ThreeBond
TECHNICAL NEWS

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Adhesives for Liquid Crystal Displays

Introduction

Computer systems continue to become more important as information media, analyzing tools and controlling tools. Human vision is said to be the most sensitive and most highly developed of the five senses. Therefore, visual displays are the most vital interface between computers and human beings.

Compared to other visual displays, LCD (liquid crystal displays) are the most practical because they are compact, lightweight and energy efficient. Three Bond offers a variety of sealants that contributes to the improvement of productivity and reliability of liquid crystal displays.

This report discusses ultraviolet setting resin and anisotropic conductive adhesives used in the cellularization and mounting process of liquid crystal displays.

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1. Types of Electronic Display Device

1-1. Comparison

Electronic display devices, in general, transmit a variety of information from various equipment through visual displays. There are two basic types of devices: One is a "light emitting display" in which information signals are sent using a self generated light such as, CRT (cathode ray tube). The other is a "light-passive display" in which information signals are sent by controlling ambient light by means of reflection, scattering and interference, namely, by means of light modulation. LCD is a representative of this type of display.

Table 1 compares characteristics of the major types of electronic display devices. Among these devices, the CRT still outranks the others in terms of display quality, prices, etc. However, needs are rapidly expanding for a FPD (flat panel display) that is compact, lightweight, has low drive voltage and low power consumption. With the exception of CRT all displays are classified as flat panel type.

Of these FPDs, liquid crystal displays are rapidly becoming popular because they meet the needs for compact, lightweight displays free of quality problems.

1-2. Liquid crystal display

Most organic crystalline substances have only one melting point at which it changes from a solid to a transparent liquid (isotropic). Some substances called liquid crystals change into opaque liquids (anisotropic) within a certain temperature range. They behave as a fluid, but at the same time exhibit optical double refraction. These latter substances are used to make LCDs. There are many ways to drive LCDs, but this report discusses the most common type, TN (twisted nematic) liquid crystals.

As shown in figure 1, ambient light enters the display through the front polarizing filter. With no voltage applied to a twisted nematic cell, light passes through (usually appears bright). A cell formed by the two transparent electrode substrates is filled so that the molecular axis of the liquid crystal forms a twisted array filled approximately 90˚ between substrates. Since the pitch of this twist is sufficiently large compared with the wavelength of visible light, the direction of polarization of linearly polarized light incident vertically on one of the electrode substrates is rotated through 90˚ by the twist of the liquid crystal molecules as it passes through the cell as in Fig. 1 (a). Therefore this twisted nematic cell transmits light if placed between two orthogonal polarizing filters.

When voltage is applied as in Fig. 1 (b) to a twisted nematic cell, the molecule axes begin to align themselves with the electric field. When sufficient voltage is applied, the majority of molecules have their axes realigned in the direction of the electric field and 90˚ optical rotary power is eliminated. In this case, in completely the opposite fashion to the case when a voltage is not applied, light will not pass through (usually appears dark).

In addition to TN, there is the STN (super twisted nematic) type which has a greater twisting angle. Another type in which every pixel is furnished with a switching element (active element) is called TFT (thin film transistor) as well as MIM (metal-insulator-metal).

For further growth of the LCD market, cost and quality must be improved. Increased productivity and yield will keep LCD cost competitive with other types of displays. Also required is minimizing distortion and slippage caused by the heating process, improving the mounting technique of ultraminiturization and improving the picture quality to equal or surpass CRT. Figure 2 shows the future requirements for improving LCD.

