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Sealant Technology to Support Electric Vehicle Evolution: Development of Non-silicone-based FIPGs

Introduction

In the automobile industry, electrification is accelerating as part of initiatives related to the SDGs. Accordingly, producers of components and raw materials must also develop products with the characteristics that electric vehicles require.

ThreeBond produces formed in place gaskets (FIPGs) to seal against oil and coolant in internal combustion engines. As liquid sealants, FIPGs are applied to the mating surface of components, then cured to achieve a sealing function.

FIPGs can also be applied to areas that require sealing in electric vehicles. ThreeBond offers a lineup of products for the electric vehicle market that meet the characteristic requirements specific to electric vehicles and comply with European Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulations.

In this article, the authors describe ThreeBond 1160 and other FIPG products that meet diverse electric vehicle needs.

Hereafter, ThreeBond in product names is abbreviated as TB.

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1. About FIPGs

FIPG stands for formed in place gasket. FIPGs are liquid gaskets. They are applied to a mating surface, then cured to achieve a sealing function.[1)]

Figure 1 shows the sealing mechanics of solid gaskets and FIPGs. Unlike solid gaskets, which achieve their sealant function through repulsive force, FIPGs achieve their sealant function through adhesive force, bonding force and cohesive force, meaning that they can be used at low surface pressures. In addition, because FIPGs are liquid before they are cured, a single type of FIPG can be applied to various flange shapes, simplifying inventory management. Automation can also be implemented through the use of application devices, leading to improved productivity, consistent quality, and lower personnel costs.[1, 2)]

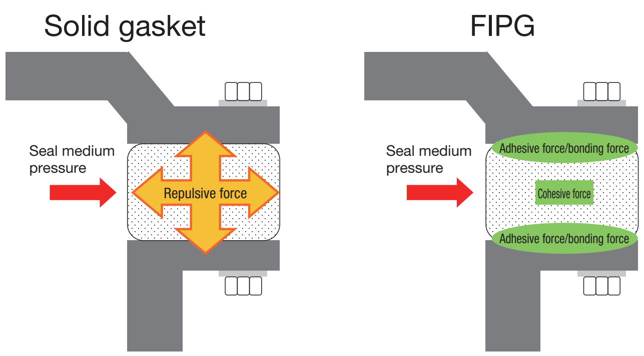


Fig. 1 Solid Gasket and FIPG Seal Mechanics

2. Use of FIPGs in Internal Combustion Engines

Internal combustion engines are sealed against materials such as oil and coolant at several locations. FIPGs are used to prevent liquid leakage in these areas.

Important characteristics required of FIPGs include heat resistance appropriate for the anticipated usage environment (up to 200°C), chemical resistance (oil resistance), and conformability to adapt to vibrations during driving and to movements in the mating surface due to thermal expansion and contraction. To achieve these required characteristics, silicone-based FIPGs with good heat and chemical resistance, together with excellent conformability, are used.

3. Use of FIPGs in Electric Vehicles

The major difference between internal combustion engines and electric vehicles is that the latter are fitted with batteries and motors instead of engines. With batteries, FIPGs are garnering attention for use in sealing to protect batteries from external environmental factors, such as water and dust.

Areas where FIPGs are used are shown in Table 1 and Figure 2. In addition to batteries and motors, autonomous driving and other recent evolutions in electric vehicles mean these vehicles are being fitted with more electronic components, and FIPGs are being adopted in more cases.

ThreeBond aims to provide for future market trends by offering a lineup of FIPGs with various characteristics. In this article, the authors give background on the development of non-silicone-based FIPGs for electric vehicles and describe products with various characteristics.

Table 1 FIPG Use Areas

Use areas	Battery case sealing	Transmission case sealing	Inverter/converter case sealing	ECU board potting
Required FIPG characteristics	Heat resistance: Up to 120°C Moisture resistance: 85°C, 85%RH Flame retardance: UL94 V-0 standard	Heat resistance: Up to 150°C Oil resistance: Up to 150°C	Heat resistance: Up to 120°C Moisture resistance: 85°C, 85%RH Adhesion to resin materials	Heat resistance: Up to 120°C Moisture resistance: 85°C, 85%RH Heat dissipation: 2.0 W/m·K or higher

