A Composite of Polyimide(PI) Film & Glass-cloth

Jiang Dongyun Zhou Dan
Guilin Electrical Equipment Scientific Research Institute,
Guilin, P.R. China 541004

Abstract

PI film is a high performance insulation material often used as motor slot-insulation. This paper reports a composite of PI film and glass cloth that has the same thermal stability as PI and superior tensile strength to PI film. The discussion is concentrated on the function of glass cloth and its effects on the composite.

Key-Words: Composite; Polyimide Film; Glass-cloth; Slot-insulation

Introduction

With its rigid polymer structure, polyimide(PI) features high tensile strength and excellent electrical properties. And also in high temperature and intense nuclear radiation, PI has been proven a suitable insulation material.

The film of polyimide is often used as electric motor slot-insulation with a layer of polyimide-varnished glass cloth in case of laceration or cracking of the film when the wires are embedded into the slot. In later steps, the slot-insulation together with other materials is to be impregnated with an insulating varnish. To construct a robust bulk part of motors, the impregnating varnish must soak into the varnished cloth, and bond the PI film behind. However, to soak into an imidizated varnished cloth is practically impossible. In fact, less impregnating varnish can seep into small air gaps between the varnished cloth and PI film. Thus, after the varnish cured, a weak bond between the film and other materials forms.

To improve the adhesion to PI film, and take full advantage of this high performance material, we suggest that the glass cloth be compounded with PI film in advance. And, to ensure the high temperature properties of the composite, polyimide of bis(4-aminophenyl) ether and pyromellitic dianhydride is also employed as the adhesive between.

Experimental

1. Preparation of Polyamide Acid Resin

Polyamide acid resin was prepared by the reaction of bis(4-aminophenyl) ether and pyromellitic dianhydride in N,N- dimethyl acetamide.

2. Preparation of Composites of PI Film & Glass-cloth.

The prepared resin of polyamide acid was cast on PI film. Then, an electric-purposed glass cloth covered the film. The cloth was stretched to get wetted into the resin and eliminate the air. When N,N-dimethyl acetamide was dried out, the composites were imidizated at 300℃ for 60 minutes.

Different types of glass cloth were used to compound with PI film.

3. Measurement

PERKIN-ELMER 7 Series Thermal Analysis System was used to investigate in air the heat decomposition behavior of PI film/glass-cloth composites, and of the PI film used as adherend. The heating rates were 10℃/min.

Electrical properties and tensile strength of the materials were tested according to the standard method in JB/T2726-1996. To simulate the application condition, the dielectric strength of the materials were measured in normal state and in 200℃ respectively.

