

Preparation and Properties of Graphite/Epoxy Resin Conductive Composites

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Abstract: Graphite / epoxy resin conductive composites were prepared by mixing and molding process, using graphite and epoxy resin as raw materials, filling carbon fiber cloth and mixing a small amount of metal powder. We investigated effects on the different ratio of graphite raw materials and the amount of carbon fiber cloth and different metal powder on the resistance and bending strength of graphite / epoxy resin conductive composites. The optimum ratio of raw materials was determined by the experiment. The results showed that the electrical and mechanical properties of the composites were good when the ratio of the two kinds of graphite was 1:1, filling two layers of carbon fiber cloth and the content of aluminum powder was 1%. The resistivity was up to $0.0800 \Omega \cdot \text{cm}$, and the bending strength was up to 47.32MPa.

1.Introduction

Graphite materials are widely used in many fields such as chemical industry, petroleum refining and energy conversion due to its excellent conductivity, thermal conductivity, corrosion resistance and thermal shock resistance^[1-2]. Epoxy resin is widely used in the matrix of resin matrix composites due to its excellent corrosion resistance, bond behavior and high specific strength^[3-5].

The graphite/epoxy resin composite has the advantages of both, not only maintaining good conductivity, but also has a higher modulus and tensile strength. Although the resin content is low, the composite basically retains the processing properties of the polymer and can be molded through typical plastic processing techniques such as extrusion, molding, or injection process^[6]. Therefore, the graphite/epoxy composite is easy to mass production and a molding, which can greatly reduce the production cost of materials. As the epoxy resin is thermosetting resin, it can knockout without cooling, which reduces the time required for the whole process. Moreover, thermosetting resin can form strong three-dimensional reticular structure in composites, so it has stronger bending strength^[7-8].

In this paper, the graphite/epoxy resin conductive composite was prepared by the hot-press molding process. Mechanical and electrical properties of the composites were investigated by using a universal testing machine and a direct current resistance tester. The effects of different ratio of graphite raw materials, the amount of carbon fiber cloth and a small amount of metal powder on the composites were discussed.

2.experiment part

2.1experimental materials and equipment

Graphite A, purity of 70%, Jilin Graphite Industry Company; Graphite B, purity of 90%, Jilin Graphite Industry Company; Epoxy resin (E-51), Nantong Xingchen Synthetic Material Co Ltd.; Carbon fiber



cloth, 12K, Jilin Jiyan High-tech Fibers co.LTD.; Phthalic anhydride, AR, Tianjin North Tianyi Chemical Reagent Factory.

HL-200 mixing roll, Jilin University Science And Education Instrument Factory; XLB-D thermal plate press, HuzhouXunhefu New Horsepower Rubber Machinery Factory; AST10A dc resistance tester, Beijing Aisideke Electric Power Equipment co. LTD; WDW3010 micro-controlled electronic universal testing machine, Changchun Kexin Test Instrument co., LTD; SU8010 scanning electron microscope, made by HITACHI, Japan.

2.2 Preparation of graphite/epoxy resin conductive composites

According to the different ratio of graphite A and graphite B, phthalic anhydride and epoxy resin (graphite / epoxy resin = 3 / 1) were mixed in the mixer, and the mixture was put into the molding mould, and then the carbon fiber cloth and metal powder were added to the hot pressing molding machine, samples were processed on a grinder to the sizes required for resistivity and flexural strength testing.

2.3 conductivity and mechanical properties testing

The resistivity of the composites were measured by AST10A DC resistance tester; WDW3010 micro-controlled electronic universal testing machine was used to test the bending strength of composites.

3. result and discussion

3.1 The influence of different purity graphite ratio on the properties of composites

In order to reduce the cost of raw materials. Two kinds of graphite raw materials were selected for the experiment. Graphite A has a low price and graphite B has a high price, and fixed graphite/epoxy resin = 3/1. Investigated effects of different proportions of graphite A and graphite B on the conductive and mechanical properties of the composite materials. The experimental results were shown in table 1.

