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Anisotropical Conductive Adhesives

Introduction

Anisotropical conductive adhesive is a high insulation adhesive with uniformly dispersed conductive particles that is used to establish electrical connections between relative electrodes of electronic components, isolate neighboring electrodes, and fix chips.

This functional material was first introduced onto the LCD market approximately 15 years ago. Since then it has been improved to meet the needs for higher performance, keeping pace with the development of LCDs. This material is now expected to find new applications in other devices.

This issue provides related information and introduces recent products and technologies developed by Three Bond.

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1. What is anisotropical conductive adhesive?

Anisotropical conductive adhesive is used to establish an electrical connection between relative electrodes and fix them. It is also useful for materials that cannot be fixed by soldering and those that cannot be exposed to high temperatures during soldering.

Anisotropical conductive adhesive is made of glue (binder) and will hold electrodes and conductive particles that are uniformly dispersed in the binder. The binder is required to have adhesivity to serve as glue, and to be sufficiently electrically insulative to isolate neighboring electrodes with high reliability. If the binder meets those basic requirements, it can be any resin, such as synthetic rubber, thermoplastic, or thermocure resin.

The conductive particles lie between electrodes as shown in Fig. 1. Thus, they are required to have stable conductivity between relative electrodes, and a shape and dispersed population that will not cause them to contact with neighboring electrodes. They can be metals (nickel or composites that are gold-coated nickel), metal-coated plastic or resin, or those that have conductive cores covered by insulative skin that is broken due to pressure[1] or high temperatures.[2] The materials that have shape of approximately round, and diameter from several μm to a few tens μm are selected in accordance with the requirements, particularly those concerning the electrode gap.

As the anisotropical conductive adhesive, a film type, a paste type that can be printed on electrodes, and a liquid type that can be applied to electrodes are available to meet different types of mounting-process needs.

The bonding process uses heat and pressure to spread the binder, and thereby enables the conductive particles to contact the electrodes. With some adhesives, ultraviolet light is used instead of heat to cure the binder.

The resulting electrical connection has five resistances: resistance of electrode-A, contact resistance between electrode A and the conductive particle, intrinsic resistance of the particle, contact resistance between electrode B and the particle, and resistance of electrode-B. Accordingly, resistance between electrodes must be uniform among any pairs of electrodes.

Thus, the materials with anisotropical conductive adhesives are fully adjusted in order to function according to the applications.

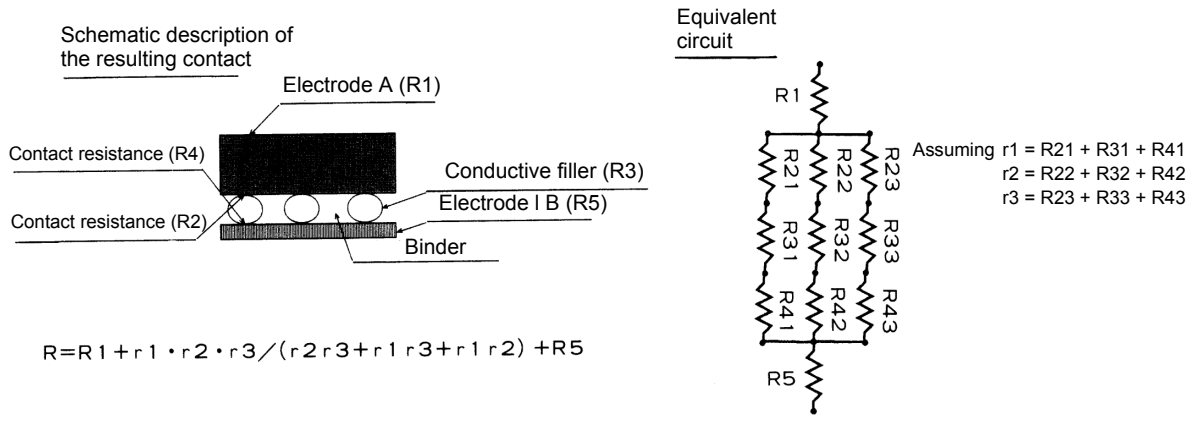


Figure 1. Schematic description of the electrical connection established with the anisotropical conductive adhesive

