ThreeBond TECHNICAL NEWS

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Screen Printable Anisotropic Conductive Paste (ACP)

Introduction

ThreeBond's Anisotropic Conductive Paste (ACP) is a liquid material consisting of electroconductive particles uniformly dispersed within a highly-insulating adhesive component. A functional material, ACP produces an anisotropic conductive film through application and drying in the screen-printing process. It is capable of achieving all three of the following actions at a physical junction through a heat press process for several ten seconds: (1) forming an electric connection between electronic components; (2) retaining insulation between adjacent electrodes; and (3) bonding and fixing.

ThreeBond has pursued research and development related to ACP for the past 30 years, introducing products that have drawn wide acclaim in markets for heat seal connectors, display devices, cell phone backlights, membrane switches, and touch panels, among others. During this time, the development of increasingly advanced high-function electronic components has significantly altered expectations for ACP. In addition to high reliability and functionality, the market now demands increased usability, increased storability over extended periods, and compatibility with environmental standards that require, for example, halogen-free[*1] and toluene-free products.

This issue discusses the traits that distinguish our ACP from other connector materials and argues for ACP's superiority. It also introduces products (the ThreeBond3373 series) developed to comply with market demands and environmental requirements.

*1: Chlorine < 900 ppm, bromine < 900 ppm, chlorine + bromine < 1,500 ppm

Hereafter, ThreeBond will be abbreviated to "TB."

Contents

1. The ACP concept and market trends

As described before, anisotropic conductive paste is a liquid material with electroconductive particles uniformly dispersed in a highly-insulating adhesive component. This material makes it possible to achieve connections along the Z-axis, insulation between adjacent electrodes, and substrate-to-substrate adhesion, all through a simple heat press process involving temperatures elevated above 120°C for 10 seconds.

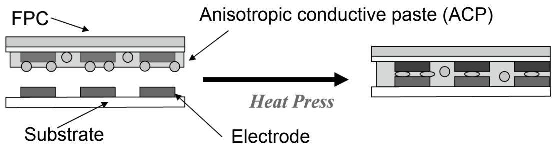


Fig. 1. Connection concept underlying anisotropic conductive paste

Due to their high usability, ThreeBond's ACP products have been adopted for use across a wide range of electronic components. One representative application involves connecting touch panel substrates. At the start of the 1990s, our ACP was adopted for use in pen-based electronic notepads. Thereafter, it was adopted for use in various mobile devices, including portable game units, cell phones, portable audio devices, and digital cameras. The growing preference for touch panel systems as interfaces for machines such as ticket-vending machines has made ACP essential in the electronic devices that provide the various functions supporting our daily lives.

We are currently seeing dramatic growth in demand for ACP in the East Asia region, including South Korea, China, and Taiwan, countries at the forefront of the global production of electronic devices. In response to growing demand for eco-friendly materials in recent years, ThreeBond has developed and introduced products with reduced chlorine and bromine content that meet halogen-free standards.

■ Representative applications

- Connecting touch panel substrates in mobile devices
- Connecting distributed-type inorganic EL backlight elements
- Connecting membrane substrates in personal computers

In general, anisotropic conductive connector materials fall into one of two basic categories: paste or film (Anisotropic Conductive Film: ACF). The following table compares the characteristics of ACP and ACF.

Table 1. ACP/ACF comparison

ACP	Item	ACF
Screen printing machine	Facility	Preliminary pressure bonding unit
Drier		Separator winding unit
Heat press machine		Heat press machine
Three-step process (1) Screen printing (2) Drying (deposition) (3) Final pressure bonding	Number of steps required to establish connection	Five-step process (1) Cutting (2) Pasting (3) Preliminary pressure bonding (4) Separator peeling (5) Final pressure bonding
The wide temperature range of the pressure bonding improves manageability.	Management of heat press process	Requires management of both temperature and time (complete heat curing)
Thermoplastic elastomer	Major component	Epoxy resin (heat curing)
Approx. 1/10 of ACF	Material cost	-
Refrigeration	Storage condition	Refrigeration or freezing
3 to 6 months	Storability of film	Three days at room temperature after application
120 to160°C	Pressure bonding temperature	150°C or above
Excellent	PET adhesiveness	Adequate
Good (compliant product available)	Halogen-free	None (derived from epoxy resin)
Compatible with narrow pitch	Technical issues	Extended shelf life of material and product
0.2-mm pitch (current)		Improved PET adhesiveness
High reliability		

As Table 1 suggests, ACP offers the benefits of low production costs, fewer steps in the manufacturing process, reduced production times, and low-halogen content meeting environmental standards.