Results and Discussion

1. Thermal Stability of the Composite

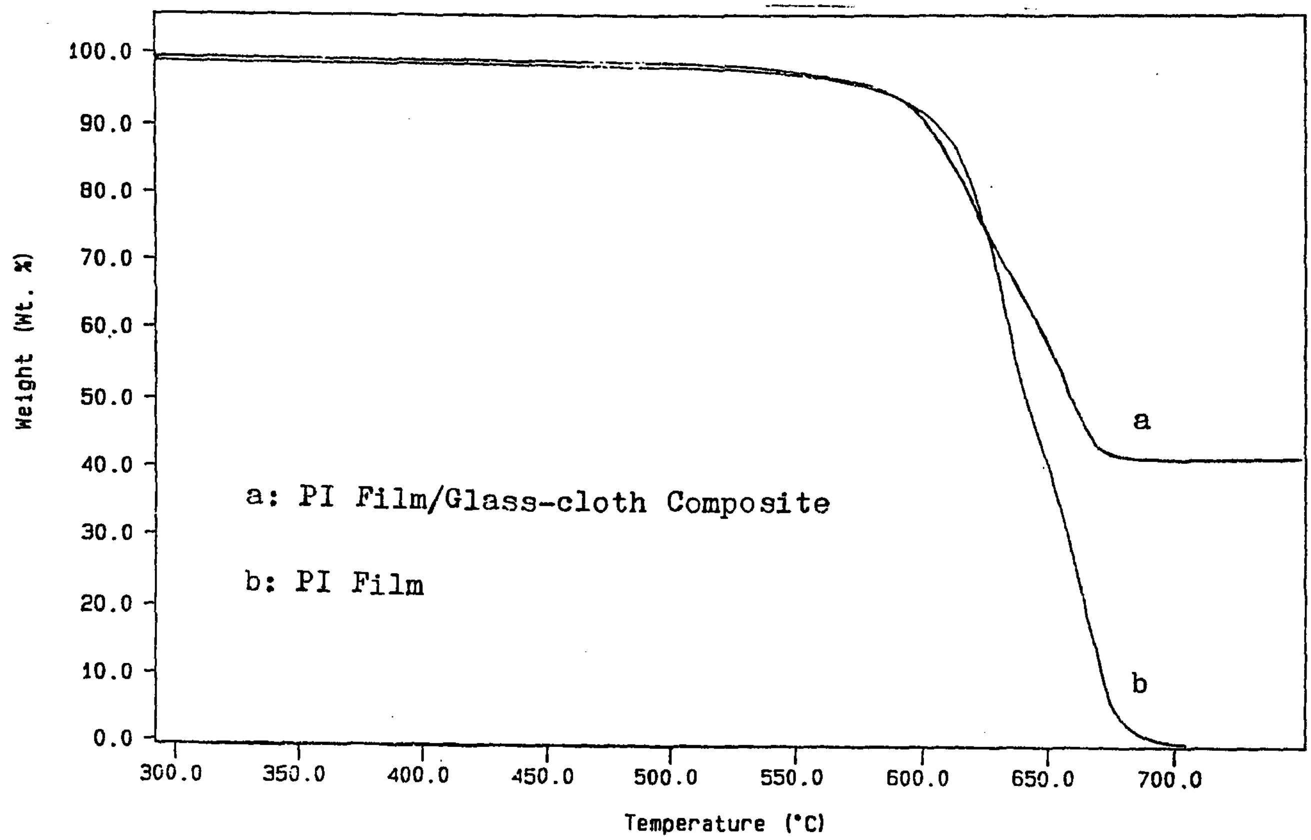

Fig.1 TGA Curves for PI Film and the Composite

Fig.1 displays the thermal stability of the composite. In air, it has the same excellent heat resistance as PI film. When temperature is up to 500℃, the composite begins to decomposed, and , in TGA curve, lose its gravity. Because the inorganic glass cloth does not lose its weight in this range of temperature, Curve A displays a less steep slop than Curve B does.

2. Dielectric Strength and Breakdown Voltage

Table 1. Dielectric Properties of film and composites

Sample	Composite	Thickness (mm)			Breakdown Voltage (kV)		Dielectric Strength (MV/m)	
		PI	G	Total	N	200℃	N	200℃
A	PI film	0.05	/	0.05	9.1	/	180	/
B	PI/Glass I	0.05	0.03	0.116	11.0	10.1	95.5	85.7
C	PI/Glass II	0.05	0.055	0.13	10.56	10.1	82.7	76.8
D	Glass I /PI /Glass I	0.05	0.03×2	0.165	11.6	10.0	70.4	62.6

Table 1 shows the comparison of dielectric properties of PI film and PI film/glass-cloth composites. In column of breakdown voltages (N), the sequence is $U_D>U_B>U_C>U_A$. However, in column of dielectric strength (N), the sequence is different. $E_A>E_B>E_C>E_D$. Another sequence is in thickness $d_D>d_C>d_B>d_A$.

