ThreeBond
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Materials for Sealing Liquid Crystal

Introduction

Computers have become indispensable as information carriers and as tools for analysis and control. Because sight is the human sense that brings us the most information, the computer display is the most important interface between computers and human beings.

A liquid crystal display (LCD) is the most advanced kind of display, using little power in minimum space and with a light weight. Three Bond offers materials that contribute to the high productivity and reliability of LCDs.

This issue describes ultraviolet-curing resin and anisotropically conductive adhesives for use in the cellification and mounting of LCDs.

Contents

1. Electronic display devices

1-1. Electronic displays

Electronic displays are the devices that convey information from various instruments to humans through the sense of sight. Among them, those that visualize optical information signals by emitting light are referred to as "light-emitting-type displays." The most common example of such devices is the CRT (cathode-ray tube). Meanwhile, those devices that visualize signals by controlling external light, specifically light modulation such as reflection, scattering, and interference, are referred to as "light-receiving displays." The most common example of such devices is the LCD (liquid crystal display).

Table 1 summarizes the characteristics of representative electronic display devices. While CRT ranks higher in the list in terms of image quality, price, and other performance factors, there are rapidly growing expectations for flat-panel displays (FPDs), which have the advantages of being compact, lightweight, low in voltage, and energy-saving. Displays other than CRTs are classified into this flat-panel display category. Among those FPDs, LCDs are growing remarkably in the market, meeting the needs for thinness and light weight with no problem in terms of image quality.

Table 1. Comparison of the characteristics of the major electronic display devices

Display	CRT	VFD	LCD	PDP	LED	ELP
Display mode	Light-emitting	Light-emitting	Light-receiving	Light-emitting	Light-emitting	Light-emitting
Colors	Full colors	Red, yellow, green, blue	Full colors	Full colors	Red, green, blue	Red, green, yellow-brown, blue
Power consumption	High 85 W	Relatively high 17 W	Very low 0.7 W	Relatively high 35 W	Low 5 W	High 13 W
Weight	Heavy 7 kg	Relatively heavy 3 kg	Light 0.7 kg	Relatively heavy 1.3 kg	Relatively heavy 1.5 kg	Relatively heavy 0.9 kg
Thickness	Thick 345 mm	Thin 47 mm	Thin 14 mm	Thin 19 mm	Thin 30 mm	Thin 26 mm
View angle	Wide 160 degrees	Wide 160 degrees	Narrow <40 degrees	Wide >120 degrees	Wide 160 degrees	Wide 140 degrees
Price	Inexpensive	Relatively expensive	Relatively inexpensive	Relatively expensive	Relatively inexpensive	Expensive
Large screen size	Max. 40 inches	Difficult	Difficult	Easy	Easy	Difficult
Major applications	TV OA	AV Car instrument panels	Calculators, Watches OA TV	OA FA Measurement instruments	Outdoor use Transport	OA FA
Major material	Fluorescent material		Liquid crystal, Pigment Semiconductor thin film	Rare gas Fluorescent material	Semiconductor	EL fluorescent material

1-2. What is LCD?

Normal solids change to transparent liquids (isotropic) at the melting point. A liquid crystal, on the other hand, changes to an opaque liquid (crystalline) at the melting point, and further changes to a transparent liquid (isotropic) as the temperature increases. This opaque crystalline state is referred to as the "liquid crystal state," and electronic display devices utilizing this crystal state are referred to as "LCD displays."

There are many LCD operating principles. This paper explains the operating principle of the TN liquid crystal that is the most commonly used material in LCDs. For example, a liquid crystal is sandwiched between transparent electrode plates with a thickness of several μm to form a twist array cell in which liquid molecules are twisted by approximately 90 degrees continuously between the two electrode plates. The light entering the cell perpendicular at right angles rotates by 90 degrees along the twisted liquid molecules. Then, the cell shuts out the light when a polarizer is adhered in parallel to the cell, while it passes the light through when a polarizer is adhered perpendicularly.

