ThreeBond
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Epoxy Resins for Vehicle Electrical Devices

Introduction

The situation with regards to vehicles has changed significantly in recent years, from weight reduction and electrification due to tightening CO_2 emission regulations to the adoption of advanced driving support systems to improve safety and automatic driving. The structure and mechanisms of vehicles are also changing.

Up to now, various epoxy resins have been used for electrical components in vehicles such as ECUs, inverters, converters and motors. Use of epoxy resins in vehicles is expected to increase further in future as the number of electrical components increases with the electrification of vehicles, the introduction of automatic driving, the use of alternatives to welding in order to reduce weight and the installation of new components due to structural changes.

Although epoxy resins are used for a variety of areas and applications in vehicles, the required properties vary depending on the location and application.

For this reason, we have been developing products that deliver the required characteristics. This article describes the features and concepts behind these products.

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1. Required Characteristics

Epoxy resins are used for a variety of areas in vehicles and the required properties vary depending on the environment surrounding each location.

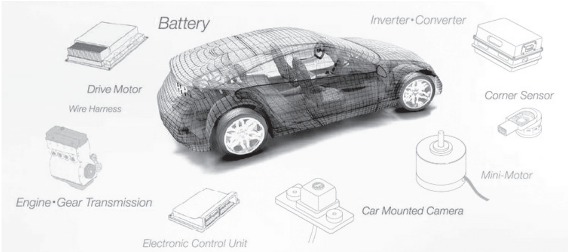

Fig. 1 Components in which Epoxy Resins are Used

When used near the engine or in positions exposed to high temperatures created by moving parts, high heat resistance is required to ensure that adhesive strength is maintained even at high temperatures.

In areas that undergo large changes in temperature, resin with a low linear expansion coefficient is required.

High heat dissipation is needed in areas where generated heat must be dissipated.

In addition, flame-retardant material may be required in some areas to prevent the spread of any fire that occurs.

The following sections describe products with these characteristics.

2. Epoxy Resin with High Heat Resistance

The bond strength of adhesives changes drastically at the glass transition temperature, usually dropping significantly at temperatures above the glass transition temperature.

Although the glass transition temperature of typical epoxy resins is between 100 and 120°C, the environmental temperature in some areas in which epoxy resins are used in vehicles exceeds 120°C. If the bonded area is exposed to temperatures above the glass transition temperature of the adhesive, peeling and other defects may occur.

ThreeBond 2237J was developed to prevent this decrease in bond strength in high temperature environments and has a high glass transition temperature in order to maintain a high elastic modulus and high bond strength in high temperature environments.

2-1. ThreeBond 2237J

ThreeBond 2237J (hereafter ThreeBond is abbreviated to TB) is a single-component heat-curing epoxy resin with the following characteristics.

1. High glass transition temperature
2. Excellent tensile shear bond strength and peel adhesive strength

2-2. Characteristic Values

The characteristic values of TB2237J are shown in Table 1 and the bond strength to various materials is shown in Table 2.

As shown in Table 2, TB2237J exhibits high bond strength to a wide range of materials.

TB2237J has a high glass transition temperature of 150°C and can maintain bond strength in high temperature environments, as shown in Fig. 2. The material also exhibits high heat resistance and no decrease in bond strength is observed after 2,500 hours at 150°C (Fig. 3).

Table 1 TB2237J Characteristic Values

Test item		Unit	Characteristic value	Testing method	Remark(s)
Appearance		—	White	3TS-2100-020	—
Viscosity		Pa·s	115	3TS-2F00-007	Shear velocity: 5.0 s^{-1}
Cure shrinkage		%	1.6	3TS-2600-001	—
Tensile shear bond strength		MPa	26	3TS-4100-011	Fe/Fe (SPCC-SD)
T type peeling adhesive strength		kN/m	3.6	3TS-4130-021	Fe/Fe (SPCC-SD)
Glass transition temperature		°C	150	3TS-4740-001	TMA
Linear expansion coefficient (α_1)		ppm/°C	30		20 to 60°C
Linear expansion coefficient (α_2)			121		260 to 300°C
Storage elastic modulus (E')	25°C	GPa	8.3	3TS-4730-001	DMA 1Hz
	200°C		0.25		
Peak loss elastic modulus (E")		°C	177		
Peak loss tangent (tanδ)			186		
Curing conditions		—	120°C × 60min	—	—