Table 1 Comparison of characteristics of electronic display devices

Display	CRT	VFD	LCD	PDP	LED	ELP
Display method	Light-emitting	Light-emitting	Light-passive	Light-emitting	Light-emitting	Light-emitting
Full color	Full color	Red, yellow, green, blue	Full color	Full color	Red, green, blue	Red, green, yellowish- orange, blue
Power consumption	85 W	17 W	0.7 W	35 W	5 W	13 W
Weight	7 kg	3 kg	0.7 kg	1.3 kg	1.5 kg	0.9 kg
Thickness	345 mm	47 mm	14 mm	19 mm	30 mm	26 mm
Angle of visibility	160˚	160˚	<40˚	>120˚	160˚	140˚
Price	Low	Slightly high	Slightly low	Slightly high	Slightly low	High
Increase in size	40 inches max.	Difficult	Difficult	Easy	Easy	Difficult
Major application	TV, OA equipment	AV equipment, instrument panel for vehicles	Electronic calculator, watch, OA equipment, TV	OA equipment, FA equipment, measuring instrument	Outdoor display equipment, transportation	OA equipment, FA equipment
Main material	Fluorescent matter		Liquid crystal, coloring matter, semiconductor film	Noble gas, fluorescent matter	Semiconductor	Fluorescent matter for EL

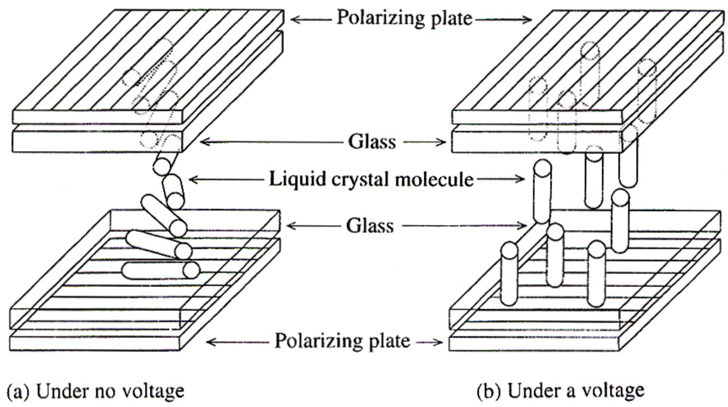


Fig. 1 Configuration of TN type liquid crystal cell

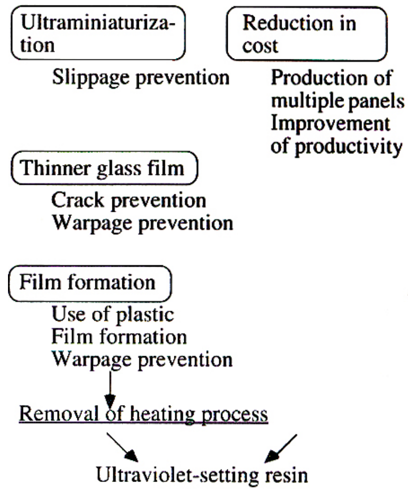


Fig. 2 Desired liquid crystal panel

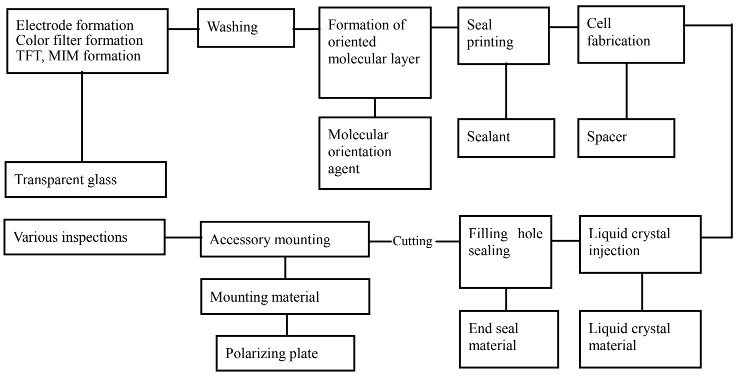


Fig. 3 General LCD production process

1-3. LCD production process

The production process is outlined in Figure 3 & 4 which show how and where sealants/adhesives are used. First, two glass substrates are prepared. TFT or other active elements are mounted on the front substrate. The production process is similar to that of a semiconductor silicone wafer. A color filter is mounted on the rear substrate. A polyimide film for orienting liquid crystal molecules is mounted onto both substrates, then the film is subjected to rubbing process. The side sealing adhesive is applied by screen printing or by dispenser. Next spacer material is sprayed on to make the thickness between the glass substrates uniform then the substrates are affixed to each other. After alignment, they are temporarily fixed using ultraviolet setting resin. If using a thermosetting side sealing adhesive, about 10 panels are placed into a press jig then subjected to heat curing. After vacuum injection of the liquid crystals, the ultraviolet setting resin is applied to charge port seal. After the subsequent isotropic treatment (heating) for rearraying the liquid crystal, the LCD panel is cut to produce a cell (Figure 4).