When a voltage is applied to the cell, the liquid molecules (their long axes) incline in parallel in the direction of the formed electric field, and then the 90-degree rotation effect vanishes. Then, in contrast to the state of no voltage, the cell passes light when the polarizer is adhered in parallel, while it blocks light when adhered to the cell perpendicularly. Figure 1 illustrates the TN-cell operating principle for a case where the polarizer is adhered perpendicularly (normally white). When the polarizer is adhered in parallel (normally black), the cell works reversely.

There are STN (super-twisted nematic)-type displays that use STN crystals that have larger twist angles and active-matrix-type displays such as TFT and MIM, in which each pixel has one switching device (active device).

The keys to further development of the LCD market are lower production cost and higher resolution for attaining image quality as high as or even higher than that of CRT. In terms of production cost, higher productivity and higher production yield are important. In terms of resolution, reducing the heating steps that cause distortion and mislocation and improving mounting techniques are the challenges of greatest importance. Figure 2 shows the trends in the LCD-related materials that are expected to be used in meeting such challenges.

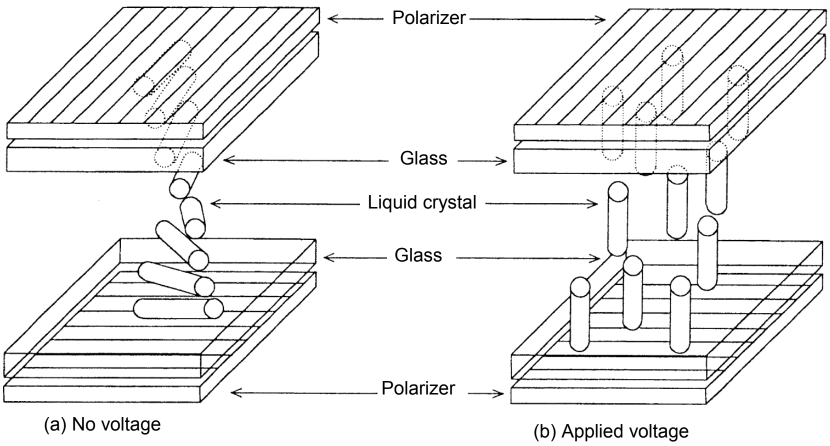


Figure 1. TN liquid-crystal cell structure

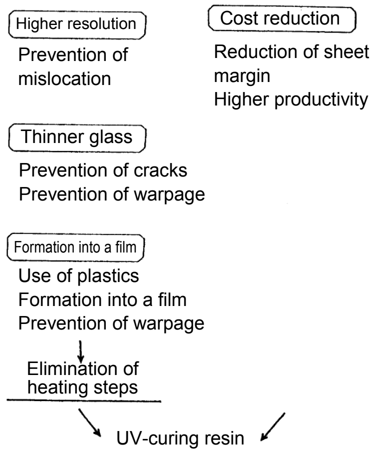


Figure 2. LCD-panel trends

1-3. LCD manufacturing process

To understand what adhesives are used in what part of an LCD, it will be helpful to review the LCD manufacturing process briefly.

Figure 3 illustrates the ordinary LCD manufacturing process. Of the top and bottom glass substrates, the bottom substrates will have active elements such as TFT. This device formation process is almost the same as that employed in semiconductor silicon wafer manufacturing. On the other glass substrate, a color filter is formed. The orientation films (polyimide films), which is used to give an orientation to the liquid crystal, are formed on those top and bottom glass substrates, and the orientation films will receive a rubbing treatment. The main sealant is then printed on the substrates by screen printing or dispenser coating. To keep the glass-substrate gap uniform, a spacer material is spread and the top and bottom substrates are mated and adhered to each other for temporal bonding. In recent years, UV-curing resin has often been used for this temporal bonding. If the main sealant is a thermocuring resin, ten or more panels are entered into a jig for thermal curing under pressure. The liquid crystal is loaded under a vacuum and sealed with UV-curing resin. Following an isotropic treatment (the application of heat) for rearrangement of the liquid crystal, the substrate is cut into cells (Fig. 4).