Table 2 Bond Strength of TB2237J by Material

Test item	Material	Unit	Character	Testing method
Tensile shear bond strength	Fe/Fe (SPCC-SD)	MPa	26	3TS-4100-011
	Fe/Fe (SPCC-SB)		23	
	SUS/SUS (SUS304)		24	
	Cu/Cu (1100P)		18	
	Al/Al (A1050P)		15	
	PPS/PPS		5.3	
	Epoxy glass/epoxy glass		13	
T type peeling adhesive strength	Fe/Fe (SPCC-SD)	kN/m	3.6	3TS-4130-021
	Al/Al (A1050P)		2.4	

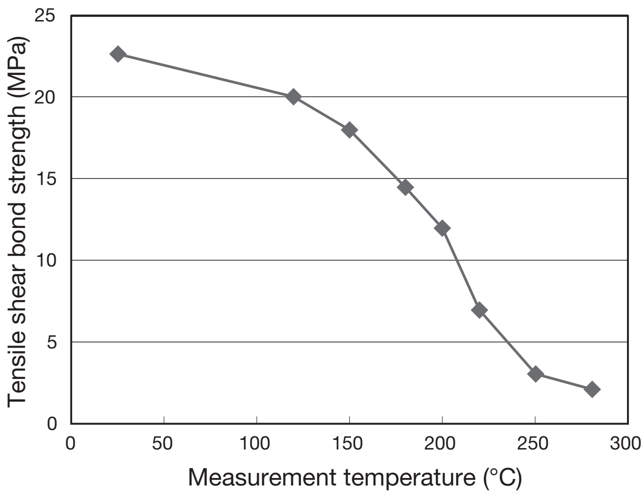

Fig. 2 TB2237J Lap Shear Strength Test

Curing conditions: 60min at 120°C
Test piece material: SPCC-SD/SPCC-SD

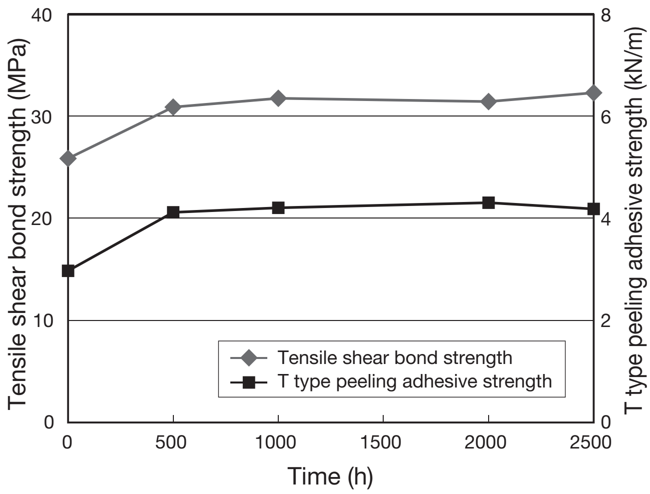

Fig. 3 Heat Resistance of TB2237J

Curing conditions: 60min at 120°C
Environmental conditions: 150°C
Measurement conditions: 3TS-4100-011, 3TS-4130-021
Test piece material: SPCC-SD/SPCC-SD

3. Epoxy Resin with Low Linear Expansion Coefficient

The volume of substances expands as the temperature rises. The rate of this expansion per degree change in temperature is called the linear expansion coefficient. The linear expansion coefficient of epoxy resin is relatively low among organic materials, but higher than that of metals (Table 3).