The cell is washed, and TAB (tape automated bonded) substrate is joined to the mounting terminal pattern around the periphery above and below the cell via an ACF (anisotropic conductive adhesive). Then the cell is light-checked and molding material is applied to the mounting section on the periphery of the cell for prevention of electric corrosion of panel terminals and leakage between terminals. Then the cell is attached to a circuit board and a shield plate is attached to the panel. After final inspection, the panel is completed.

2. Side Sealing Adhesive

2-1. Problems in current process

In general, a solvent type, thermosetting, one part epoxy resin is currently being used as the side sealing adhesive. This type of side sealing adhesive is screen printed and baked at 90°C for 1 hr to evolve the solvent. Then after substrates are affixed to each other, they are secured with a jig and cured at 150°C for 2 hours. The following are the problems found in such a process.

①Increase in epoxy viscosity due to solvent evaporation
②Batch processing for heat curing
③Consumables necessary for affixing jigs
④Slippage and distortion of glass substrates due to heat curing

2-2. Merits of ultraviolet-setting side sealant

As a solution to the above problems, Three Bond offers ultraviolet-setting side sealants for improved productivity and ultraminiaturization. Fig. 5 shows the process comparison between the ultraviolet-setting side sealant, ThreeBond 3025, and the thermosetting

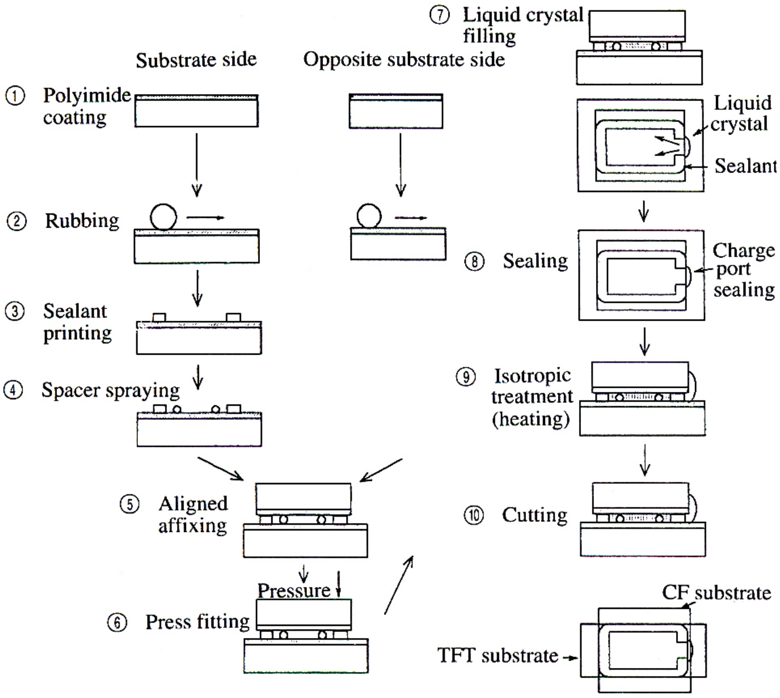


Fig. 4 Liquid crystal fabrication process

side sealant, ThreeBond3025B. ThreeBond 3025B, that is subjected to heat curing after ultraviolet curing, is pressurized only for a couple of seconds during ultraviolet irradiation, requiring no pressure jigs during after-baking (90˚C×1 hr). ThreeBond 3025 permits fabrication of an empty cell in a couple of seconds during ultraviolet irradiation under pressure, thus eliminating distortion of glass substrates due to heat curing. Use of film type and hard plastic type liquid crystal panels has been examined recently in order to make the best use of the merits of ultraviolet-setting side sealants that do not need a heating process.