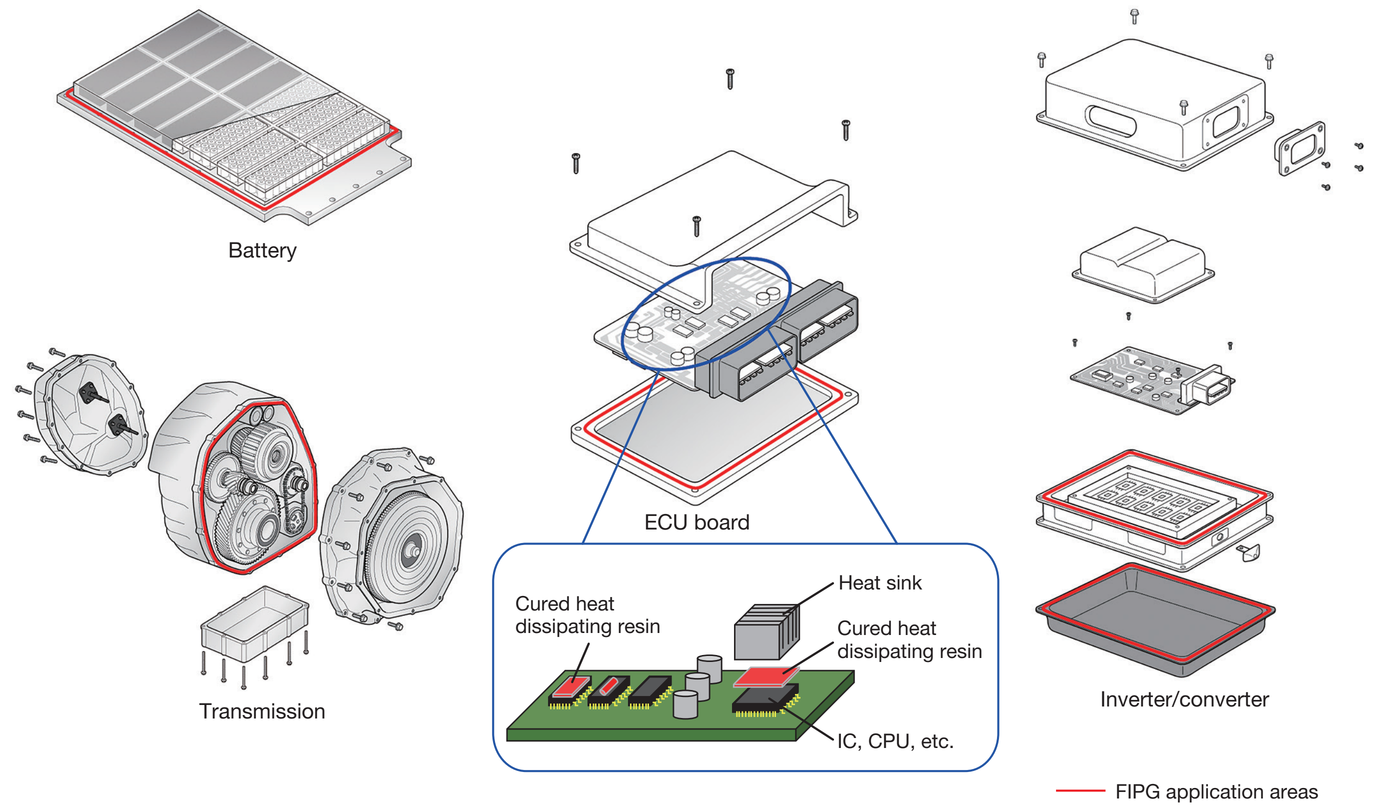


Fig. 2 FIPG Use Areas

4. TB1160 (Single Component Moisture-curing Resin)

Since its founding, ThreeBond has provided silicone-based FIPGs that offer heat resistance and chemical resistance as sealants for oil in internal combustion engines. Through the application of existing technology, it has released a non-silicone-based FIPG that fulfills the characteristics required by electric vehicles (TB1160) into the market. This product has the following qualities.