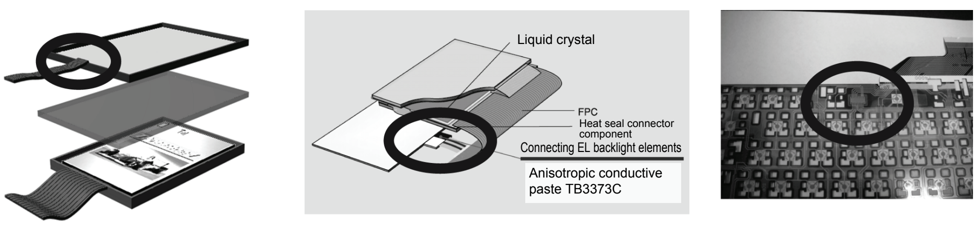


Fig. 2. Representative examples of ACP application

2. TB3373 series product lineup

TB3373C is widely used in the electronic device market, mainly in touch panel systems to connect and bond FPC/touch panel substrates.

In addition to the features (1) to (5) listed to the right, TB3373C owes its wide acceptance to the recognition of its various characteristics, including low temperature and short processing times, film storability, low production costs (due to lower component costs and fewer process steps), and high reliability.

Demand for halogen-free products has increased sharply in recent years. ThreeBond has responded swiftly to this demand, introducing the TB3373E in 2009. TB3373E is free of both halogen and toluene. Additionally, we now offer a new product, the TB3373F, which offers the higher reliability and improved printability and storability of dried film.

2-1. Features of the TB3373 series

(1) Deposition is carried out by screen printing so that the formed adhesive film closely follows the contours of the adherend surface.
(2) Any number of contact points can be connected in a single process.
(3) Allows bonding to surfaces such as transparent conductive glass, which cannot be joined with solder.
(4) For permanent bonding, unlike conductive rubber or metal-wire reinforced rubber, the TB3373 series requires no pressure after initial adhesion.
(5) Compared to conventional products, the TB3373 series offers improved adhesion to film materials and can be used with a wider range of adherends.
(6) TB3373E and TB3373F comply with halogen-free and toluene-free standards.

2-2. Properties of TB3373 series

Table 2. Properties of TB3373 series

Items	Unit	TB3373C	TB3373E	TB3373F	Notes
Major component	-	Synthetic-rubber-based resin	Synthetic-rubber-based resin	Synthetic-rubber-based resin	
Solvent	-	Toluene, isophorone	Isophorone	Aromatic solvents	
Conductive particle	-	Gold-plated particles			
External appearance	-	Pale yellowish-green	Grayish white	Grayish white	3TS-201-02
Viscosity	Pa•s	75	95	60	3TS-210-10*1
Specific gravity	-	1.01	1.04	1.08	3TS-213-02

*1: Shear rate: 10.0 (1/s)

2-3. Characteristics of TB3373 series

Table 3. Characteristics of TB3373 series

Items	Unit	TB3373C	TB3373E	TB3373F	Notes
Connection resistance	Ω	Less than 1			Four-terminal resistance measurement
Insulation resistance	Ω	10^9 or greater			3TS-403-01
90° peel strength	N/m	800 or greater*2			3TS-304-42

*2: ITO glass/PET film

2-4. Special notes

Table 4. Special notes on the TB3373 series

Items	Unit	TB3373C	TB3373E	TB3373F	Notes
Solution storability	-	Refrigerated for 6 months	Refrigerated for 6 months	Refrigerated for 6 months	
Storability after deposition	-	Left to stand at room temperature for 6 months	Refrigerated for 3 months	Left to stand at room temperature for 6 months	
Compliance with halogen-free standards	-	×	○		
Compliance with toluene-free standards	-	×	○		

2-5. Reliability data

ACP is often perceived to exhibit poor heat cycle performance. However, as the following graphs show, any changes from initial values in various accelerated tests are negligible. Tests confirm that the TB3373 series provides the reliability needed.