Since the static electricity must be minimized in the liquid crystal display production process, efforts are made to reduce processes in which panels are rubbed. A method to apply sealant with a non-contact dispenser has been examined recently to do away with screen printing. The ultraviolet-setting resin that is of a non-solvent type will be easily applied by a dispenser.

2-3. Desired physical properties of side sealant

① Screen-printability
Side sealants must maintain clean linearity and keep identical conditions for several hours after screen printing. The same applies to the application of materials with a dispenser.

② Fast curing
Although ultraviolet curing requires no heat, active elements may be deteriorated by ultraviolet rays. To minimize the adverse effect of ultraviolet irradiation, the fastest curing possible is desired.

③ Dimensional stability
Liquid crystal displays must have a gap of a certain thickness. Side sealant should contract very little during curing and should be free of swelling or contraction after curing.

④ High purity
Liquid crystal panels are extremely vulnerable to impurities. Side sealants cannot leave impurities before and after curing. Therefore, adhesives with the highest possible purity have been sought by measuring the concentration of hydrolysistic ions and the electric conductivity of extract.

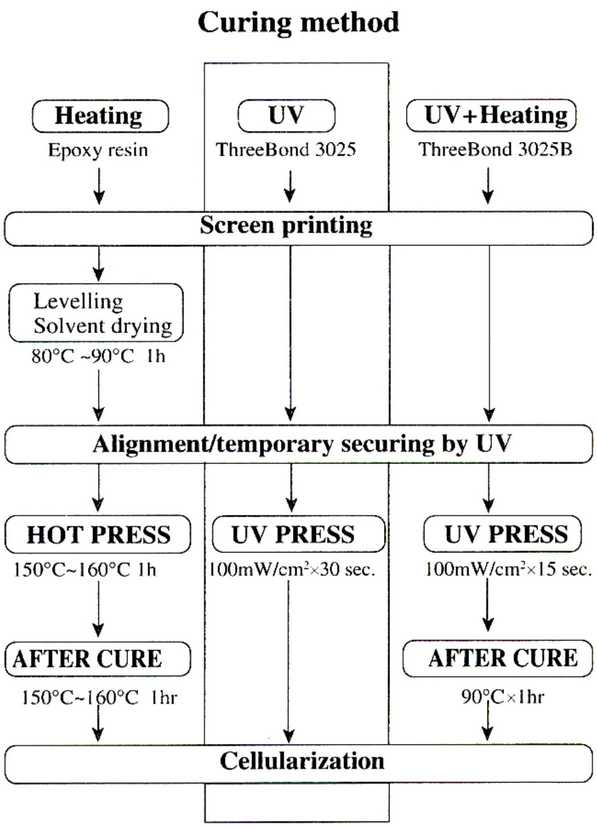


Fig. 5 Comparison of liquid crystal cell fabrication

⑤ Moisture permeability
Liquid crystal panels are devices that are hypersensitive to humidity. Liquid crystal molecules are protected from moisture by side sealants. In other words, side sealants must be made of substances that will restrict permeation of moisture as much as possible. In comparison with general ultraviolet-setting resin (moisture permeability: 200g/m²·24h), the moisture permeability of ThreeBond 3025 has been substantially reduced.

Table 2 shows simplified physical properties of ThreeBond 3025 and 3025B.

3. Charge Port Sealant

3-1. Present condition

Ultraviolet-setting resin has long been used as an charge port sealant, because it cures shortly after ultraviolet irradiation and the reliability required of charge port sealants is not as severe as that required of side sealants. However, needs for high-reliability charge port sealants have been increasing, because the distance between side sealants or charge port sealants and actual pictures has been shortened and ultraviolet-setting resin has been introduced as a side sealant. Thus similar characteristics are expected from charge port sealants.

3-2. Characteristics required of charge port sealant

The characteristics required of charge port sealant are basically the same as those required of side sealants. However, unique characteristics are required of charge port sealants because they come into direct contact with liquid crystal materials under uncured conditions.

① Charge port sealants shall not be mixed with liquid crystal under uncured conditions.

② Charge port sealants shall not be mixed with liquid crystal under cured conditions.