Table 1. Anisotropical conductive adhesive application areas

Area	Application	Types of anisotropical conductive adhesives
Compact LCD devices	LCD/Printed circuit Printed circuit/PCB	Print type
Large LCD, Plasma displays	LCD/TCP, FPC TCP, FPC/PCB LCD/IC (COG)	Thermocure film type
Bear-chip mounting	Bear chip IC/PCB	Thermocure paste type

2. Applications and types of anisotropical conductive adhesives

As shown in Table 1, the current anisotropical conductive adhesive market can be roughly divided into three categories.

The first category includes compact LCD devices, which are often used in low-cost mass-produced products such as electronic calculators and PDAs that have small displays for showing relatively simple numerals and characters. Such products normally use low-cost polyester in their printed circuit boards. Print-type anisotropical conductive adhesives are particularly useful for such products, as they can be used as they are in the printing process (Fig. 2-1).

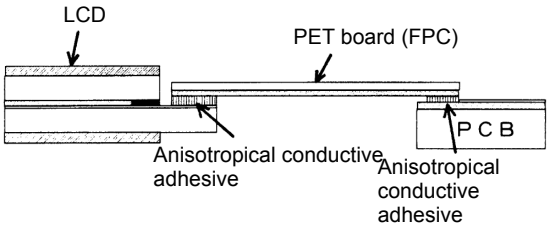
In similar applications, they are used to make electrical connections in EL devices and plastic LCD devices for making LCD components light and durable.

The second category consists of large LCD devices, typically notebook PCs, word processors, LCD TV sets, and car navigation systems, all of which display colorful images and a diverse range of information. To ensure reliable, efficient electrical connection between those LCD device electrodes, film-type anisotropical conductive adhesives are employed.

A few types of electrode bonding are available for such use. The bonding most commonly used is the junction (Fig. 2-2, upper) between LCD display panel and chips that are called as Tape Carrier Package (TCP). Recently, the Chip On Glass (COG) technology used to fix ICs directly on the frame of the LCD display for higher portability and wider display areas has been employed in 5" to 6" navigation systems and TV sets. This technology is used for bonding (referred to as "Outer Lead Bonding") between LCD chips and control chips. In the meantime, anisotropical conductive film used instead of solder is also seen for bonding between control devices and keyboard circuits (Fig. 2-2, lower).

Also, the usage on the junctions that need high connection current such as for PDP (Plasma Display Panel) is accelerated. PDP is remarked as successor display device of CRT and LCD. As for the third category, anisotropic paste is studied as one of flip chip mounting techniques at the inside of chips called as BGA, PGA, and MCM (Fig. 3).

(1) [Bonding with print-type anisotropical conductive adhesive]



(2) [Bonding with film-type anisotropical conductive adhesive]

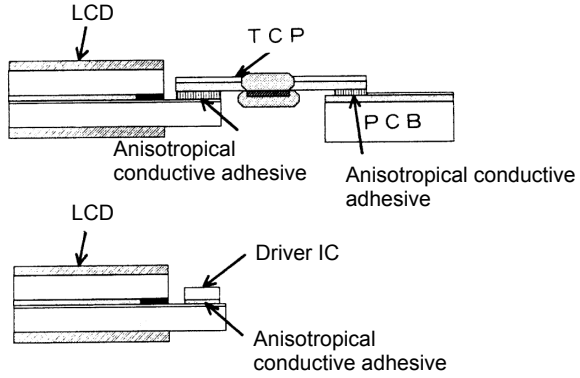


Figure 2. Application of anisotropical conductive adhesive (1)

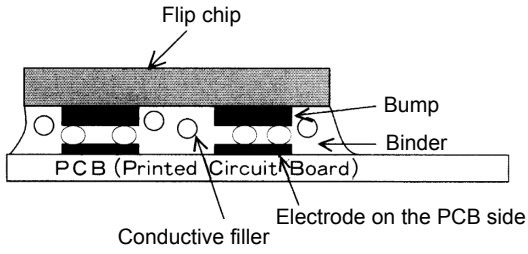


Figure 3. Application of anisotropical conductive adhesive (2)

The next section introduces the anisotropical conductive adhesive newly developed by Three Bond for the applications described above.

