0.22 μ M polyvinylidene oxide membrane, the samples on the membrane were washed three times with ethanol solution to further remove the ungrafted coupling agent. Then it was dried under vacuum at 120 ℃ for 24h to obtain the chopped glass fiber after surface treatment.

④Mixing reagent: use vacuum planetary stirrer. Add the curing agent into the epoxy resin, and then put the short cut heat conducting filler with surface treatment into the epoxy resin, rotating speed: 1000r min, time: 600s. Then add accelerator, rotating speed: 1200rimin, time: 1200s Vacuum degree: conduct under the condition of 98kpa defoaming. (the specific time and speed depend on the experiment)

⑤Sample preparation: pour the mixed suspension into the mold, cure at 80 ℃ for 2h, and then rise to 110 ℃ for 4H.

(selective curing process, the specific temperature depends on the experimental situation) in the process of determining the thermal conductivity, we used the test standard of ISO 22007-2 and the hotdisk2500s thermal conductivity meter to measure the thermal conductivity of composite materials. The thermal conductivity measured by the hot disk thermal conductivity meter ranges from 0.005 to 500 w/mk, and the temperature ranges from -260 ° C to 700 ° C. It is applicable to metals, alloys, ceramics, ores, composite materials, circuit boards (PCBs), silica gel and other materials, At the same time, it can measure the thermal transient energy of various forms of materials such as solid, powder, coating, film, liquid and anisotropic materials, and complete the test of thermal conductivity, thermal diffusivity and heat capacity within a few seconds. During the test, place the polyimide film probe between two samples of the same composite material, heat the sample with constant power, and record the change of the average temperature on the probe surface with time, The thermal conductivity can be obtained from the mathematical model, and the average value can be obtained through three tests. As show in Table 1, the experimental data.

**Table 1.** The experimental data1

| Serial number | Resin | Curing agent | Accelerator | Fiberglass | Basalt fiber |
|---|---|---|---|---|---|
| 1 | 31.79650238 | 27.02702703 | 0.294117647 | 0 | 0 |
| 2 | 31.02097794 | 26.36783125 | 0.286944046 | 0.286944046 | 0 |
| 3 | 30.28238322 | 25.74002574 | 0.280112045 | 0.5602240896 | 0 |
| 4 | 29.57814175 | 25.14142049 | 0.273597811 | 0.8207934336 | 0 |
| 5 | 28.90591126 | 24.57002457 | 0.267379679 | 1.069518717 | 0 |
| 6 | 28.90591126 | 24.57002457 | 0.267379679 | 0 | 1.069518717 |

2. Performance testing

(1) Thermal conductivity test

The thermal conductivity of epoxy resin composite was characterized by DRL-II thermal conductivity instrument (Xiangtan Xiangyi Instrument Co, Ltd.). Before the test, the surface of the sample was evenly coated with thermal conductive silicone grease to ensure good contact between the sample and the test electrode. As show in Figure 1 and Table 2.

**Table 2.** The experimental data2

| Number | Test Temperature | Thermal conductivity W/m·K |
|---|---|---|
| 1 | Room temperature | 0.0664 |
| 2 | | 0.0658 |
| 3 | | 0.0675 |
| 4 | | 0.0622 |
| 5 | | 0.0695 |
| 6 | | 0.0672 |

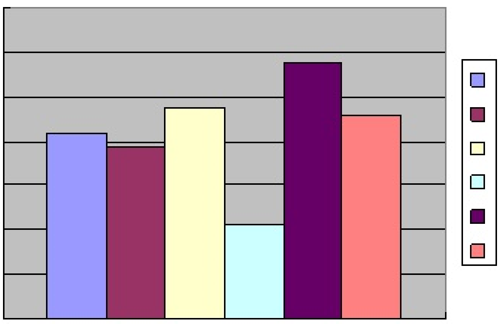

**Figure 1.** Two or more references

(2) Dielectric test

The dielectric constant and dielectric loss of epoxy resin composites were measured by using Concept 80 broadband dielectric spectrometer (NovoControl, Germany).

(3) High frequency breakdown characteristic test

Use the high frequency and high voltage power supply HFHV20-1 (Institute of Electrical Engineering, Chinese Academy of Sciences) to test the breakdown characteristics of epoxy resin composites under high frequency and high AC electric field.

3. Screen

According to the test results, we compare the properties of various materials, and the materials before compositing. Considering the advantages of various aspects, we select the materials with improved thermal conductivity but basically unaffected dielectric properties.

4. Setting of Concentration Gradient and Preparation of New Material

For the above selected composite materials, we set the concentration gradient of the doped composite materials, and the preparation method of the composite materials is the same.

5. Perform performance testgand screen

## 3.2. Study on Characteristics of Epoxy Resin

Epoxy resin (EP) is widely used in power transmission and transformation equipments such as dry-type transformer because of its excellent insulation performance. However, the thermal conductivity of pure epoxy resin is poor, and its thermal conductivity is in the range of 0. 17 ~ 0. 21 W/m/K. Especially in the actual operation of large transformers, the problem of heat dissipation is urgent to be solved. The thermal conductivity and mechanical properties of epoxy resin and its composites will change with the change of temperature, so it is necessary to further explore the influence of temperature on the performance of epoxy resin.

The improvement of the thermal conductivity of the epoxy resin material can be achieved by filling the epoxy resin material with high thermal conductivity fillers[6]. Hexagonal Boron Nitride (h-BN) has high thermal conductivity, excellent mechanical properties and insulating properties, so it has wide application prospects to modify epoxy resin. In recent years, researchers at home and abroad have done a lot of researchs on hexagonal boron nitride modified epoxy resin materials through experiments.

Molecular simulation technology simulates the physical and chemical properties of materials from the atomic scale, which greatly shortens the research cycle. In recent years, with the development of computer technology, the method of Molecular Dynamics (MD) simulation has been widely used. It is convenient to study the changes of microstructure parameters of materials by molecular simulation, and to establish the relationship between micro and macro. Thus, the mechanism of the interaction between the filler and the matrix can be explained more reasonably.

## 4. Conclusion

This paper provides a preparation method of epoxy resin with high conductivity for dry-type transformer casting, which improves the thermal conductivity. At the same time, its conductivity, insulation strength, dielectric loss and mechanical strength can meet the expected requirements. The product has achieved satisfactory results in the experimental process and put into use. In addition, the method can be used and innovated on other products, and has popularization value.

To sum up, the composites prepared in this study have excellent insulation properties, which can not only meet the requirements of insulation materials in the field of electric power, but also be suitable for insulation protection in the field of live working robots.

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