2-5-1. Electrical connection reliability

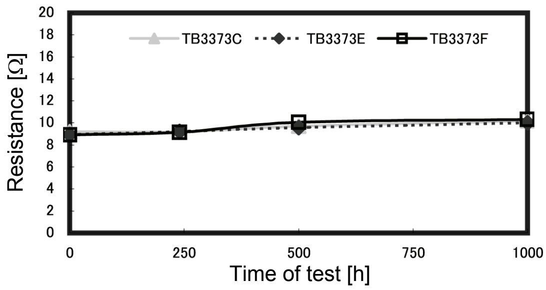


Fig. 3. Change in resistance when left at 85°C

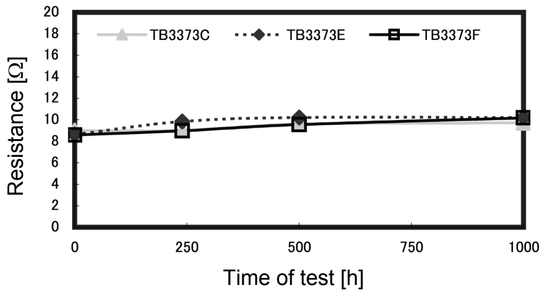


Fig. 4. Change in resistance when left at 60°C × 95%RH

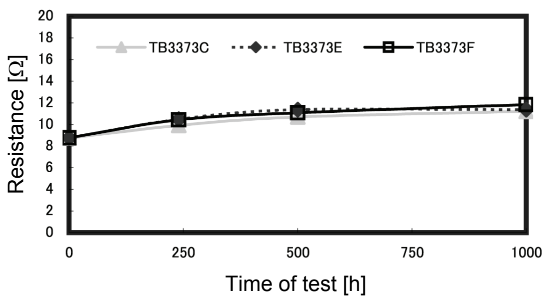


Fig. 5. Change in resistance in heat cycles consisting of 30 minutes at each of two temperature extremes, -40°C and 85°C

2-5-2. 90° peel strength

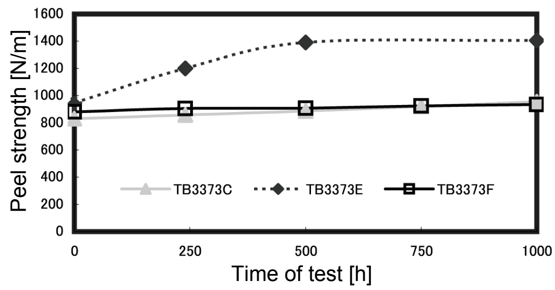


Fig. 6. Change in 90° peel strength when left at 85°C

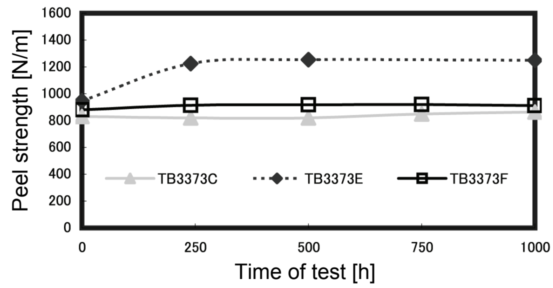


Fig. 7. Change in 90° peel strength when left at 60°C × 95%RH

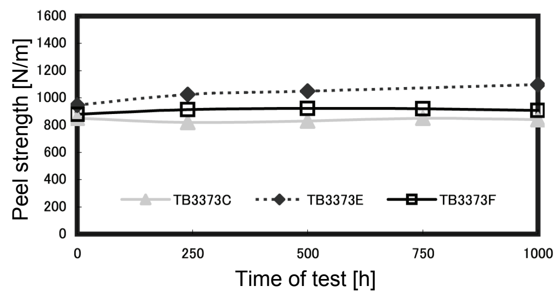


Fig. 8. Change in 90° peel strength in heat cycles consisting of 30 minutes at each of two temperature extremes, -40°C and 85°C