1. Compatibility with low-molecular mass siloxane

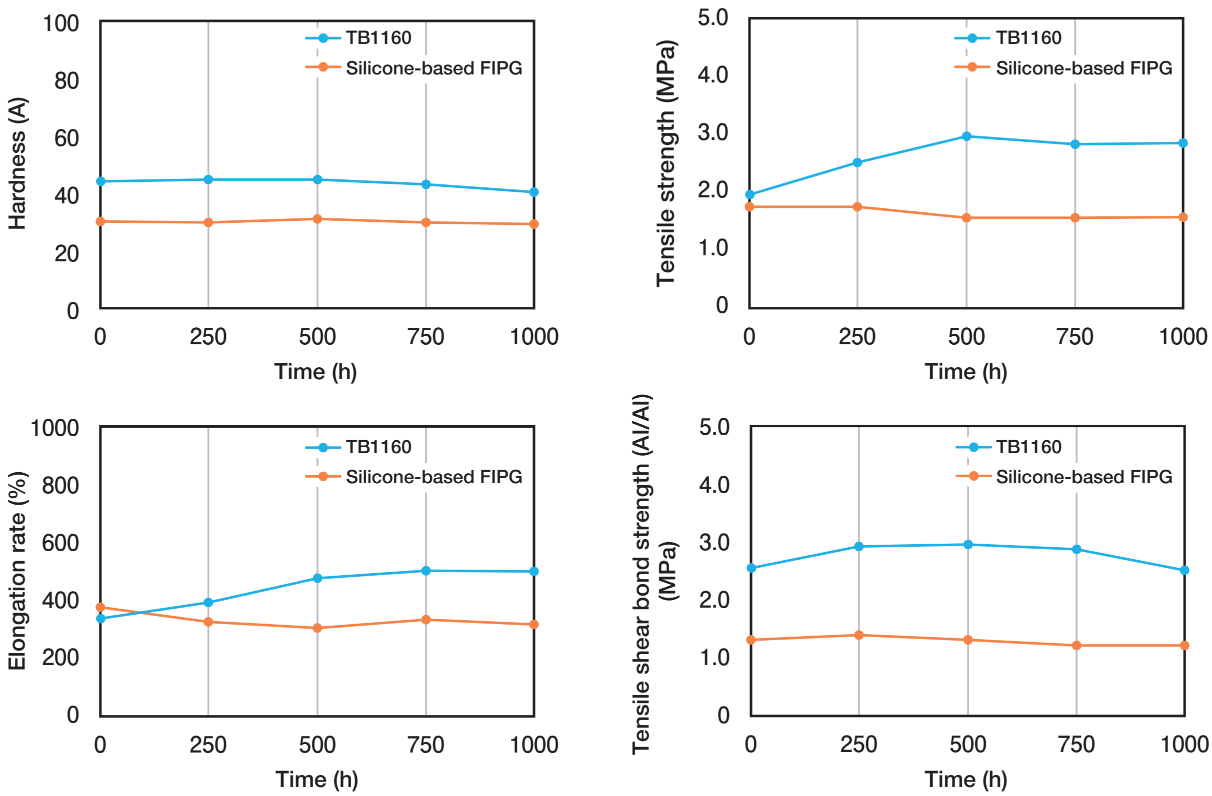
Electronic components such as batteries and inverters are known to be affected by the low-molecular mass siloxane contained in silicone materials. Low-molecular mass siloxane is a silicone compound with a Si-O-Si structure. It has a low molecular mass and is volatile, meaning that arc discharge can cause it to decompose, forming a silicon dioxide film with electrical insulation properties. As this silicon dioxide film can cause switch contact faults, TB1160 is made using non-silicone-based raw materials.

2. Compliance with European Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulations

Some conventional FIPG products use tin compounds, which are subject to REACH regulations. In consideration of worker safety and environmental persistence, restrictions on use are implemented based on the product application. Consequently, TB1160 uses non-tin compounds.