In the case of ①, it is conceivable not to use low molecular weight materials that are compatible with liquid crystal materials.

In the case of ②, it is conceivable to shorten curing time and minimize gas generation during curing as much as possible. Especially in the latter case, intensified illuminance of an irradiator is known to reduce gas generation during curing, and customers are requested to follow such a method.

Table 3 shows the simplified characteristics of ThreeBond 3026 that is available on the market.

Table 2 Characteristics and physical properties of main sealant

Test item			ThreeBond 3025	ThreeBond 3025B	Test standards
Type			UV	UV+IR	
Curing condition			3000mJ/cm²	1500mJ/cm² +90˚C×1h	Illuminance 100mW/cm²
Appearance			Milk-white liquid	Milky-brown liquid	3TS-102
Viscosity	Pa·s [P]		80 [800]	40 [400]	3TS-203
Specific 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 (2h)	%		0.1	1.0	3TS-607
Moisture permeability	g/m²·24h		7.0	6.9	JIS Z-0208
Percentage of contraction upon curing	%		6.5	3.2	3TS-365
Volume resistivity	Ω·cm		8.0×10^{14}	1.0×10^{14}	3TS-405
Surface resistivity	Ω		5.0×10^{14}	5.0×10^{14}	3TS-405
Dielectric constant (1 MHz)	20˚C 120˚C		4.11 4.38	3.92 4.26	JIS K6911
Dielectric loss tangent (1 MHz)	20˚C 120˚C		0.032 0.030	0.017 0.017	JIS K6911
Corning 7059	kgf		2.0	2.0	
7059 with ITO			1.3	1.1	
Ion concentration PCT×24h extraction	Cl^-	ppm	10	50	3TS-906
	Na^+		3	3	
	K^+		1	1	
Electric conductivity	µS/cm		30.0	30.0	

4. Anisotropic Conductive Adhesive

4-1. Present condition

An anisotropic conductive adhesive is used for electric connection and physical joining of liquid crystal displays with transparent electrodes and driving circuits. At present, the most popular transparent electrode material is ITO. Since solder and other metallic materials do not allow formation of eutectic metal, organic materials are used as adhesives.

Organic adhesive include zebra rubber, heat seal connector, anisotropic conductive paste, and anisotropic conductive films, which are used for respective purposes.

① Zebra rubber itself is not adhesive and is used for joining by means of mechanical contact. Due to the positioning performance and the nature of the joining method, zebra rubber is not used for fine pitch joining.
② The heat seal connector is joined by thermo-compression bonding. This cannot be used for fine pitch joining, either, due to its construction.
③ Anisotropic conductive paste is joined in the printing (silk screen printing, etc.), drying, and thermal press fitting processes. This printing method widens the application range in terms of the electrode size and thickness. However, the flocculation of conductive particles and lack of uniform dispersion make anisotropic conductive paste unsuitable for fine pitch joining.
④ Anisotropic conductive film is joined in the tentative press-fitting and regular press-fitting (thermal press fitting) processes. Such film is used in the TAB method that is the most popular method to join liquid crystal display driving ICs. Use of a thermosetting material (epoxy resin) permits 0.1 mm pitch or finer joining.

The above are major materials used currently.

4-2. Characteristics required of anisotropic conductive adhesive

Ultraminiaturization of liquid crystal displays are being established, and the two factors affecting its development are cost and creativity of panel maker. In terms of costs, improvement of productivity and reduction in material costs are being sought, while in terms of originality, possibility of the use of organic materials that will replace glass substrates has been positively examined.

Three Bond has put on the market ③ anisotropic conductive paste (ThreeBond 3370G) and ④ anisotropic conductive film (ThreeBond 3370C). Both of them are made by dispersing conductive filler over thermoplastic resin, whose major characteristics are shown in Table 4. Regarding the anisotropic conductive paste, development has been made in order to apply organic materials to film-type LCDs and to apply anisotropic conductive film to the super fine pitch joining process.