Table 1 Effects of different proportions of graphite A and graphite B on electrical conductivity and maximum bending strength of composite

Experimental number	GraphiteA/GraphiteB	Resistivity / $\Omega \cdot \text{cm}$	Maximum flexural strength /MPa
1	7/3	1.2350	48.05
2	5/5	0.6597	42.65
3	3/7	0.6077	28.40

Graphite has a nice layered structure. Three carbon atoms covalent are bonding around each carbon atom, and the layers are bonding with Van der Waals' forces. Since each carbon atom will release along pair electron which can move freely along the plane direction, which made graphite has a good conductivity and thermal conductivity. As we can see from table 1, when graphite A/ graphite B was 3/7, the electrical conductivity of the composites were lower, but the maximum bending strength was smaller. When graphite A/ graphite B was 7/3, the resistivity was high and the conductivity was poor, but the maximum flexural strength was great. According to the two indexes of conductivity and mechanical properties, the suitable ratio of graphite A / graphite B was 5/ 5, the composite material resistivity was $0.6597 \Omega \cdot \text{cm}$ and maximum flexural strength was 42.65 MPa.

3.2 The influence of the number of layers of carbon fiber woven fabric on the properties of composites

Added carbon fiber cloth to the graphite/epoxy resin composite to investigate the effect of the number of layers added to the carbon fiber fabric on the conductive and maximum flexural strength of the composite material. The experimental results were shown in table 2.

Table 2 Effect of carbon fiber woven fabric on electrical conductivity and maximum bending strength of composite

Experiment number	GraphiteA/GraphiteB	Additive carbon fiber woven fabric/layers number	Resistivity / $\Omega\cdot\text{cm}$	Maximum flexural strength/MPa
1	7/3	monolayer	0.3619	37.58
2	5/5	monolayer	0.2628	37.42
3	3/7	monolayer	0.2141	25.71
4	5/5	double	0.1434	34.75

It can be seen from table 2 that when single-layer carbon fiber cloth was added, the conductivity of the product was significantly improved. When the graphite A/ graphite B was 3/7 and the single-layer carbon fiber cloth was filled, the conductive and mechanical properties of the composite materials were better. It indicated that with the increasing of graphite B content, the conductivity of the composite increased accordingly. At the same time, the resistivity was the lowest, but the maximum flexural strength was lower. Integrated conductivity and mechanical properties of the two indicators, graphite A/graphite B was suitable for 5/5, the resistivity was up to 0.2628 $\Omega\cdot\text{cm}$, maximum flexural strength was up to 37.42 MPa. In order to improve the conductivity of the composite, in the experiment, fixed graphite A/graphite B at 5/5, and increased the amount of adding carbon fiber cloth from single to double, the resistivity of composite material was decreased, conductive performance was improved obviously, the maximum bending strength also kept the good level, the resistivity of the composite material was up to 0.1434 $\Omega\cdot\text{cm}$, the maximum flexural strength was up to 34.75 MPa. These results can be attributed to the good interfacial adhesion between the surface of carbon fiber cloth and epoxy resin. This interface adhesion can effectively transfer the load from the matrix to the carbon fiber cloth, thus effectively absorbing the external energy to improve the bending strength.

3.3 The influence of mixed metal powder on properties of composite materials

The effects of zinc powder, aluminum powder and copper powder (mass fraction 1%) on the electrical and mechanical properties of the composites were investigated when the fixed graphite A/ graphite B was 5/5 and filled with double-layer carbon fiber cloth. The results were shown in table 3.