3. Print-type anisotropical conductive adhesive--ThreeBond 3373

This type of adhesives is used in the bonding of compact LCD electrodes, as previously described.

This section introduces the usage for ThreeBond 3373, along with its basic properties.

3-1. Details of bonding applications

Reducing cost of basic materials and shortening production time are among the key requirements for the LCD-related components of electronic calculators and similar devices. They are common requirements for the components used for electronic connection in LCDs. These points are similar with the materials of the electrode connections for LCD. Thus, low cost materials are used for the conductive material of the printed circuit board used to drive LCDs.

Specifically, it is not a copper etched circuit board, but a flexible printed circuit board that is made by printing circuits with silver or carbon paste on polyester film or similar materials. On one hand, such material is low cost, but on the other hand, heat resistance is poor. Therefore, the anisotropical conductive materials that are able to bond at low temperatures in a short time must be used for this connection. Table 2 shows the major characteristics of the polyester film[3], base board material used for this application, and the polyimide film[4] used on the connections for large LCD display pannels.

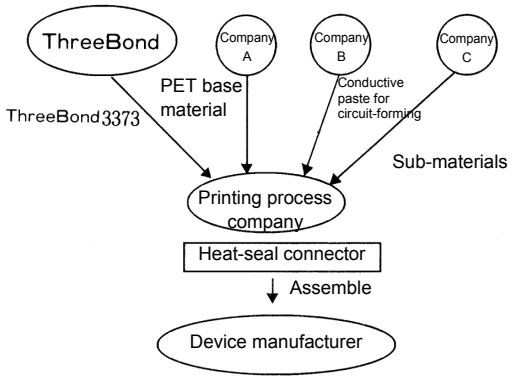


Figure 4. ThreeBond 3373 supply system

Table 2. Typical characteristics of polyester films and polyimide films

Item	Unit	Polyethylene terephthalate	Polyimide
Mechanical properties			
Tensile strength (MD)	MPa	20.6	39.2
Elongation (MD)	%	160	30
Electric properties			
Specific volume resistance	Ω • cm	10^{17}	10^{17}
Surface resistance	Ω	10^{16}	$>10^{17}$
Thermal properties			
Melting point	°C	263	500 or higher (glass transition point)
Linear expansion coefficient	/°C	1.5×10^{-5}	2.0×20^{-5}
Flame resistance	-	None	UL94VTM-0
Price ratio	-	1:20 or higher	

* Film thickness: 25 μm

Table 3. Characteristics of ThreeBond 3373 and recommended film-forming conditions

Product name		ThreeBond 3373	Remark
Properties	Type	One-liquid solvent, volatile type	
	Appearance	Pale yellow-green paste	Visual
	Main composition	Synthetic rubber type adhesive	
	Conductive filler	Special compound powder	
	Viscosity	100Pa•s (100, 000cp)	BH-type viscometer No. 7 × 10 rpm
	Specific weight	0.98	JIS6835 specific-weight cup
Basic properties	Contact resistance	12 Ω	ITO/printed circuit
	Inter-line insulation resistance	10^9 Ω	0.4-mm pitch
	Possible minimum conductor width	0.2mm	
	Bonding force	490 N/m (500 gf/cm)	ITO/PET
Recommended film-forming conditions	Printing conditions		
	Mesh type	Stainless steel screen, 80 mesh	
	Emulsion thickness	10-20 μm	
	Squeegee type	Urethane rubber	
	Squeegee angle	30-60°	
	Drying conditions	100°C × 10-20 min 120°C × 5-10 min	Use a fan driven heat-dryer furnace

3-2. Heat-seal connector

As illustrated in Fig. 4, ThreeBond 3373 is a paste-type anisotropical conductive adhesive and it is formed into a film by the printing company.