Table 3 Charge port sealant/characteristics and physical properties

Test item			ThreeBond 3026	Test standards
Appearance			Milk-white liquid	3TS-102
Viscosity	Pa·s [P]		15 [150]	3TS-203
Hardness	JIS D		90	3TS-387
Percentage of contraction upon curing	%		6.1	3TS-365
Shearing adhesive strength	MPa [kgf/cm²]		7.0* [71.4]	3TS-310
Glass transition point	˚C		80	3TS-392
Coefficient of thermal expansion	˚C		6.3×10^{-5}	3TS-392
Moisture permeability	g/m²·24h		36.0	JIS Z-0208
Ion concentration PCT×48h extraction	Cl^-	ppm	100	3TS-906
	Na^+	ppm	3	
	K^+	ppm	1	

* Indicates material failure

5. Pin Lead Fixing Resin

5-1. Present condition

Most panels for business and household use are of a pin type, and their production is enormous. Under these circumstances, fast-curing type ultraviolet-setting resin is used, in general, for fixing pin leads. Since productivity is the most important factor for pin type panels, workability (viscosity) and curing rate are vital characteristics.

5-2. Required characteristics

① Colored resin
Most makers are required to use colored resin for comfirmation of resin application.
② Fast-curing performance
③ Small percentage of contraction upon curing
Current reduction is glass substrate thickness is causing distortion and cracking due to contraction. Therefore, contraction during curing and stress against glass substrates must be minimized.
④ Excellence in low-temperature characteristics
For the same reason as ③, it is necessary to prevent distortion and cracking due to stress at low temperatures.
⑤ Adhesive strength at high temperature
Since pin type panels are mounted on vehicles in many cases, adhesive strength at high temperature is required.
⑥ High purity
Although not to the extent of the purity required of main sealants, pin lead securing resin must be of a high purity type to a certain extent to prevent leakage.

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

Table 4 Basic characteristics of anisotropic conductive adhesive

Product name		ThreeBond 3370C	ThreeBond 3370G
Properties	Application	For fine pitch	Solvent vaporization, general pitch
	Appearance	Gray transparent film	Gray paste
	Main ingredient	Thermoplastic resin	Thermoplastic resin
	Conductive filler	Resin plating powder (8 μm)	Resin plating powder (8 μm)
	Sheet construction	3-layer (with separating film)	—
	Film thickness	35±5 μm	—
	Specifications	3,4,5 mm (width) ×30 m	70±20 Pa·s
Basic characteristics	Joining resistance	1~5Ω (FPC/PCB) (0.3 mm-pitch, 3 mm-wide)	20Ω max. (FPC/ITO) (0.3 mm-pitch, 3 mm-wide)
	Line insulation resistance (Comb type 0.2 mm-pitch×100, 10VDC)	10^8Ω or more	10^8Ω or more
	Min. available conductor width	0.1 mm (0.2 mm-pitch)	0.1 mm (0.2 mm-pitch)
	Adhesive strength	500N/m	500N/m
Usage	Press-fitting temp. condition	130~150˚C (140˚C)	150~160˚C (150˚C)
	Press-fitting time condition	10~30sec. (20 sec)	10~30sec. (20 sec)
	Press-fitting pressure condition	2.9 MPa	2.9 MPa

Note: The parenthesized values on the lines of "Usage" are recommended conditions.
Filming condition for ThreeBond 3370G: Printing condition….60~100 mesh
Drying condition …...120˚C×10~20 min

Table 5 Pin lead securing resin/characteristics and physical properties

Test item		ThreeBond 3050	Test standards
Appearance		Transparent blue liquid	3TS-102
Viscocity	Pa·s	5.5 (55)	3TS-203
Specific 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/cm²)	34.3 (350)	3TS-311
Young's modulus	MPa (kgf/ cm²)	118 (1200)	3TS-311
Shear adhesive strength	MPa (kgf/ cm²)	7.0* (71.4)	3TS-351
Glass transition point	˚C	66	3TS-310
Coefficient of thermal expansion	/˚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
Volume resistivity	Ω·cm	6.10×10^{11}	JIS K-6911
Surface resistivity	Ω	1.27×10^{13}	JIS K-6911

* Indicates material failure.