The greater the difference in linear expansion coefficient between the adherend and the adhesive, the greater the stress due to expansion and contraction during heat cycles. This repeated stress causes defects such as cracking and peeling.

Some parts of vehicles undergo large differences in temperature between when driving and when stationary and materials with a low linear expansion coefficient that have a small difference in volume during expansion and shrinkage are required. For this reason, TB2235L was developed with consideration given to heat cycle resistance.

Table 3 Linear Expansion Coefficient by Material

Material		Linear expansion coefficient	Material		Linear expansion coefficient
Metal Inorganic material	Aluminum	23	Organic material	Epoxy	45 to 65
	Iron	12		Acrylic	50 to 90
	Magnesium alloy	27		Polypropylene	58 to 100
	Stainless steel	17		Polyethylene	120 to 140
	Hard glass	9		Polycarbonate	66

3-1. TB2235L

TB2235L is a single-component heat-curing epoxy resin with the following characteristics.

1. Low linear expansion coefficient
2. High glass transition temperature

3-2. Characteristic Values

The characteristic values of TB2235L are shown in Table 4. Tensile shear bond strength when heated, heat resistance and heat cycles are shown in Fig. 4, Fig. 5 and Fig. 6, respectively.

In addition to having a low linear expansion coefficient, TB2235L has a high glass transition temperature. This means that is has high bond strength in high temperature environments (Fig. 4) and excellent heat resistance at 150°C (Fig. 5).

With regards to heat cycles, Fig. 6 shows that the epoxy resin has excellent heat cycle resistance, showing no significant decrease from the initial bond strength even after 2,000 cycles.

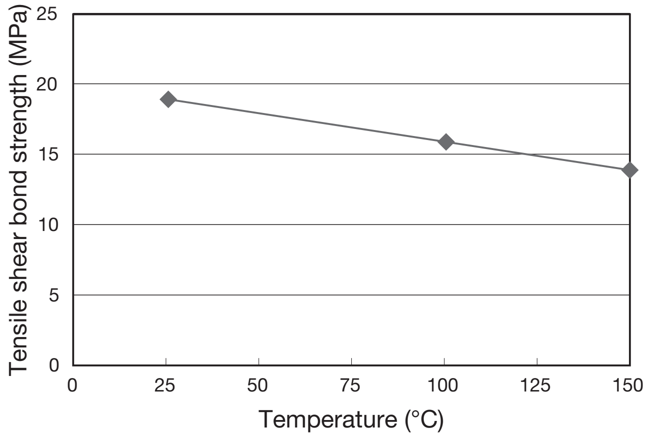

Fig. 4 TB2235L Lap Shear Strength Test

Curing conditions: 30min at 140°C
Measurement conditions: 3TS-4100-011
Test piece material: SUS/SUS (SUS304)

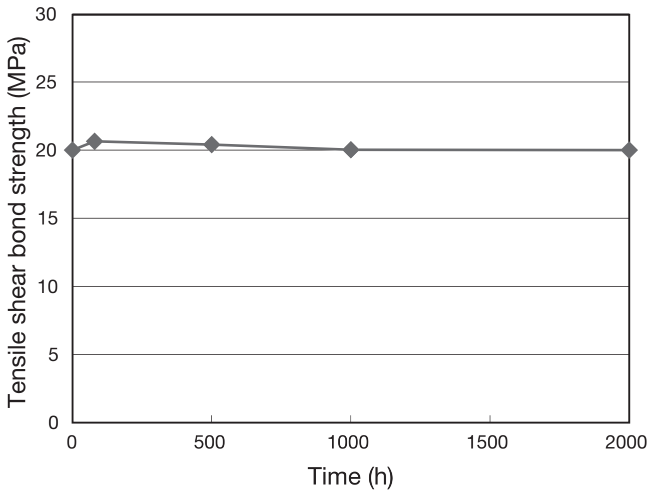

Fig. 5 Heat Resistance of TB2235L

Curing conditions: 30min at 140°C
Environmental conditions: 150°C
Measurement conditions: 3TS-4100-011
Test piece material: SUS/SUS (SUS304)