The panel is washed, and then the panel frame terminal patterns are connected to TAB tapes using an anisotropically conductive adhesive (ACF). Next, it is confirmed that the panel turns on/off normally, and a mold material is applied to the panel frame circuit to prevent electrolytic corrosion of the panel terminals and inter-terminal leaks. The panel is attached to the circuit board together with the shield plate, and receives an inspection to complete the manufacturing process.

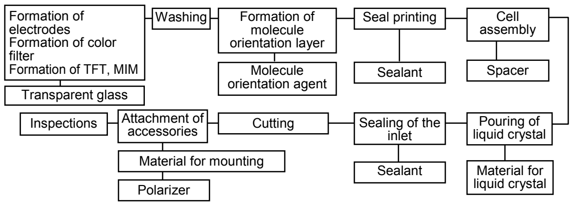


Figure 3. Common LCD manufacturing process

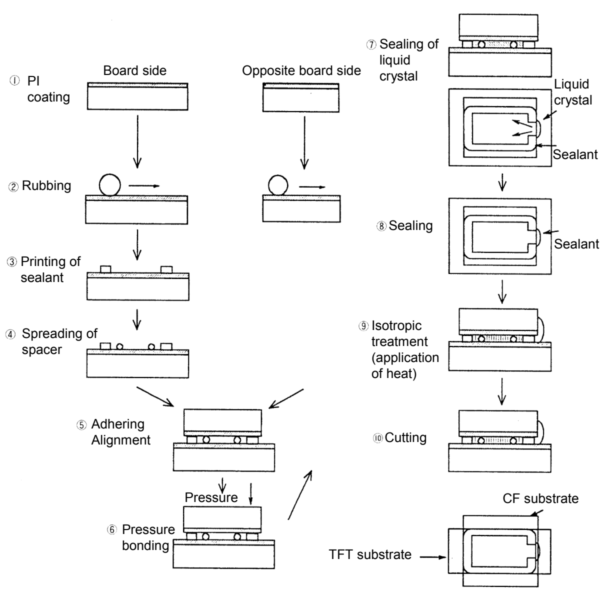


Figure 4. LCD-panel assembly process

2. Main sealant

2-1. Problems with the current manufacturing process

Currently, one-part solvent-type thermosetting epoxy resin is commonly used as the main sealant. After screen-printing of the main sealant and its pre-baking (at 90°C for 1 hour) for solvent vaporization, the glass substrates are adhered to each other and secured with a jig, and are left for 2 hours at 150°C for permanent curing. The problems with the present manufacturing process are as follows:

i. Viscosity increases as the solvent vaporizes.
ii. Batch processed are needed for thermal curing.
iii. Adhering a jig requires a supply of consumables.
iv. The thermocuring process causes mislocation and distortion of the glass substrates.

2-2. Advantages of the UV-curing main sealant

Three Bond has proposed a UV-curing main sealant for higher productivity and resolution. Figure 5 compares the manufacturing processes of ThreeBond UV-curing main sealant 3025 and the thermosetting-type main sealant 3025B. ThreeBond 3025B, which is thermosetting after being UV-cured, requires only several seconds for pressing during UV exposure. No pressing jig is required for after-baking (at 90°C for 1 hour). Using ThreeBond 3025, vacant cells can be assembled by UV exposure of several seconds under pressure, so there is no need to worry about the distortion of the glass substrates during thermosetting. With the investigation of film-type and hard-plastic-type LCD panels, the advantage of UV-curing main sealant that it eliminates the need for a heating process is becoming increasingly important.

Because static electricity is a serious problem in the LCD manufacturing process, the number of panel-rubbing steps should be minimized. The use of a non-contact dispenser coating in place of the conventional screen-printing has been investigated in recent years. The solvent-free UV-curing resin is easy to use in such dispensers.

2-3. Material suitable as the main sealant

(1) Screen-printing performance

It is important that linearity and the initial state be maintained for several hours after screen-printing. This is also true for the dispenser coating.