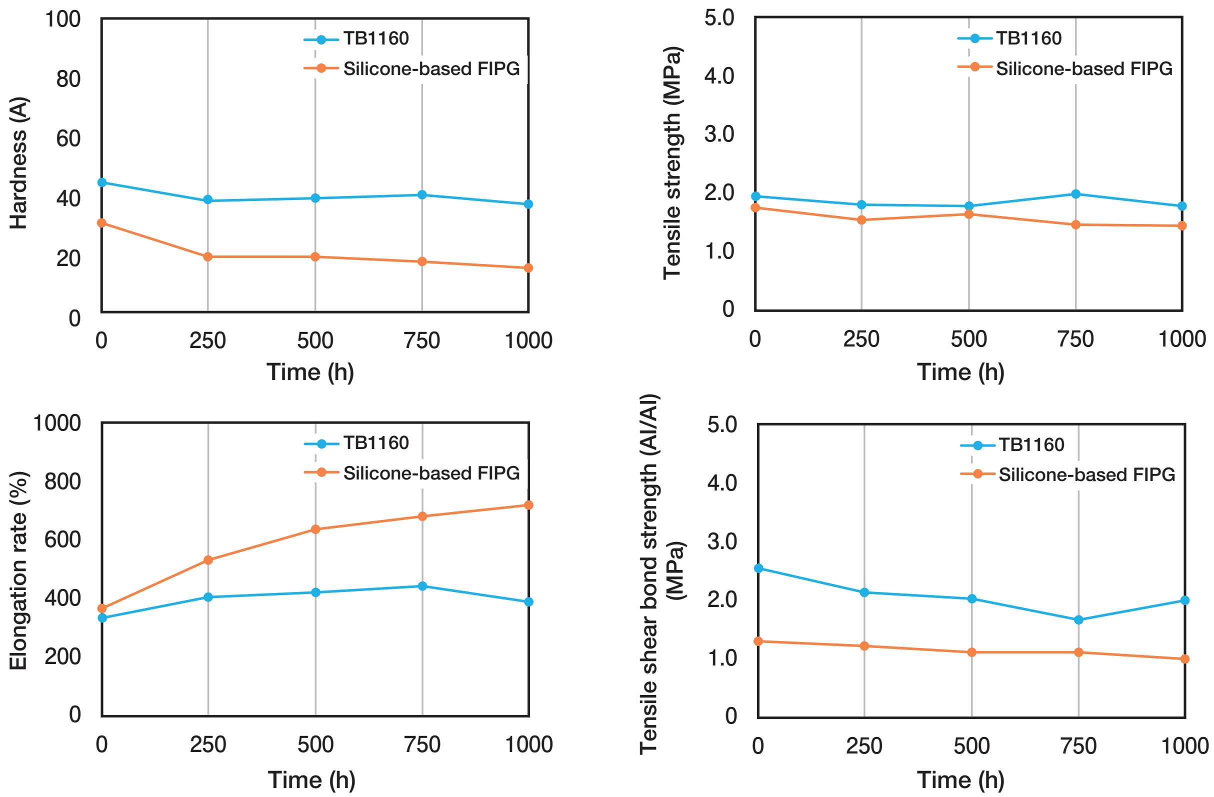
3. Reliability of TB1160

In electric vehicles, heat from batteries and motors can lead to high temperatures of 80 to 120°C and humid conditions can occur during rain. The raw materials used in TB1160 were selected to provide the characteristics required in these situations. As shown in figures 3 and 4, the adhesive force and bonding force do not decrease over a long period, and reliability equivalent to silicone-based FIPGs with a track record in the market is achieved.



Curing conditions: (23±2)˚C, (50±5)%RH, 168h

Fig. 3 Heat Resistance (120°C) Comparison Data



Curing conditions: (23±2)˚C, (50±5)%RH, 168h

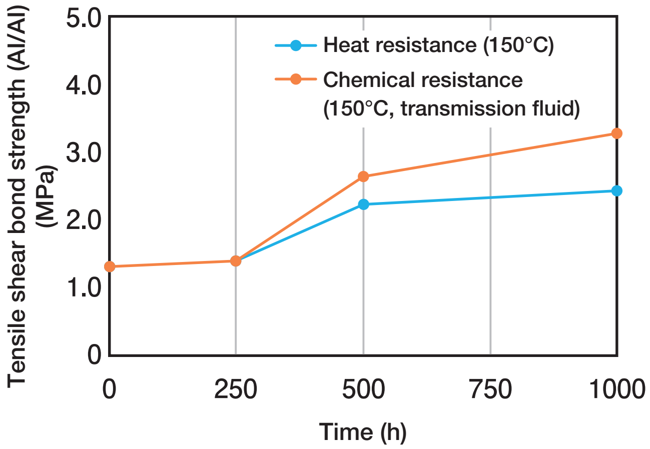
Fig. 4 Moisture Resistance (85°C, 85%RH) Comparison Data

5. Lineup of FIPGs for Electric Vehicles

ThreeBond has established a lineup of FIPGs that meet the diverse needs of electric vehicles, with grades offering high heat resistance, grades with high adhesion to resin materials, grades with high heat radiation, and grades with high incombustibility performance. The specifications of these products are shown in Table 3. As described in section 1 of this article, FIPGs derive their sealant function from adhesive force, bonding force and cohesive force. Consequently, in the following product descriptions, the results of shear bond strength durability tests are shown as examples.