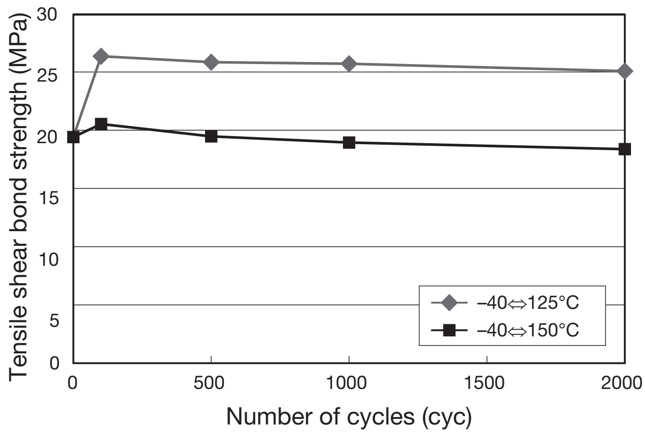

Fig. 6 TB2235L Heat Cycles

Curing conditions: 30min at 140°C
1 cycle: (30min at -40°C and 30min at 125°C)
(30min at -40°C and 30min at 150°C)
Measurement conditions: 3TS-4100-011
Test piece material: SUS/SUS (SUS304)

Table 4 TB2235L Characteristic Values

Test item	Unit	Characteristic value	Testing method	Remark(s)
Appearance	—	Black	3TS-2100-020	—
Viscosity	Pa·s	80	3TS-2F00-007	Shear velocity: 10.0 s^{-1}
Cure shrinkage	%	1.7	3TS-2600-001	—
Tensile shear bond strength	MPa	23	3TS-4100-011	Fe/Fe (SPCC-SD)
T type peeling adhesive strength	kN/m	2.0	3TS-4130-021	Fe/Fe (SPCC-SD)
Glass transition temperature	°C	149	3TS-4740-001	TMA
Linear expansion coefficient (α_1)	ppm/°C	16		20 to 40°C
Linear expansion coefficient (α_2)		24		160 to 200°C
Storage elastic modulus (E’) 25°C	GPa	10	3TS-4730-001	DMA 1Hz
Peak loss elastic modulus (E”)	°C	154		
Peak loss tangent (tanδ)		170		
Curing conditions	—	140°C × 30min	—	—

4. Epoxy Resin with High Heat Dissipation

The amount of heat generated by electrical components has increased in recent years with the miniaturization and increase in output of electrical components. Because this heat generation affects the operation and performance of mounted parts, the growing need for adhesives with heat dissipation properties needs to be addressed. Our silicone rubber adhesive dissipates heat. However, as silicone heat radiating agents have low adhesive strength, there is demand for heat radiating agents that combine high bond strength with heat resistance. We have developed the heat radiating epoxy resin TB2270J to meet this demand.

4-1. TB2270J

TB2270J is a single-component heat-curing epoxy resin with the following characteristics.

1. High heat conductivity
2. Low linear expansion coefficient and low cure shrinkage
3. Excellent durability and curability at low temperatures

4-2. Characteristic Values

The characteristic values of TB2270J are shown in Table 5.

TB2270J is a thermally conductive material with a high storage elastic modulus and bond strength. It also has excellent heat resistance and no decrease in bond strength is observed even after 2,000 hours in a 125°C environment (Fig. 7).

As shown in Fig. 8, the extremely low linear expansion coefficient also provides excellent heat cycle resistance, with no significant decrease from the initial bond strength even after 2,000 cycles.