The printing company buys a base film (such as polyester film) from Company A as the base of the printed circuit board, prints conductive resin for forming printed circuit (silver or carbon paste) purchased from Company B on the base, and prints ThreeBond 3373 thereon to make a complex material. This complex material is referred to as a "heat-seal connector." Then, process to connect heat-seal connector to LCD panel follows.

Because ThreeBond 3373 is used in such a complex material, its properties must match the technology for forming circuit. For this reason, Three Bond needs close technological collaboration with the printing company. Three Bond will continue to perform sufficient follow-up activities for such technological collaborations.

3-3. Processing key points

Following the screen-printing of ThreeBond 3373, the solvent is dried to leave a film. In this process, the thickness of completed films is very important points. Therefore, precise printing process control must be required. Final properties of completed products change depending on drying temperature, drying duration, and drying facility. If the solvent is left in the film, the heat resistance may be affected. Also, if the drying temperature and its duration are extremely high and long, its adhesivity will decrease. Table 3 shows the characteristics of ThreeBond 3373 and the recommended film-forming conditions.

Figure 5 is a photo of the surface of completed film. It shows some conductive particles jutting from the binder layer. The binder layer should be at least 15-25 μm in thickness, depending on the bonded parts, i.e. LCD panel or PCB for driving.

Table 4. Recommended bonding conditions for ThreeBond 3373

Pressure-bonding temperature (°C)	120-160
Applied pressure (MPa) (kgf/cm^2)	2.9 (30)
Pressure bonding duration (sec)	5-10

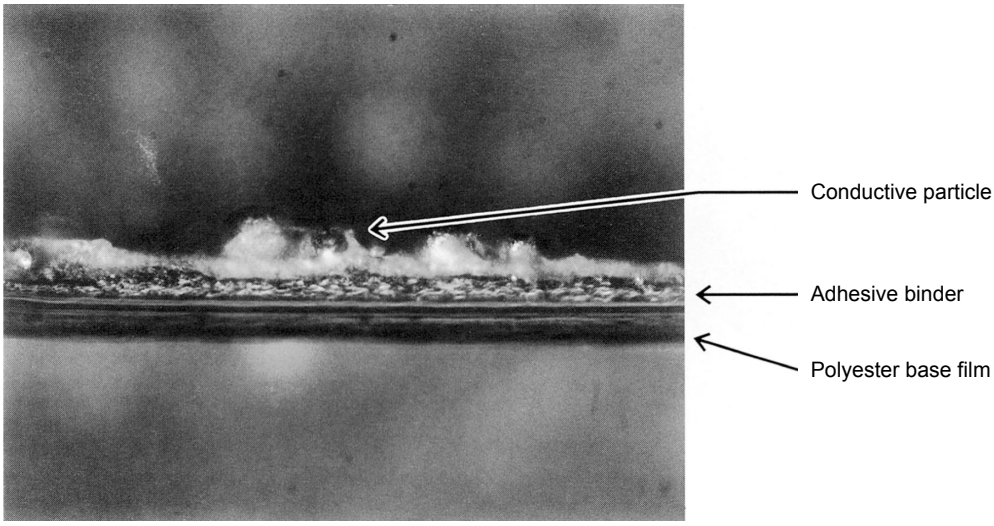


Figure 5. Cross-section of a ThreeBond 3373 print

3-4. Basic properties of ThreeBond 3373

As previously discussed, ThreeBond 3373 is used as a heat-seal connector material. Thus, it must be able to complete bonding as short as possible because of the restrictions such that it can be connected below the degradation temperature of the base PET film and that it is incorporated into low cost products. Reliability must be maintained within those conditions. ThreeBond 3373 has the formation that is shown in Fig. 5 previously, in order to achieve high reliability.

Synthetic rubber that has low fluidity during heat applied bonding is used for the binder resin. It takes the method that fixes to LCD with utilizing heat adhesiveness, but not heat melting. The conductive particles are sufficiently large to jut beyond the binder surface, so that they easily make connections with the target electrodes when collapsed with applying heat and pressure. High reliability is thereby attained over a broad bonding conditions. Table 4 shows the recommended bonding conditions.