5-1 TB1161 (High Heat Resistance Grade)

TB1161 has high heat resistance and chemical resistance. As shown in Figure 5, in heat resistance (150°C) and chemical resistance (150°C, transmission fluid) tests, performance was maintained for a long time without the bonding force decreasing.



*Curing conditions: (23±2)°C, (50±5)%RH, 168h
Oil used in chemical resistance tests: Transmission fluid

Fig. 5 Heat and Chemical Resistance Evaluation Results

5-2 TB1163 (High Resin Adhesion Grade)

TB1163 provides adhesion to resin materials used in automobile components.

FIPGs that demonstrate sufficient functionality are expected to exhibit cohesive fractures (CFs) (Figure 6). As shown in Table 2, TB1163 demonstrates CFs with various resin materials. In addition, as shown in Figure 7, in heat resistance (120°C) and moisture resistance (85°C, 85%RH) tests, performance was maintained for a long time without the bonding force decreasing.

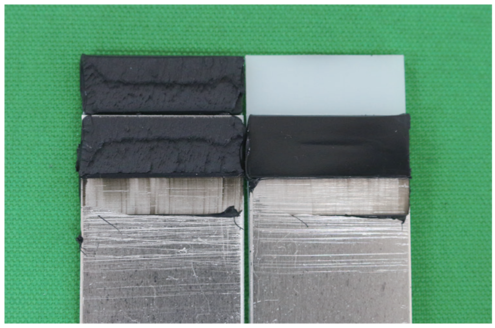
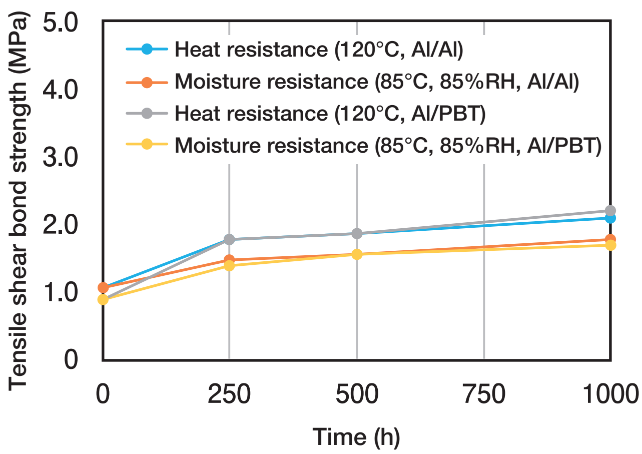


Fig. 6 Tensile Fracture Surfaces
Left: Cohesive fracture (CF) Right: Adhesive fracture (AF)

Table 2 Tensile Shear Fracture Comparison by Material

Material	Conventional product	TB1163
Aluminum	CF	CF
PET	AF	CF
PMMA	AF	CF
PPS	AF	CF
PBT	AF	CF
PC	AF	CF
ABS	AF	CF
Soft PVC	AF	CF
Hard PVC	CF	CF
Nylon 6	CF	CF
Nylon 66	CF	CF
Nylon 9T	CF	CF
Epoxy glass	CF	CF



*Curing conditions: (23±2)°C, (50±5)%RH, 168h

Fig. 7 Heat and Moisture Resistance Evaluation Results

5-3 TB1165 (High Heat Dissipation Grade)

TB1165 offers heat dissipation and flexibility. It has high thermal conductivity of 3.0W/m·K, providing excellent heat dissipation. As shown in Figures 8 and 9 it has thixotropy in consideration of application processes and forms a highly-flexible cured material, enabling use on diverse shapes. In addition, as shown in Figure 10, in heat resistance (120°C) and moisture resistance (85°C, 85%RH) tests, performance was maintained for a long time without the bonding force decreasing.