Table 5 TB2270J Characteristic Values

Test item		Unit	Characteristic values	Testing method	Remark(s)
Appearance		—	White	3TS-2100-020	—
Viscosity		Pa·s	150	3TS-2F00-007	Shear velocity: 1.0 s^{-1}
Cure shrinkage		%	1.4	3TS-2600-001	—
Tensile shear bond strength		MPa	9	3TS-4100-011	Fe/Fe (SPCC-SD)
Glass transition temperature		°C	117	3TS-4740-001	TMA
Linear expansion coefficient (α_1)		ppm/°C	11		20 to 40°C
Linear expansion coefficient (α_2)			58		160 to 180°C
Storage elastic modulus (E')	25°C	GPa	32	3TS-4730-001	DMA 1Hz
Peak loss elastic modulus (E")		°C	118		
Peak loss tangent (tanδ)			134		
Heat conductivity		W/m·K	4.2	3TS-4750-002	—
Curing conditions		—	100°C × 40min	—	—

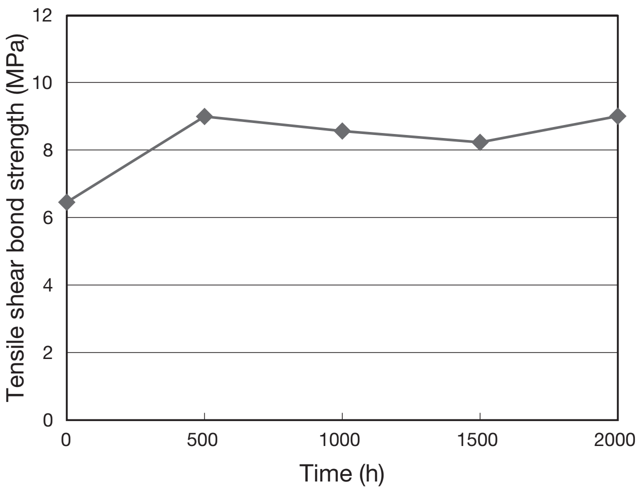

Fig. 7 Heat Resistance of TB2270J

Curing conditions: 40min at 100°C
Environmental conditions: 125°C
Measurement conditions: 3TS-4100-011
Test piece material: Al/Al (A1050P)

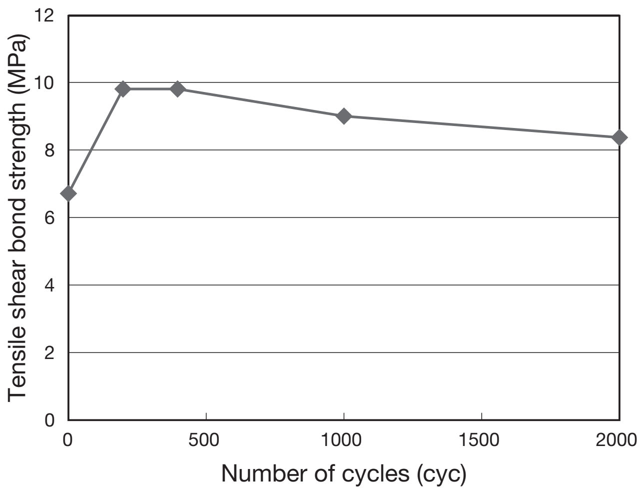

Fig. 8 TB2270J Heat Cycles

Curing conditions: 40min at 100°C
One cycle: (30min at -40°C and 30min at 125°C)
Measurement conditions: 3TS-4100-011
Test piece material: Al/Al (A1050P)

Figures 10 and 11 show the results of thermal conductivity evaluation of TB2270J carried out using thermography.

Measurement method

TB2270J was applied at a thickness of 0.1mm between two aluminum rods with a length of 50mm and diameter of φ20. A Peltier element was attached to either end, with the upper element set to 45°C to provide a temperature gradient (Fig. 9).

Results

A thermographic image is shown in Fig. 10. The sample with TB2270J applied to a thickness of 0.1mm is shown on the left. A sample with two aluminum rods in direct contact without the application of a heat radiating agent is shown on the right. A graph of the temperature at the center line is shown in Fig. 11.

These results show that heat transfer does not occur at the joint between the rods if TB2270J is not applied and that there is almost no temperature difference in the joint between the rods (the section where TB2270J is applied) when TB2270J, which dissipates heat, is applied. This means that the heat is being transferred effectively.