Table 5. Conditions for electrical connection reliability test

Test specimen composition	FPC	25-μm-thick polyimide film/35-μm-thick gold-plated copper foil, 0.4-mm pitch (L/S = 0.2 mm/0.2 mm)
	Glass	ITO sputtering vapor deposition on soda lime glass, 60 mm × 25 mm × 0.7 mm, sheet resistance 20 to 50 Ω/cm^2
Environmental conditions		(1) 85°C (2) 60°C × 95%RH (3) Heat cycle (heat cycles consisting of 30 minutes at each of two temperature extremes, -40°C and 85°C)

Model 34980A multifunction switch/measure unit (Agilent Technologies International Japan, Ltd.)

Table 6. Conditions for 90° peel strength test

Test specimen composition	38-μm-thick PET film/ITO-coated soda lime glass
Environmental conditions	(1) 85°C (2) 60°C × 95%RH (3) Heat cycle (heat cycles consisting of 30 minutes at each of two temperature extremes, -40°C and 85°C)
Tension speed	50 mm/min

Model RTC-1210A universal tensile and compression testing machine (Orientec Co., Ltd.)

2-5-3. Creep test

Our company uses the creep test to test products under conditions that closely approximate those of actual use. In a creep test, the peel distance is measured after subjecting the sample to a constant load along the axis of the peeling at 85°C (Fig. 9).

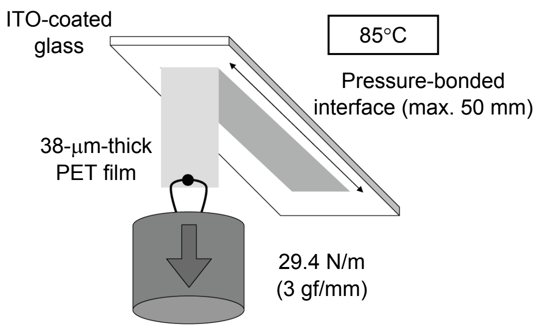


Fig. 9. Schematic diagram showing a creep test in a heated environment

Table 7. Peel distance in creep test at 85°C

[mm]	2 h later	12 h later	24 h later
TB3373F	0	0	2
Product by Company A	50 (dropped)	50 (dropped)	50 (dropped)
Product by Company B	0	2	8

As shown in Table 7, the product from Company A peeled completely at 85°C × 24 hours, with loss of weight. Virtually no signs of peeling were observed with the TB3373F. A product from Company B was subjected to heat cycle treatment for 100 hours after pressure bonding; observations of the bonded interface showed changes similar to those presented in Fig. 10. This is believed to be attributable to resin relaxation induced by heat and humidity and to the formation of the air bubbles associated with such relaxation (Fig. 11).

The TB3373F showed no signs of air bubble formation when left under the same conditions for 1,000 hours.

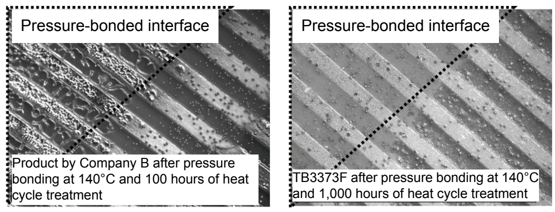


Fig. 10. Comparison of pressure-bonded interface after heat cycle test for TB3373F and product from Company B

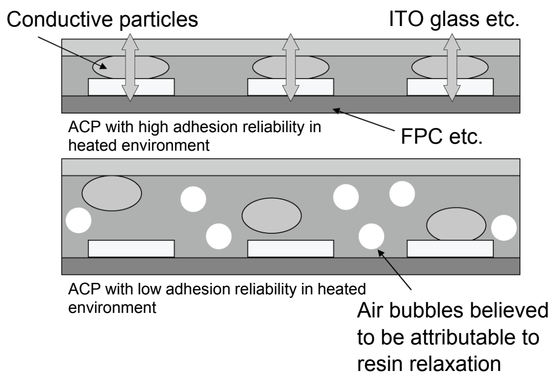


Fig. 11. How reliability degrades

As Fig. 11 shows, the air bubbles believed to be generated by resin relaxation will repeatedly expand/contract in response to heat, pushing apart the connection interface and significantly degrading reliability.

