Development of Low Dielectric Constant Polyamide-imide Varnish with High Breakdown Voltage

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1 Abstract

In recent years, industrial motors operating by PWM (pulse width modulation) inverter control have become mainstream. Surge voltages due to high-speed switching of the inverter (inverter surge) damage the coil insulation of the motors.To improve the coil insulation, reducing the dielectric constant of the enamel varnish is essential. For this purpose, a novel polymer alloy system with polyamide-imide and a reactive polymer has been developed. This varnish “HI-406P” exhibits a low dielectric constant and high breakdown voltage and is applicable to electric vehicle motor insulation.

2 Characteristics

HI-406P was able to improve the breakdown voltage from 12.1 kV to 15.2 kV by reducing the relative dielectric constant by 0.6 compared with the conventional product. The other properties of the enameled wire remain unchanged.

3 Background of the Development

Voltage and frequency have both become higher due to inverter control of industrial motors. Therefore, at the relative dielectric constant of conventional polyamide-imide varnish, it is difficult to suppress inverter surge that reduces the withstand voltage of motors. Polyamide-imide varnish using low dielectric materials has been developed as a method to suppress inverter surges. However, the drop in breakdown voltage and softening point due to thermal degradation or a hygroscopic environment are not satisfactory.

Therefore, Hitachi Chemical has developed a polyamide-imide varnish with excellent withstand voltage and heat-resistance characteristics by forming voids in the polyamide-imide varnish cured film and creating a fine phase separation structure of the reactive resin.

4 Technical Details

1. Development concept for HI-406P

Conventional techniques for lowering the dielectric constant suffer from problems of thermal degradation of the cured film and reduction in breakdown voltage due to moisture absorption by the cured film. To overcome these problems, we first created minute voids in the polyamide-imide cured film to reduce the dielectric constant, as shown in **Figure 1**. In addition, we adopted a reactive resin with a lower dielectric constant and different reactivity and polarity compared to the polyamide-imide resin. This formed a phase separation structure with a structural period of about 20 nm after curing, as shown in **Figure 2**. The dielectric constant was lowered with no reduction in other physical properties.

2. Breakdown voltage

The breakdown voltage was evaluated using the breakdown voltage of a twisted pair used as a winding **Figures 3** and **4** show the breakdown voltage after the heat resistance test (260 °C/168 hours) and the moisture absorption test (60 °C/90 % R.H./24 hours). It achieved higher breakdown voltage compared to conventional polyamide-imide wire after both the heat resistance test and moisture absorption test.

The reduction of the relative dielectric constant could be cited as a factor for the improvement in breakdown voltage. But in addition, due to the adoption of a fine phase separation structure, the charged particles at the time of discharge wrap around the low dielectric constant voids in the reactive resin phase, and collide with the polyamide-imide phase. This gains some creepage distance and reduces the collision energy of the charged particles due to reflection and scattering.

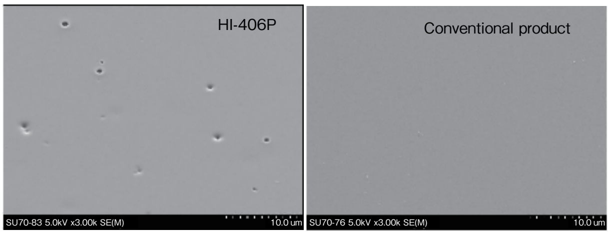

Figure 1 Comparison of SEM observation results between HI-406P film and conventional film

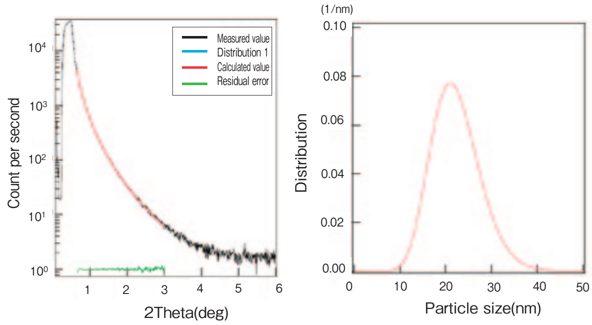

Figure 2 Small angle X-ray scattering results of HI-406P film

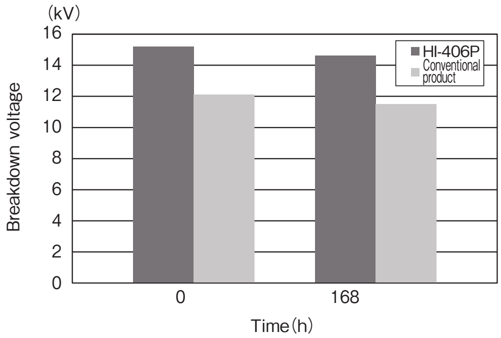

Figure 3 Comparison of breakdown voltage after heat resistance test between HI-406P and conventional PAI

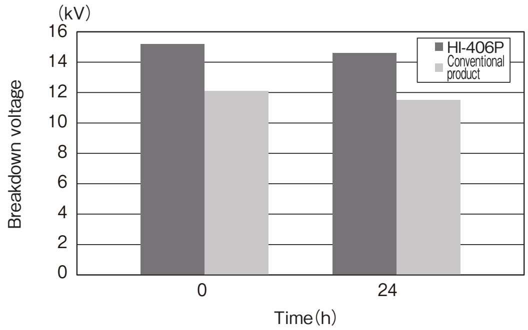

Figure 4 Comparison of breakdown voltage after moisture absorption test (60 ℃ / 90 % R.H.) between HI-406P and conventional PAI

3. General properties of HI-406P

Table 1 shows the general properties of HI-406P. HI-406P was able to improve the breakdown voltage from 12.1 kV to 15.2 kV by reducing the relative dielectric constant by 0.6 compared with the conventional product. The other properties of the enameled wire remain unchanged and we believe it can be applied in motors for electric vehicles for which demand is expected to grow rapidly.

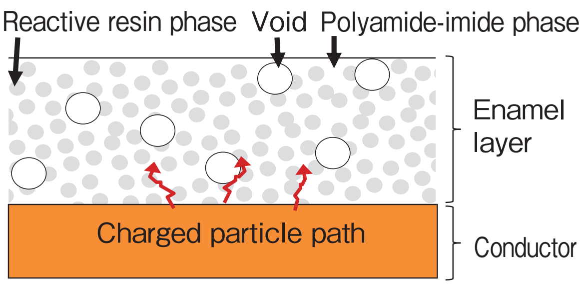

Figure 5 Schematic diagram of cross-section of enameled wire

Table 1 General1 properties of HI-406P

Item	Units	Conditions	HI-406P	Conventional product
Relative dielectric constant	-	1 kHz	4.0	4.6
Film thickness	mm	-	0.032	0.032
Enameled wire external appearance	-	Visual	Good	Good
Flexibility[2]	-	20 % elongation	2d	2d
Adhesion[2]	mm	Rapid extension method	2.0	2.0
Wear resistance[3]	N	Unidirectional	17.3	16.8
Breakdown voltage[4]	kV	Normal	15.2	12.1
Softening resistance[5]	℃	Load: 0.7 kg	453	449
Glycerin pressure resistance	kV	Glycerin/ saturated saline: 85/15	5.2	3.8

5 Future Business Development

- Further development of low dielectric constant technologies
- Development of insulation materials for next-generation electric vehicles

【Related patents】

Patent No. 5896006 Patent No. 5804314 Patent No. 5880914

【References】

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