Table 3 Influence of doped zinc powder, aluminum powder and copper powder on the electrical conductivity of composite

Experiment number	GraphiteA/GraphiteB	Doped metal	Resistivity / $\Omega\cdot\text{cm}$	Maximum flexural strength/MPa
1	5/5	zinc powder	0.1478	43.25
2	5/5	aluminum powder	0.0800	47.32
3	5/5	copper powder	0.0869	36.20

It can be seen from table 3 that mixing different metal powders had a great difference in the conductivity of the composites. Mixing aluminum powder and copper powder significantly improved the conductivity of the composite, while mixing zinc powder did not significantly improve the conductivity of the composite material. Considering the conductivity and mechanical properties of the composite material, the effect of mixing aluminum powder was the best. With the addition of carbon fiber cloth and metal powders, the resistivity of the composites decreased significantly. These results can be attributed to the high conductivity of carbon fiber cloth and metal powder, which formed a good conductive pathway in the graphite/epoxy resin composites.

3.4 Scanning electron microscope analysis of composite materials

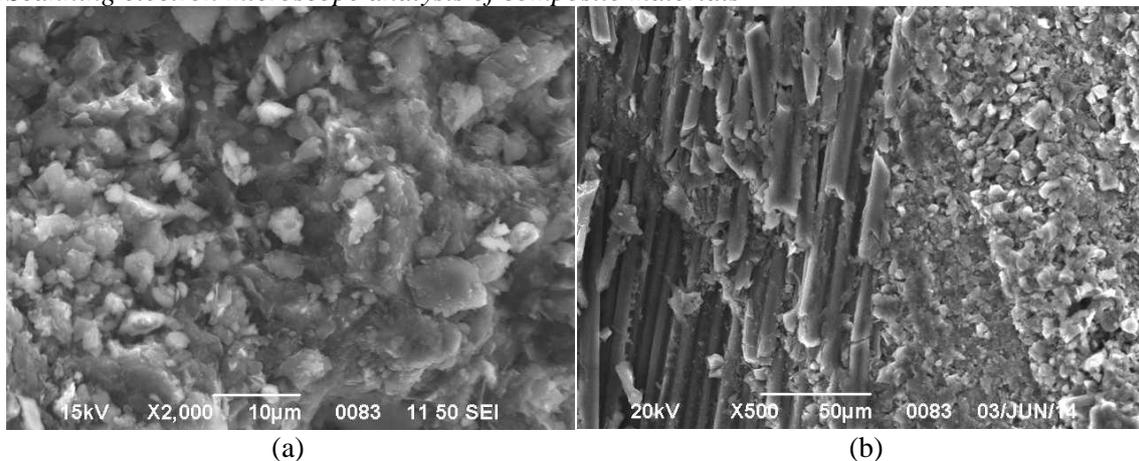


Figure 1 Scanning electron microscope pictures of composite materials

Figure. 1 (a) was the cross section morphology of graphite / epoxy resin composites. It can be observed from the figure that white epoxy resin and black graphite were relatively uniformly dispersed on the fracture surface of graphite/epoxy resin composites. Figure 1 (b) was filled with double carbon fiber cloth , mixing aluminium section morphology of graphite/epoxy resin composites. It can be observed from the figure that the solidification structure of the section was sufficient, and the dispersion degree of aluminum powder, graphite and curing agent was even, carbon fiber cloth fabric and graphite contact section was very clear, the middle part had obvious interface, on the left side of figure can be seen the carbon fiber cloth and graphite were well combined and evenly distributed , on the right side of figure can be seen the combination of graphite and metal aluminum powder were more evenly. The conductivity and mechanical properties of the composites were improved by the obvious difference and uniform distribution on both sides.

4. Conclusion

Graphite/epoxy resin composites were prepared by melt blending and compression curing combined. Through measuring bending strength and resistivity respectively, the mechanical and electrical properties were characterized, and the suitable material ratio was determined: graphite/graphite B was 5/5, filled double carbon fiber cloth, doped with a small amount of aluminium powder, the preparation of the composite material resistivity was up to $0.0800 \Omega \cdot \text{cm}$, maximum bending strength was up to 47.32 MPa. SEM images showed that the white epoxy resin and black graphite were relatively uniformly dispersed on the fracture surface of the composite. The bending properties and conductivity of the composites were improved by adding carbon fiber cloth or metal powders.

Reference

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