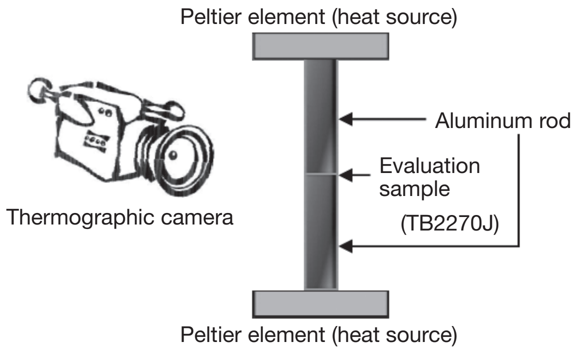

Fig. 9 Thermographic Observation Model

Fig. 10 Thermographic Observation

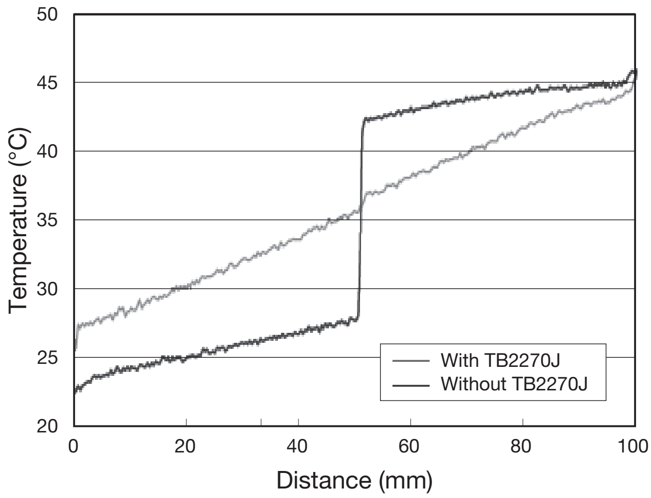

Fig. 11 Aluminum Rod Temperature Distribution

5. Flame-Retardant Epoxy Resin

The number of parts that can cause ignition in vehicles is increasing with fires caused by heat generated from electronic components installed in vehicles, which have become more numerous, miniaturized and lightweight, and the introduction of powertrains including high-voltage and high-current batteries and motors in electric cars and other next-generation automobiles. When there is a source of ignition, flammable materials catch fire, which causes the fire to spread. For this reason, materials used near areas with potential sources of ignition must have flame-retardant properties. TB2272F was developed in response to the fact that, as adhesives are flammable, an epoxy resin with flame-retardant properties is required in these areas.

5-1. TB2272F

TB2272F is a single-component heat-curable epoxy compound resin that is certified to UL94-V-0 flammability standard using the vertical flammability test. This makes it suitable for bonding and sealing near parts that are a potential source of heat.

Fig. 12 shows an image of the flame from a gas burner being applied to a material cured with TB2272F.

Whereas typical epoxy resin, which does not have flame-retardant properties, spreads fire immediately after flame is applied, the fire-retardant TB2272F does not easily catch fire even when a flame is applied and any flames disappears immediately.

5-2. Characteristic Values

The characteristic values of TB2272F are shown in Table 6 and the results of the vertical flammability test are shown in table 7.

Vertical flammability test conditions

- Testing method and evaluation method: According to 3TS-2700-002
- Testing environment: Temperature of 25°C and relative humidity of 50%
- Flame size: 20mm blue flame
- Sample conditioning: Left for at least 48 hours in an atmosphere with a temperature of 23°C and relative humidity of 50%
- Sample size: 125 mm × 13 mm × 3 mm