2-5-4. Storability of dried film for TB3373F

As Table 1 shows, one advantage of ACP over ACF is the extended shelf life of anisotropic conductive film at room temperature after formation. Figure 12 shows the change over time in the peel strength of the dried film formed by screen printing and drying of TB3373F when stored at room temperature (25°C). Since TB3373F contains no reactive components, no observable change in peel strength occurs, even after storage at room temperature for six months.

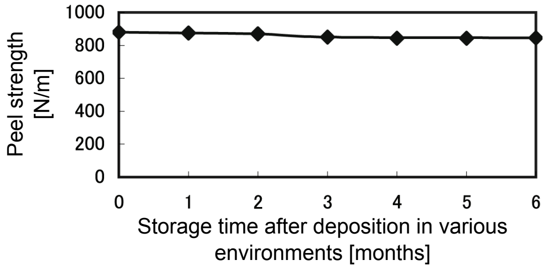


Fig. 12. Storability of dried film for TB3373F at room temperature

3. Points to note when designing the manufacturing process

Given below are two points to note for process management when using ACP.

(1) Optimal thickness and drying conditions of anisotropic conductive film

As shown in Fig. 13, anisotropic conductive films have an optimal range of thicknesses. If the film is too thin, the amount of resin filling the space between the electrodes will be insufficient to achieve the adhesive strength needed, adversely affecting connection reliability. If the film is too thick, adhesive strength will be adequate, but the resin relaxation induced by heat will reduce the contact area of the conductive particles, increasing resistance.

Any residual solvent present due to insufficient drying will generate air bubbles during pressure bonding (Fig. 14), degrading connection reliability.

These factors must be taken into account to set the optimal conditions for a given application.

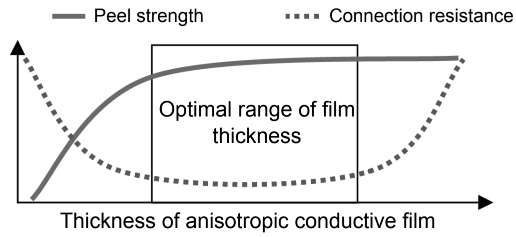


Fig. 13. Conceptual relationship between optimal thickness of ACP and reliability

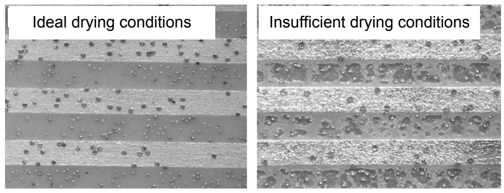


Fig. 14. Effect of drying conditions on pressure-bonded interface

(2) Pressure, temperature, and time of pressure bonding

As shown in Fig. 15, ACP does not require management procedures as rigorous as ACF. Check the following if you note significant deviations from predicted values even after confirming adequate film thickness and drying conditions:

- Low adhesive strength
  The set pressure of the pressure bonding process may be too low.
  The set temperature of the pressure bonding process may be too low.
  The set time of the pressure bonding process may be too short.
  The surface of the adherend may not be clean.
- High resistance
  The pressure of the pressure bonding process may have been too low for adequate breakdown of conductive particles.
  The temperature of the pressure bonding process may be too low.
  The time of the pressure bonding process may be too short.
- Presence of voids
  The pressure of the pressure bonding process may be too high.
  The temperature of the pressure bonding process may be too high.

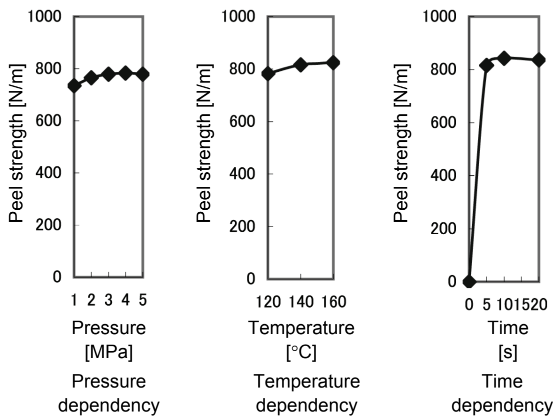


Fig. 15. Dependency of peel strength of TB3373F on pressure bonding conditions

4. How to use TB3373F

Below is an example of an application of TB3373F. Since the conditions for printing, drying, and pressure bonding will depend on the instruments used, we recommend performing thorough validations with the instruments used in the actual manufacturing processes. Also, note that the values for the physical properties and characteristic values given in this issue are examples of measurement results from studies performed to company standards. They are not guaranteed values.