Figure 6 demonstrates the adhesivity of ThreeBond 3373 as proven in a reliability test, and Fig. 7 shows the resulting contact resistance.

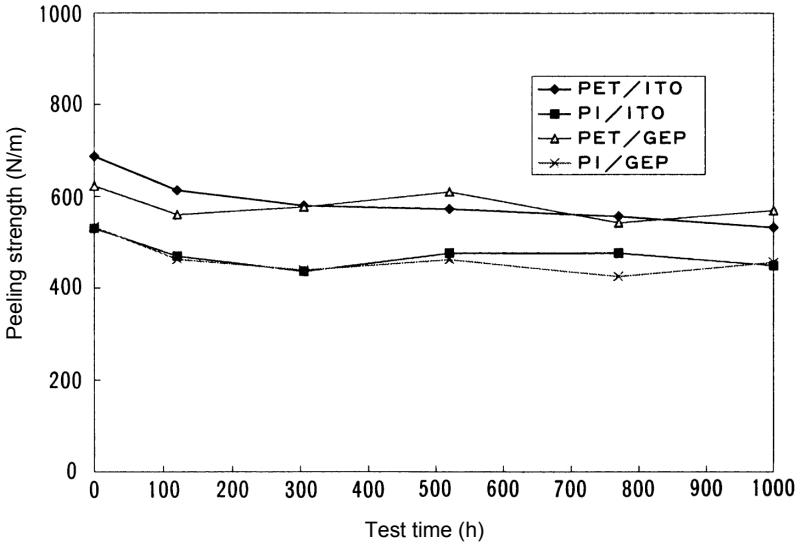


Figure 6. ThreeBond 3373 reliability test at 60°C × 95% RH (adhesivity change)

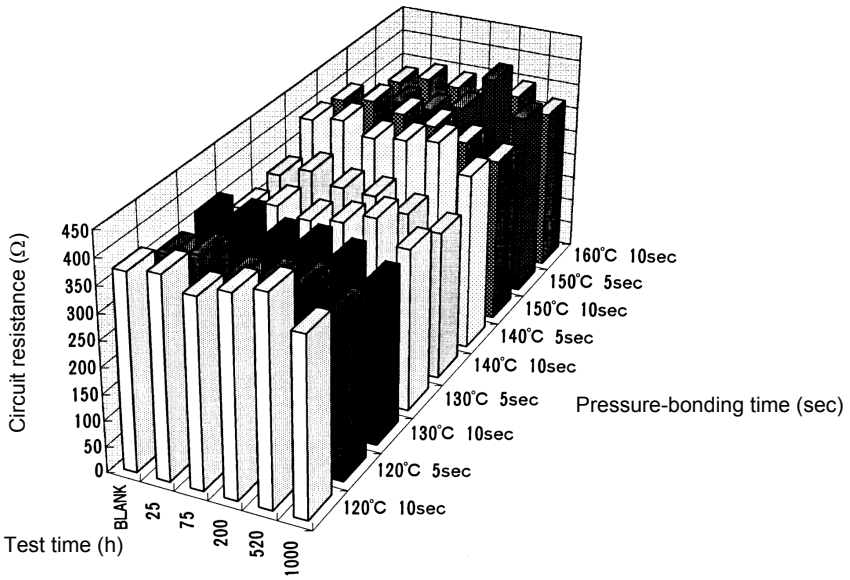


Figure 7. ThreeBond 3373 reliability test at 60°C × 95% RH (circuit resistance change)

4. Film type anisotropical conductive adhesive--ThreeBond 3370K

This section describes the fine pitch compatible, film type thermocure anisotropical conductive adhesive that has been developed for electrical connections between a large LCD panel and driver ICs on TCP. The related peripheral technology trends are also discussed.

4-1. Requirement functions in the market

(1) Change of bonding peripheral materials

The resolution is increased in large LCDs, and the LCD glass panel is made thinner, from the conventional 1.1 mm to 0.7 mm, which also makes it lighter in weight. As the transparent electrode materials, not only antimony doped ITO (indium tin oxide), but aluminum or chromium coated electrodes are getting popular.