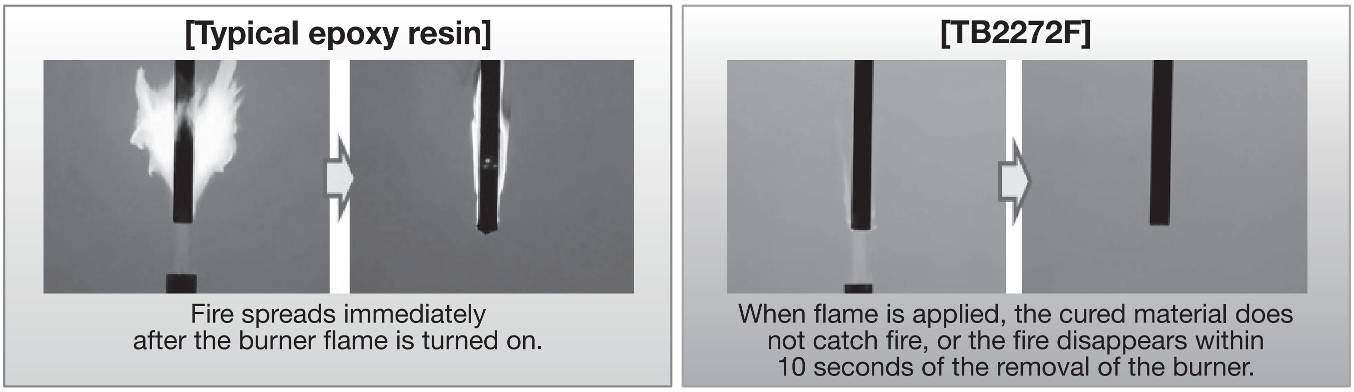

Fig. 12 Flammability Comparison

Table 6 TB2272F Characteristic Values

Test item	Unit	TB2272F	Testing method	Remark(s)
Appearance	—	Black	3TS-2100-002	—
Viscosity	Pa·s	75	3TS-2F00-007	Shear velocity: 5.0 s^{-1}
Tensile shear bond strength	MPa	21	3TS-4100-011	Fe/Fe (SPCC-SD)
Glass transition temperature	°C	117	3TS-4740-001	TMA
Linear expansion coefficient (α_1)	ppm/°C	29		0 to 40°C
Linear expansion coefficient (α_2)		119		160 to 200°C
Storage elastic modulus (E') 25°C	GPa	12	3TS-4730-001	DMA 25°C
Peak loss elastic modulus (E")	°C	118		1Hz
Peak loss tangent (tanδ)		147		
Non-flammable grade	—	UL94V-0 certified	—	—
Curing conditions	—	100°C × 60min	—	—

Table 7 V-0 Flammability Standard Criteria for UL94 Vertical Flammability Test and Results for TB2272F

Evaluation item	V-0 standard	Measured value for TB2272F
t1 or t2 for each sample	≤10 seconds	≤4 seconds
Total burning time after 5 flame exposures (including second flame contact)	≤50 seconds	≤10 seconds
Total time of t2 and t3	≤30 seconds	≤8 seconds
Combustion or sparking reaching up to the clamp	No	No
Ignition of absorbent cotton by falling objects	No	No

t1: burning time after first flame exposure, t2: burning time after second flame exposure, t3: afterglow time after second flame exposure

Closing

This article introduces products with high heat resistance, low linear expansion coefficient, heat dissipation and flame retardancy, some of the key properties required for epoxy resins used in vehicle electrical devices.

Demand for adhesives for vehicles is expected to grow as vehicles continue to evolve. As the range of applications expands, it will be necessary to develop products that suit the needs of each application.

ThreeBond will continue to contribute to the industry by focusing on product and technology development in line with market trends.

<References>

1) Habara, Takeo. *Global Trend of Electrified Vehicle and Our Country's Action, Journal of Society of Automotive Engineers of Japan, Vol. 72 (2)*, p.13-17, Society of Automotive Engineers of Japan (2018)

2) Ashida, Tadashi. *Applications of Epoxy Adhesives, Epoxy Resin Review, Vol. 4, Advanced Edition II,* p. 88-107, The Japan Society of Epoxy Resin Technology (2003)

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