4-1. Printing conditions

Table 8. Standard ThreeBond printing conditions

Mesh	Material	Stainless steel	Tetron
	Mesh aperture size	80 to 100	80 to 100
	Wire diameter	80 to 100	50 to 75
	Mesh thickness/emulsion thickness	225 μm/15 μm	86 μm/50 μm
Squeegee	Printing plate dimensions	Inner dimension: 280 mm × 280 mm	
		Frame dimension: 320 mm × 320 mm	
	Material	Urethane rubber	
	Shape	Flat	
	Hardness	A80	
Settings	Indentation	1.0 mm	
	Clearance	0.38 mm	
	Printing speed	20 to 60 mm/s	
	Squeegee angle	60°	

Model SC-150-3 semi-automatic screen printing machine (Neotechno Japan Corporation)

Fig. 16. ThreeBond's standard printing machine

4-2. Standard drying conditions

Table 9. ThreeBond's standard drying conditions

TB3373C	TB3373E	TB3373F
100°C × 10 to 20 min 120°C × 5 to 10 min	60°C × 20 to 30 min 80°C × 15 to 20 min	100°C × 15 to 20 min 120°C × 10 to 15 min

Hot-air oven: Model ETAC-HISPEC High Temperature Chamber HT220S environmental test chamber (Kusumoto Chemicals, Ltd.)

4-3. Pressure bonding conditions

Table 10. ThreeBond's standard pressure bonding conditions

Temperature	120 to 160°C
Pressure	3.0 MPa
Time	10 sec. retention
Press chip	Flat chip L: 65 mm, W: 3 mm

Model H800-V1S automatic heat press machine with precision pressure adjustment function (Emtec Co., Ltd.)

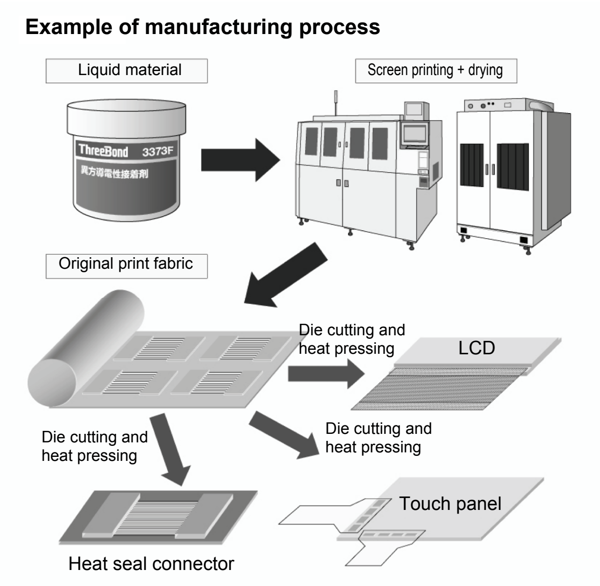
Fig. 17. ThreeBond's standard pressure bonding machine

Conclusion

ThreeBond developed its ACP to help customers who own printing technologies and machines in their pursuit of new products with added value. Our ACP provides the capabilities needed to form anisotropic conductive films on various component surfaces. Requiring only a screen printing machine and a drier unit, it will undoubtedly contribute to improved productivity and lower production costs.

The TB3373F introduced in the present issue was developed based on the concepts of high reliability, usability and manageability, and environmental compliance. Special areas of emphasis during product development included relaxed drying conditions and storability after film formation to increase user friendliness. Other goals included halogen-free characteristics for regulatory compliance and the absence of toluene to meet demands in this age of enhanced environmental awareness.

We plan to continue developing high-value-added products that meet market demands, based on our key strategy: ever-higher reliability to meet the demands of products with ever finer pitches.



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