Some TCPs with an outer electrode pitch as narrow as 70 μm have been introduced onto the market. Even pitches of 20-30 μm have been realized in prototypes. In accordance with this trend toward finer patterns, thickness of the copper foil that forms TCP electrode has had a wide variety such as 1, 3/4, and 1/2 ounces for 18μm^2. Adhesives used to bond TCP polyimide and copper foil has been improved to satisfy the characteristics. Figure 8 shows actual cross section of the bonding of LCD and TCP with film-type anisotropical conductive adhesive.

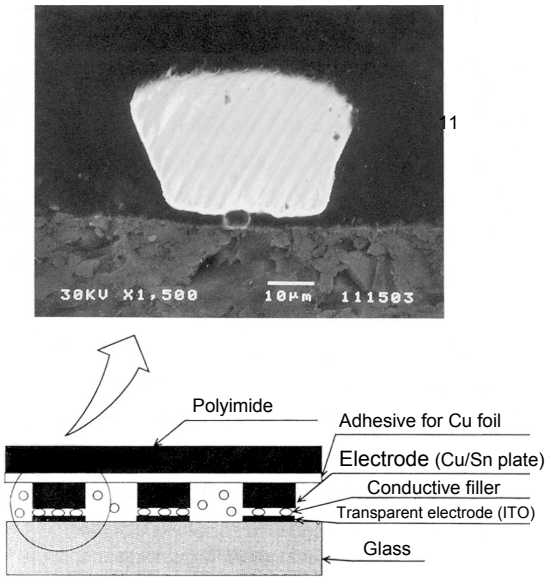


Figure 8. Cross- section of the LCD/TCP bonding and its microscopic view

Table 5 summarizes the basic characteristics of ThreeBond 3370K. The following is a further explanation of those characteristics.

Table 5. Basic characteristics of ThreeBond 3370K

1. Film characteristics

Item	Characteristics item	Characteristics	Remarks
Binder	Appearances Thickness (μm) Width (mm) Composition	Gray (semi-transparent) 17, 23 1.5, 2.0, 2.5 Thermocure resin	Visual Measurement using a micrometer 30m, 50m Epoxy resin
Conductive particle	Mean particle size Conductive plating Insulation coating Particle density	50 μm Ni/Au plating None Approx. 6400/mm^2	
Separator	Base material Peeling, separation	White PET Semi-transparent OPP	50 μm in thickness 20 μm in thickness

2. Bonding conditions

	Item	Condition
Temporary bonding	Temperature (°C) Pressure (MPa) Time (sec)	100 or less 1 or less 3 or less
Separation/peeling strength	Peeling strength (N/m)	2-6
Tack ability	Peeling strength (N/m)	3-5 (25 °C)
Permanent bonding	Temperature (°C) Pressure (MPa) Time (sec)	160-180 2-3 20-30

(2) Specifications of ThreeBond 3370K

1) Width, thickness, reel size

In accordance with the trend toward thinner LCD panel frames, tapes 1.5 mm, 2.0 mm, and 2.5 mm in width are available. In addition, tapes 17 μm and 23 μm in thickness are available to match the thickness of the TCP chip electrodes (copper foil). ThreeBond 3370K is normally 50 m in length, and is available in the form of a ϕ130 outer reel with a 1 inch inner hook.

2) Tack ability, transparency

Tack ability and transparency are the keys to the anisotropical conductive adhesive for use in such applications. The adhesive, which is manufactured as shown in Fig. 9, is required to have a transparency that allows the electrode gaps to be checked during the manufacturing process and a tack ability that allows easy temporary bonding. ThreeBond 3370K can be set with one second at 70-80°C.

3) Curing ability

ThreeBond 3370K is made of epoxy resin and is capable of completing curing with high reliability under normal pressure bonding conditions of 20 sec at 160-170°C. Figures 10-12 give an example of its performance. ThreeBond 3370K is a highly reliable material, maintaining stable elasticity up to high temperatures as shown in Fig. 13.