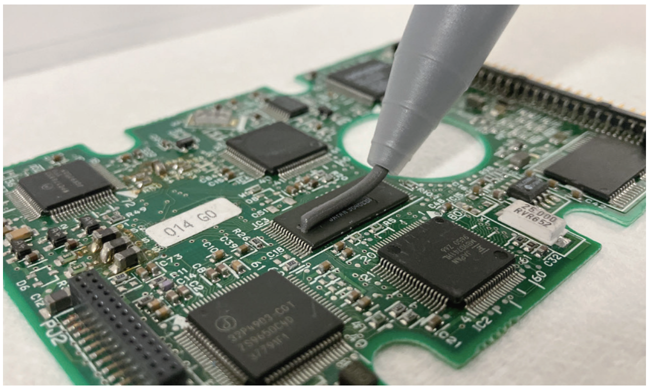


Fig. 8 Illustration of TB1165 Application

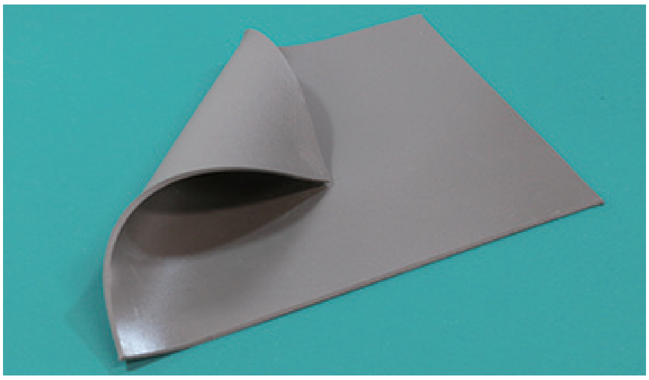
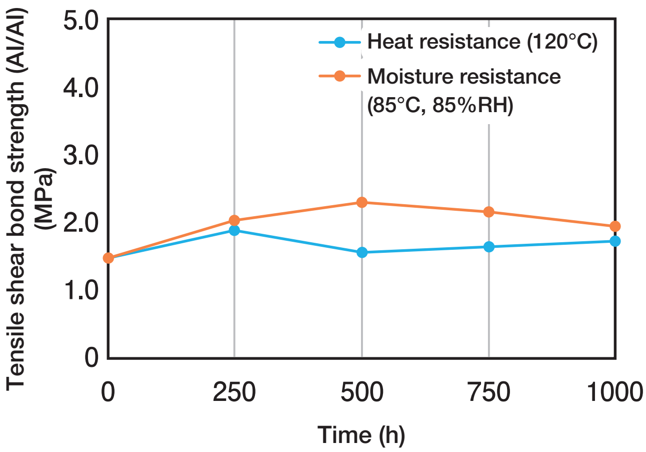


Fig. 9 Photo of Cured TB1165



*Curing conditions: (23±2)°C, (50±5)%RH, 168h

Fig. 10 Heat and Moisture Resistance Evaluation Results

5-4 TB1167 (Flame Retardant Grade)

TB1167 offers flame retardance (equivalent to UL94 V-0) and high elasticity. It has flame self-extinguishing properties equivalent to UL94 V-0 standard (Figure 11). Flame retardant FIPGs typically contain a large quantity of nonflammable raw materials, meaning that they tend to have low elasticity. However, as shown in Figure 12, TB1167 has high elasticity. Furthermore, as shown in Figure 13, in heat resistance (120°C) and moisture resistance (85°C, 85%RH) tests, performance was maintained for a long time without the bonding force decreasing.