The explanation to the result can be achieved from the unique structure of the PI film/glass-cloth composites. Fig. 2 is a sketch of the cross section structure. According to the electric breakdown theory of dielectrics:

$$E_B = \frac{U_B}{d}$$

E_B: dielectric strength
U_B: breakdown voltage
d: thickness

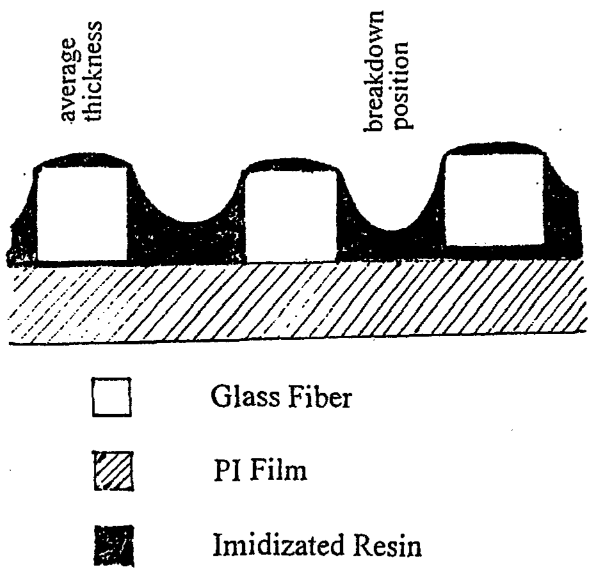

Fig 2. Cross Section of the Composites

d is also an important factor to dielectric strength of insulation. In measurement, d is an average thickness of the sample. The electric breakdown often takes place in the positions of the least thickness; which is much less than the average thickness d. Therefore, in Table 1, the sequence of E does not match the sequence of d as it is expected. Besides, the sequence of breakdown voltage U has less relationship with the average thickness, because the thickness in breakdown position only depends on the quantity of the adhesive resin in the manufacturing process. It is clear that the thickness of glass cloth makes no contribution to dielectric strength of the composites.

In Table 1, another explicit fact is in 200℃ dielectric strengths of the composites is only less lower than that in normal state, owing to the distinguished thermal stability of PI film.

3. Tensile Strength

Table 2. Tensile Strength of the Film and the Composites

Sample	Composite	Thickness (mm)			Stress	Tensile Strength
		PI	G	Total	(N)	(MPa)
A	PI film	0.05	/	0.05	91.7	116
B	PI/Glass I	0.05	0.03	0.113	111.7	65.3
C	PI/Glass II	0.05	0.055	0.125	302.8	163
D	Glass I /PI /Glass I	0.05	0.03×2	0.173	180.5	72.4

In order to prevent the slot-insulation from lacerating while processing the sheet composite should have good tensile strength. To improve the tensile strength is the principal purpose of compounding PI film with glass fiber cloth, which is usually used as a reinforcing material for organic insulations.

However, the result in Table 2 does not agree that every type of glass cloth could increase the tensile strength values of the composites. In sample B and D, the glass cloth are of the some specification which thickness is 0.03mm, but sample D has double layers of this glass cloth. In sample C thickness of the glass cloth is 0.055mm. In other words, Glass II in sample C can withstand higher tension than one layer of Glass I in sample B, and ever two layers in sample D can. Thus , tensile strength of C is much higher than that of B and D.

In addition, Since PI film features high tensile strength itself, suitable strengthening material should be chosen to make further improvement to its performance. The results in Table 2 show that Glass I in B and D is not the proper reinforcing glass cloth for polyimide film, but Glass II in sample C can highly increase the tensile strength of the composite, and achieve the goal of compounding.

Conclusion

1. The composite of polyimide film & glass cloth features the similar high temperature properties to polyimide film, and more excellent tensile strength than PI film does, employing the polyimide adhesive synthesized with pyromellitic dianhydride and bis(4-aminophenyl) ether.
2. Containing a layer of glass cloth, the composite shows lower dielectric strength than PI film does.
3. In order to reinforce polyimide film of high mechanical properties, glass cloth should have high tensile strength and proper thickness.