6. ITO Electrode Molding Material

6-1. Present condition

For moisture-proofing, ITO electrodes are coated, in general, with high purity silicone resin. Silicone resin is known to have great moisture permeability, but its respiratory function prevents collection of moisture on the surface, not causing adverse effect on panels. That is why silicone resin is used currently.

Due to time-consuming curing, however, use of fast-curing type ultraviolet-setting molding materials has been under examination.

6-2. Characteristics required of molding material

① High purity
Since there is direct contact with ITO electrodes, molding materials of a high purity type are in demand for ultraminiaturization.

② Small percentage of contraction upon curing
Since contraction of molding materials causes distortion and cracking of glass substances as in the case of pin lead securing resin, minimal contraction upon curing is desired.

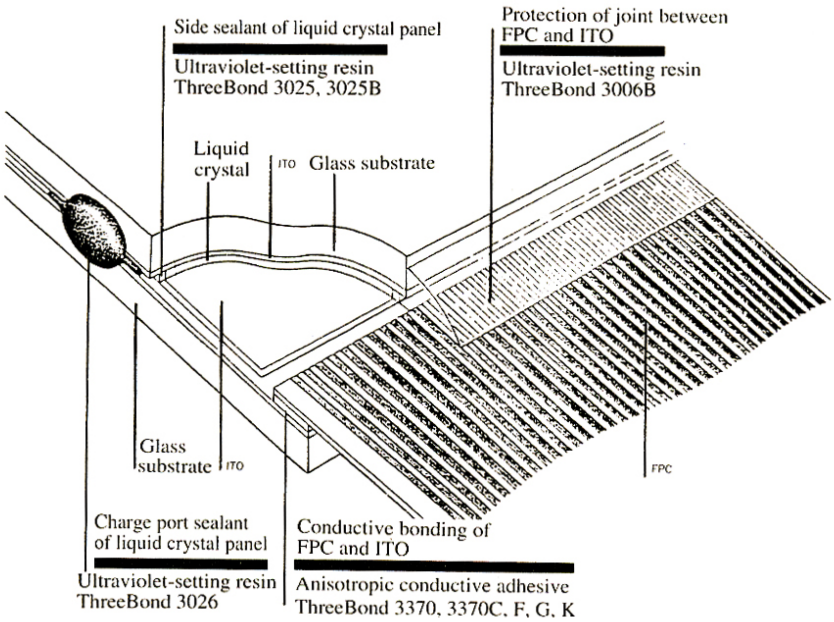
③Repairability
As in the case of anisotropic conductive adhesives, repairability is needed to a certain extent.

Table 6 shows the characteristics of ultraviolet-setting molding material, ThreeBond 3006B.

In addition to the above, Three Bond offers conductive adhesive sheets for coping with static electricity, conductive agents for upper and lower substrates, temporary fixing of side sealants, adhesives for joining panels and cases, PDLC binders, and many other materials.

Table 6 Molding material/characteristics and physical properties

Test item			ThreeBond 3006B	Test standards
Appearance			Milk-white liquid	3TS-102
Viscosity	Pa·s (P)		2.2 (22)	3TS-203
Hardness	JIS D		55	3TS-387
Shrinkage	%		6.5	3TS-365
Elongation	%		100	3TS-311
Tensile strength	MPa (kgf/cm²)		15.6 (160)	3TS-351
Young's modulus	MPa (kgf/cm²)		29.4 (300)	3TS-311
Glass transition point	°C		80	3TS-396
Coefficient of thermal expansion	/°C		6.3×10^{-5}	3TS-396
Ion concentration PCT×48h extraction	Cl^-	ppm	20	3TS-906
	Na^+		6	
	K^+		1	



Liquid crystal display and Three Bond's products

Conclusion

For further expansion of the market, the liquid crystal industry must continue its efforts to materialize greater throughput and yield. From the technical point of view, the assignment of the moment will be materialization of ultraminiaturization, thinner glass substrate, film formation, and PDLC (polymer dispersion type liquid crystal). To that end, attention will shift to low-temperature fast-curing or ultraviolet curing of epoxy resin and silicone.

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