(2) Fast curing

Although UV-curing resin requires no heat to set, some active elements may be damaged by UV light. In addition, as the UV exposure may cause heat damage to chips, the UV exposure must be as short as possible.

(3) Dimensional stability

Maintaining a constant gap is very important in LCDs. Therefore, the main sealant is required to shrink as little as possible during curing, and must be stable with no swelling or shrinkage after curing.

(4) High purity

LCD panels are highly vulnerable to impurities. It is not allowed for the main sealant to discharge impurities before curing, or even after curing. Three Bond pursues highly pure sealing material by measuring the hydrolytic ion concentration and the electric conductivity of the sample liquid.

(5) Moisture permeability

The LCD panel is very sensitive to moisture. The liquid molecules are protected from moisture by the main sealant. The main sealant must block moisture as much as possible. ThreeBond 3025's moisture-blocking capability is much higher than that of typical UV-curing resin (moisture permeability: 200 g/m^2 •24 h).

Table 2 shows the basic properties of ThreeBond 3025 and 3025B.

Table 2. Properties of main sealants

Test item		ThreeBond3025	ThreeBond3025B	Remarks
Type		UV	UV + IR	
Curing condition		3000mJ/cm^2	1500mJ/cm^2 + 90°C × 1h	Illumination 100mW/cm^2
Appearance		Milky white liquid	Milky brown liquid	3TS-102
Viscosity	Pa•s (P)	80 (800)	40 (400)	3TS-203
Gravity		1.42	1.34	3TS-211
Hardness	JIS D	90	95	3TS-387
Glass transition point	°C	95	95	3TS-392
Boiling-water absorption rate (2 h)	%	0.1	1.0	3TS-607
Moisture permeability	g/cm^2•24h	7.0	6.9	JIS Z-0208
Curing shrinkage	%	6.5	3.2	3TS-365
Specific volume resistance	Ω•cm	8.0 × 10^{14}	1.0 × 10^{14}	3TS-405
Specific surface resistance	Ω	5.0 × 10^{14}	5.0 × 10^{14}	3TS-405
Dielectric constant 1 MHz	20°C	4.11	3.92	JIS K-6911
	120°C	4.38	4.26	
Dielectric loss tangent 1MHz	20°C	0.032	0.017	JIS K-6911
	120°C	0.030	0.017	
Peeling adhesive strength	kgf			
Corning 7059		2.0	2.0	
ITO 7059		1.3	1.1	
Ion density PCT × 24h extraction	Cl^- ppm	10	50	3TS-369
	Na^+ ppm	3	3	
	K^+ ppm	1	1	
Electric conductivity	μS/cm	30.0	30.0	