4) Repairability

Despite such high reliability, it must be peeled off for repair if mal positioned electrodes are found after bonding. ThreeBond 3370K can be gently peeled off if heated to approximately 180°C. It restores thermal adhesivity to the surface of the LCD panel by cleaning its surface with ketone-based solvents.

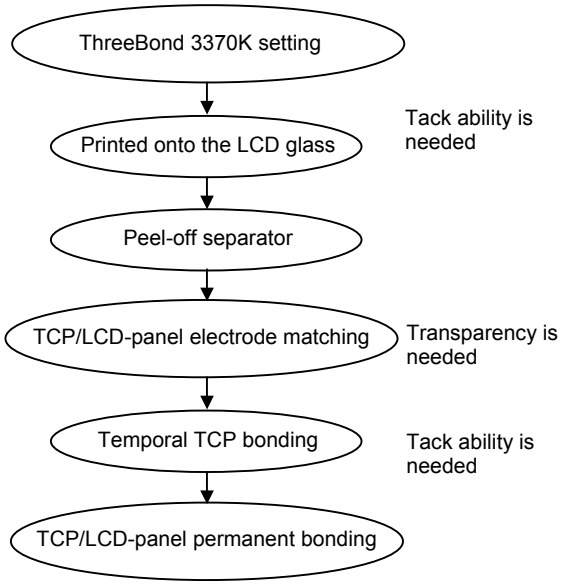


Figure 9. ThreeBond 3370K bonding process flow chart

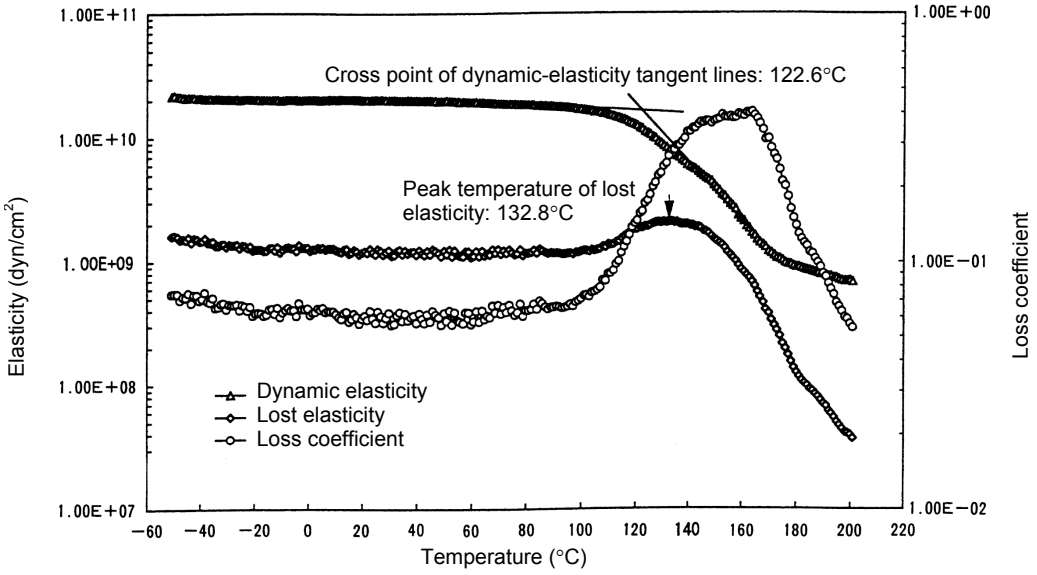


Figure 13. Temperature dependency of dynamic elasticity, lost elasticity, and loss coefficient