Flame self-extinguishes within
10 seconds of lighting

Fig. 11 TB1167 Flame Retardance Test Results

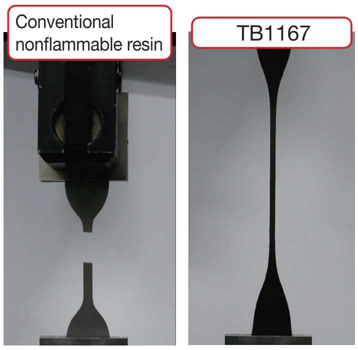
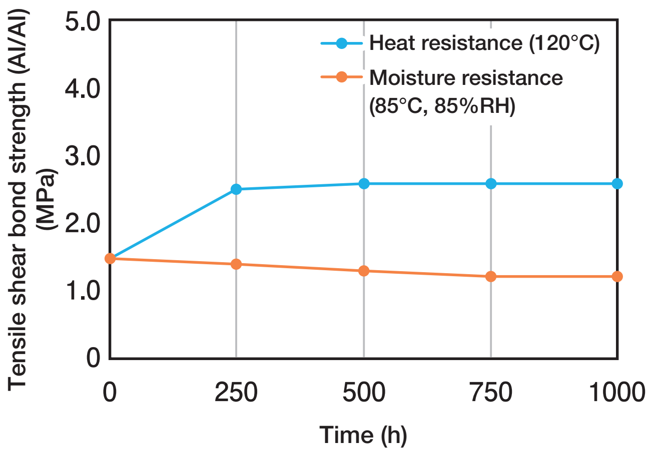


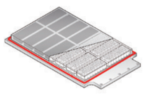
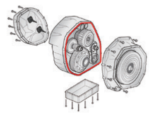
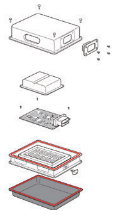
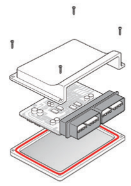
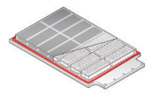
Fig. 12 Elongation Comparison



*Curing conditions: (23±2)°C, (50±5)%RH, 168h

Fig. 13 Heat and Moisture Resistance Evaluation Results

Table 3 Specifications of Products Described in this Article

Item	Unit	TB1160	TB1161	TB1163	TB1165	TB1167	Remark(s)
Use areas	–	 Battery	 Transmission	 Inverter/ converter	 ECU board	 Battery	
Appearance	–	Black	Black	Black	Gray	Black	
Viscosity	Pa·s	125	150	105	250	175	
Specific gravity	–	1.46	1.30	1.42	2.80	1.40	(23±2)˚C
Tack-free time	min	45	65	45	2	45	
Thick film curability	mm	2.3	1.5	1.7	1.8	2.2	(23±2)˚C, 24h
Hardness	–	A46	A22	A27	A83	A45	
Tensile strength	MPa	2.0	1.3	1.4	2.2	2.3	
Elongation	%	460	300	350	43	295	
Tensile shear bond strength	MPa	2.4	1.2	1.1	1.5	1.4	Al/Al
Low-molecular mass siloxane	ppm	N.D.	N.D.	N.D.	N.D.	N.D.	D4 – D10
Volume resistivity	Ω·cm	3.2×10^{9}	2.2×10^{10}	8.9×10^{8}	1.0×10^{10}	1.2×10^{9}	
Surface resistivity	Ω	8.5×10^{9}	1.8×10^{10}	1.9×10^{8}	1.3×10^{10}	5.9×10^{9}	
Permittivity	–	8.5	10.0	9.5	10.0	9.9	1 kHz
	–	7.6	8.5	7.3	8.7	7.9	1 MHz
Dielectric loss tangent	–	0.180	0.049	0.562	0.160	0.506	1 kHz
	–	0.033	0.075	0.040	0.027	0.045	1 MHz
Dielectric breakdown strength	kv/mm	17	17	9	14	10	
Heat conductivity	W/m·K	0.5	0.4	0.5	3.0	0.5	
UL94 flammability standard	–	HB equivalent	HB equivalent	HB equivalent	HB equivalent	V-0 equivalent	
REACH compliant	–	○	○	○	○	○	

Curing conditions: (23±2)˚C, (50±5)%RH, 168h

Closing

This article described the following FIPGs that meet the diverse needs of the electric vehicle market: TB1160, TB1161 (high heat resistance grade), TB1163 (high resin adhesion grade), TB1165 (high heat dissipation grade), and TB1167 (flame retardant grade).

ThreeBond will continue to deliver sealants that meet diverse needs in line with the development of electrification technologies. As a partner supporting the expansion of next-generation mobility, it will contribute to the sustainable development of society through technological innovation.

<References>

1) M. Inoue, A. Koyama. *ThreeBond Technical News No.89* (2017)

2) M. Inoue, Y. Watanabe. *ThreeBond Technical News No.85* (2015)

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