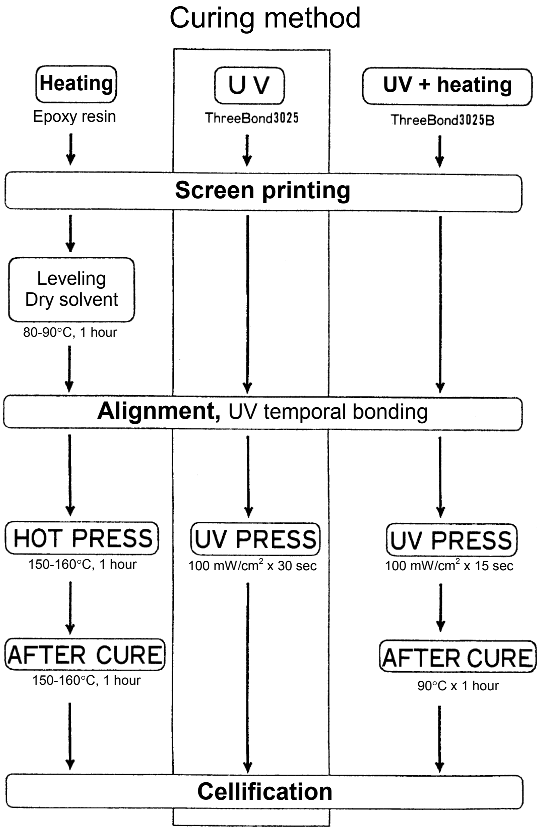


Figure 5. Comparison of the LCD cell assembly processes

Table 3. Properties of end sealant

Test item			ThreeBond3025	Remarks
Appearance			Milky white liquid	3TS-102
Viscosity	Pa•s (P)		15 (150)	3TS-203
Hardness	JIS D		90	3TS-387
Curing shrinkage	%		6.1	3TS-365
Shear adhesivity	MPa (kgf/cm^2)		7.0* (71.4)	3TS-310
Glass transition point	°C		80	3TS-392
Thermal expansion coefficient	/°C		6.3 x 10^{-5}	3TS-392
Moisture permeability	g/m^2•24h		36.0	JIS X-0208
Ion density PCT x 48h extraction	Cl^-	ppm	100	3TS-906
	Na^+		3	
	K^+		1	

* Indicates a breakage

3. End-seal material (sealant)

3-1. Current situation

UV-curing resin has been used as a sealant. This is due to the fact that it cures in a short time when exposed to UV light, and that the required reliability level is not as high as that of the main sealant. However, in recent years, the distance from the screen image to the main sealant and sealant has decreased, and part of the main sealant has been replaced by UV-curing resin. Thus, the sealants are now required to be of the same high quality as the main sealant.

3-2. Requirements for the sealant

In principle, the requirements the sealant must meet are the same as those of the main sealant. There are, however, some requirements unique to the sealant, as it directly contacts the liquid crystal material prior to curing.

i. It does not mix with the liquid crystal prior to curing.
ii. It does not mix with the liquid crystal during curing.

Meeting requirement i. is a way of avoiding the use of low-molecular-mass material that is soluble in the liquid crystal.

In order to meet requirement ii., curing should be completed as quickly as possible and the amount of outgas emitted during curing should be minimized. Particularly in the latter case, it is known that increasing the illumination intensity leads to a decrease in the emission of outgas. Thus, Three Bond has requested that its customers increase the UV illumination intensity.

Table 3 summarizes the major properties of our commercial end sealant, ThreeBond 3026.

4. Anisotropically conductive adhesive

4-1. Current situation

Anisotropically conductive adhesive is used to form mechanical bonding and electric connections between the transparent electrodes of an LCD and its driver circuit. Currently, ITO is the dominant transparent electrode material. Because metals such as soldering do not yield a low-temperature eutectic alloy, organic adhesives are used as glue.

As organic glue, zebra rubber, heat-seal connectors, anisotropically conductive paste, and anisotropically conductive films are used according to individual needs.

i. Although zebra rubber does not have adhesivity by itself, mechanical pressing provides it with adhesivity. It is not a good choice for fine-pitch products due to alignment/bonding problems.
ii. A heat-seal connector is used for thermal pressure bonding. It is not a good choice for fine-pitch products due to its structure.
iii. Anisotropically conductive paste is used in the processes of printing (silk screening, etc.), drying, and thermal pressure bonding. Because it can be printed, its application range is wide, and it depends less the electrode size or thickness. It is, however, not appropriate for fine-pitch products due to the cohesion of conductive particles and non-uniform particle

density.

iv. Anisotropically conductive film is used in the processes of temporal bonding and permanent bonding (thermal pressure bonding). It is used in the TAB method, which is the major bonding technique for LCD driver ICs. It is applicable even to products with a pitch of 0.1 mm or less when used together with a thermosetting material (epoxy resin).

The above are the major glue materials now in use.

4-2. Requirements for anisotropically conductive adhesive

Because the resolution of LCDs has become sufficiently high, the primary focus of panel makers has shifted to lower cost and demonstration of their original advantages. In terms of production costs, higher productivity and component cost reduction are key challenges. In terms of originality, organic materials that can replace the glass substrate are the focus of a great deal of attention.

Three Bond has commercialized iii. Anisotropically conductive paste (ThreeBond 3370G) and iv. Anisotropically conductive film (ThreeBond 3370C). They are made of thermoplastic resin in which a conductive filler is dispersed. Their major properties are shown in Table 4. An organic-based anisotropically conductive paste that can meet the requirements for film-type LCDs is under development. An anisotropically conductive film that meets the needs of ultrafine-pitch products is also under development.