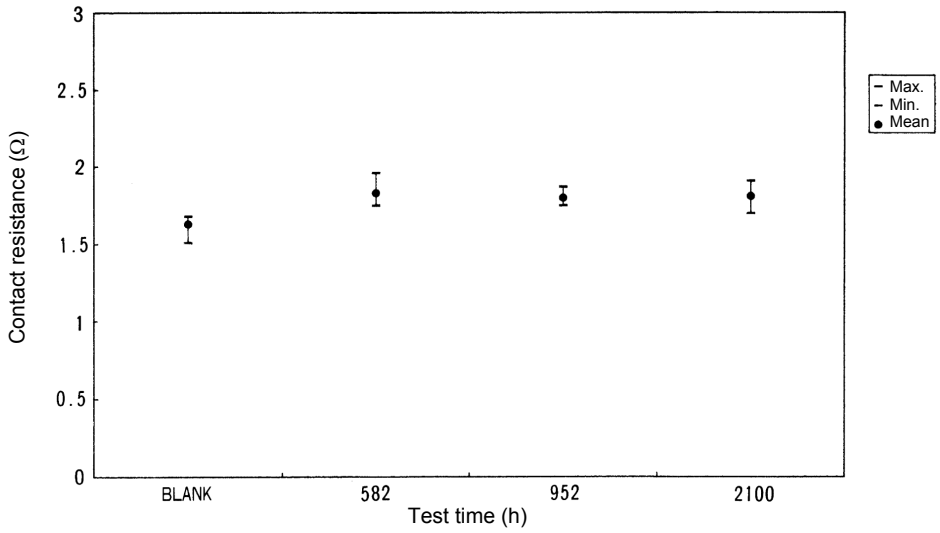


Figure 10.ThreeBond 3370K reliability test results at 85°C × 90% RH (resistance change: 170°C, 20-sec pressure bonding)

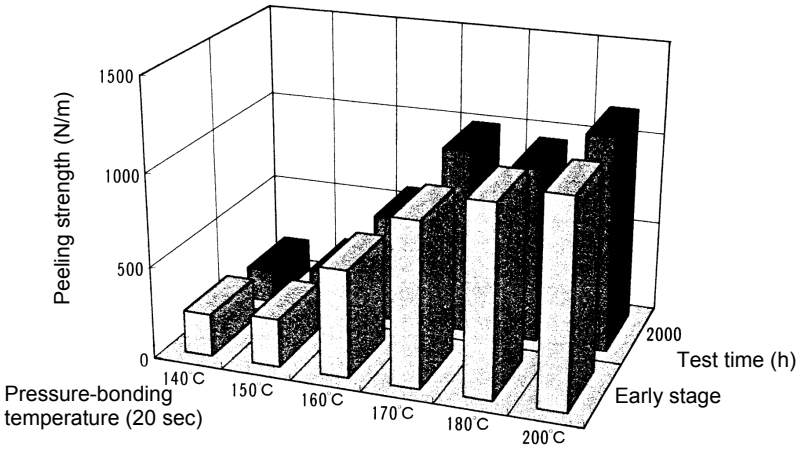


Figure 11. ThreeBond 3370K reliability test at 85°C × 90% RH (peeling-strength change)

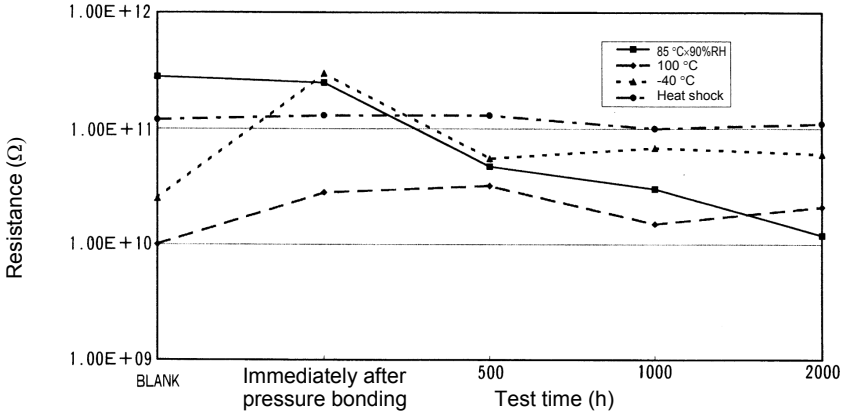


Figure 12. ThreeBond 3370K reliability test (interline resistance change)

5. Future development

ThreeBond 3370K was developed for connections between LCD panel and TCP chips. As described earlier, however, development for the applications of the connection between COG[5], PDP, TCP chips, and input-side PCB is going to further.

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