5. Pin-lead fixing resin

5-1. Current situation

Nearly all consumer panels adopt this pin-type technique, and the quantity of pin-lead panels is very large. Thus, the resin most commonly used to fix pin leads is fast-set UV-curing resin. In the manufacturing process for pin-type panels, the top priority is placed on productivity. Workability (viscosity) and curing speed are the key properties of the adopted resin.

5-2. Requirements

1) Being tinted

For easy checking of coating results, nearly all manufacturers require tinted resin.

2) Fast setting

3) Low curing shrinkage

As glass substrates have become increasingly thin, some problems are caused by distortion due to shrinkage and cracks. The shrinkage during curing, and the stress on the glass substrates must be minimized.

4) Low-temperature performance

For the same reason as specified in 3), distortion due to stress and cracks must be prevented at low temperatures.

5) Adhesivity at thermal conditions

Because pin-type panels are often employed in vehicles, the glue adhesivity must be maintained at thermal conditions.

6) High purity

Impurities may cause leaks, although the purity requirements are not as high as those of the main sealant. Thus, the resin is required to have some degree of purity.

Table 5 shows the characteristics of a pin-lead-securing resin, ThreeBond 3050.

6. ITO electrode mold material

6-1. Current situation

ITO electrodes have a protective coat to shut out moisture, and the most common coating material is high-purity silicone. Silicone resin is generally known to have high moisture permeability. However, because it has a respiratory function, moisture does not remain in the interface, nor does it adversely affect the panel. For this reason, silicone resin is currently in such wide use. Silicone, however, requires a long time to set, so fast-set UV-curing mold material is under investigation to replace silicone.

6-2. Requirements for mold material

1) High purity

Because the mold material directly contacts the ITO electrodes, it is required to be of a higher purity to meet the need for high resolution.

2) Low curing shrinkage

As in the case of pin-lead-fixing resin, the shrinkage of mold material causes distortion and cracks in the glass substrate. Therefore, the curing shrinkage of the mold material must be low.

3) Repairablity

As in the case of the anisotropically conductive adhesive, the mold material must have repairability to some extent.

Table 6 shows the characteristics of the UV-curing mold material, ThreeBond 3006B.

In addition to those listed in Table 6, Three Bond has proposed a variety of materials, such as anti-static conductive adhesive sheets, conductive glue for the top and bottom substrates, temporal bonding glue for pre-permanent bonding of the main sealant, glue for bonding between the panel and the case, and PDLC binder.

Table 4. Basic characteristics of anisotropically conductive adhesives

Product name		ThreeBond 3370C	ThreeBond 3370G
Properties	Type	For normal fine-pitch products	Solvent evaporation type
	Appearance	Gray, transparent film	Gray paste
	Main composition	Thermoplastic resin	Thermoplastic resin
	Conductive filler	Plated resin powder (8 μm)	Plated resin powder (8 μm)
	Sheet structure	Three layers (with a mold release film)	-
	Film thickness	35±5 μm	-
	Specifications	3 mm, 4 mm, 5 mm in width × 30 m	70±20 Pa•s
Basic characteristics	Connection resistance	1-5 Ω (FPC/PCB) (0.3 mm pitch, 3 mm width)	20 Ω or lower (FPC/ITO) (0.3 mm pitch, 3 mm width)
	Inter-line insulation resistance (Comb 0.2-mm pitch × 100, DC 10 V)	10^8 Ω or higher	10^8 Ω or higher
	Minimum possible conductor width	0.1 mm (0.2 mm pitch)	0.1 mm (0.2 mm pitch)
	Adhesivity	500 N/m	500 N/m
Use	Pressure-bonding temperature condition	130-150°C (140°C)	150-160°C (150°C)
	Pressure-bonding time condition	10-30 sec. (20 sec.)	10-30 sec. (20 sec.)
	Pressure-bonding pressure condition	2.9 MPa	2.9 MPa

Note: ( ) recommended conditions

ThreeBond 3370G film-formation conditions Printing............60-100 meshes
Drying..............120°C × 10-20 min.

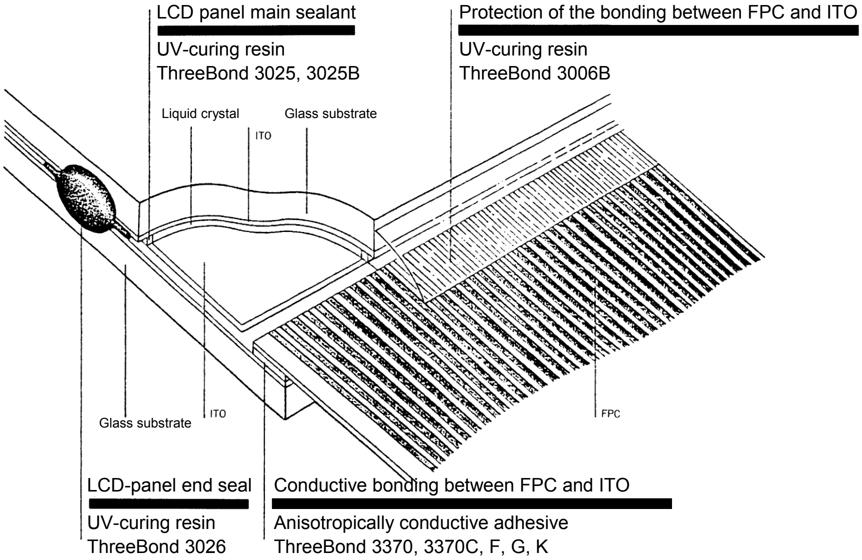
Table 5. Properties of pin-lead-fixing resin

Test item		ThreeBond 3050	Remarks
Appearance		Blue, transparent liquid	3TS-102
Viscosity	Pa•s (P)	5.5 (55)	3TS-203
Gravity		1.08	3TS-211
Hardness	JIS D	65	3TS-387
Water absorption	%	2.0	3TS-365
Elongation	%	230	3TS-311
Tensile strength	MPa (kgf/cm^2)	34.3 (350)	3TS-311
Young's modulus	MPa (kgf/cm^2)	118 (1200)	3TS-311
Shear adhesivity	MPa (kgf/cm^2)	7.0 * (71.4)	3TS-351
Glass transition point	°C	66	3TS-310
Thermal expansion coefficient	/°C	1.18×10^{-4}	3TS-396
Dielectric constant 1 MHz		4.933	3TS-396
Dielectric loss tangent 1 MHz		0.0598	JIS K-6911
Specific volume resistance	Ω•cm	6.10×10^{11}	JIS K-6911
Specific surface resistance	Ω	1.27×10^{13}	JIS K-6911

* Indicates a breakage

Table 6. Properties of mold material

Test item			ThreeBond 3006B	Remarks
Appearance			Milky white liquid	3TS-102
Viscosity	Pa•s (P)		2.2 (22)	3TS-203
Hardness	JIS D		55	3TS-387
Curing shrinkage	%		6.5	3TS-365
Elongation	%		100	3TS-311
Tensile strength	MPa (kgf/cm^2)		15.6 (160)	3TS-351
Young's modulus	MPa (kgf/cm^2)		29.4 (300)	3TS-311
Glass transition point	°C		80	3TS-396
Thermal expansion coefficient	/°C		6.3×10^{-5}	3TS-396
Ion density PCT × 48 h extraction	Cl^-	ppm	20	3TS-906
	Na^+		6	
	K^+		1	



LCD and ThreeBond products

Conclusion

The LCD market will focus on higher throughput and higher production yields to expand its market size. Higher resolution, thinner glass substrates, film formation, and the use of PDLC (polymer dispersed liquid crystal) are the present technological challenges. In the area of resin material, epoxy and silicone will be improved so that they cure faster at lower temperatures or work by UV exposure.

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