Newly Developed LCP Film Fabricated by Solvent-Casting Method

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Commercial aromatic liquid-crystalline polymers (hereafter designated as LCP), are known to be unable to dissolve in any common organic solvents except for costly fluorinated reagents. Recently, Sumitomo Chemical succeeded in the development of innovative LCP solvent casting film from its varnish. The casting film exhibits not only low water absorption characteristics, low gas permeability, low dielectric loss at high frequency and high temperature tolerance originated in using LCP as a base material, but also high tear strength because of less anisotropic property in comparison to extruded LCP films. The LCP film by this casting method has many advantages to be applied for the electro devices such as flexible print circuit board, embedded circuit board and so on.

Introduction

Currently, liquid-crystalline polymers (hereafter designated as LCP) have built a position as typical super engineering plastics, and while the demand temporarily dropped with the bursting of the IT bubble, it is recovering now. The demand is increasing a great deal centered on precision parts, such as connectors, relays, bobbins and switches, in the electrical and electronic fields as well as telecommunications. The demand for 2002 was just under 5,000 tons per year domestically and 15,000 tons per year worldwide. For 2003, it was 19,000 tons per year, and for 2004 the estimate is for it to exceed 20,000 tons per year.[1]

Behind this growth in demand for LCP is its being suitable for the applications mentioned above with the increased precision, greater miniaturization and lower amounts of backing due to its exhibiting the superior injection molding properties of high flowability, rapid solidification and no flashes. This is in addition to the superior LCP heat resistance that can withstand lead-free solder, its having superior dimensional stability suitable for precision parts and its not having corrosion at metal contact points without evolved gasses. Besides these, one of the factors is its being a material that matches the times, since flame resistance is realized

(with wholly aromatic LCP) without the addition of flame retardants, and there is no reduction of physical properties when it is recycled, making it basically recyclable.[2]

Aside from injection molding fields that focus on these electronic parts, LCP applications include fibers and films. In terms of fibers, there are amide fibers which are super strong fibers, but fibers can be made with polyester based LCP, and it can be used for fishing equipment, nets, industrial rope and sports products.[3]

On the other hand, there has been active development of applications for liquid-crystalline polymer films in recent years, focusing on their superior electrical characteristics, dimensional stability and heat resistance. Specifically, these are applications such as electrical insulator applications in motors, transformers and the like, applications in films for forming the devices in flexible solar cells, electronic circuit boards for computers and mobile equipment, and the like[4]. For applications in electrical insulators in motors and transformers, there is the merit of no reduction in the electrical insulating properties even in a moisture-absorbing environment because of the low water absorbency of liquid-crystalline polymer films. In addition, for applications in flexible solar cells, there are the merits of liq-

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uid-crystalline polymers having excellent heat resistance when devices are being molded on the film in a vacuum at high temperatures and having low water absorbency.

The applications of liquid-crystalline polymers that are attracting the most attention in electrical and electronic material fields are the applications in electronic circuit boards. The merits for these electronic circuit board applications are the superior electrical insulating properties and dielectric characteristics that liquid-crystalline polymer films have. In terms of electrical insulating properties, the maintaining of the electrical insulating properties in a high moisture absorbing environment and the obtaining of stability in dielectric characteristics even in high-temperature, high humidity environments are attracting attention. It is predicted that there will be a strong demand in the future for liquid-crystalline polymer films, with electronic circuit boards related to information and communications, starting with computers and portable equipment and electronic circuit boards related to automobiles, starting with ITS.

Because of these implications, Sumitomo Chemical is moving forward with the development of electronic circuit board applications using films obtained with a solvent-casting method for a liquid-crystalline polymer we have newly developed.

In this paper, we will give an introduction to the status of this development.

Superiority of Liquid-crystalline Polymers in Electronic Circuit Board Applications

Thermosetting resins, starting with epoxy resins, cyanate resins and metamorphic PPE, are often used in conventional electronic circuit boards, such as for rigid circuit board applications. Because of the mis-match in coefficients of linear expansion with the metals used as conductors and problems with mechanical strength (very brittle), these thermosetting resins must be used with the reinforcement of glass cloth and aramid bonded-fiber fabrics, but the effects (workability, electrical properties) may also be problematic. Specifically, we can cite the properties for laser via hole making, plating and creation of dust on the workability side and reductions in dielectric properties and resistance to migration on the electrical properties side. Furthermore, there are problems with thickness precision, surface roughness and recycling.[4]

On the other hand, in addition to the rigid circuit boards that have been around conventionally, there are polyimide films that are typical of the substrate materials used for the flexible circuit boards for which growth has been remarkable in recent years. Polyimide is a material with superior mechanical strength, dimensional stability and electrical properties, and it is used as the standard substrate material for flexible circuit boards, but there are clearly problems in terms of dimensional precision and electrical properties in moisture absorbing environments. Furthermore, since polyimide has thermosetting properties, there are problems in terms of lamination and recycling.

From this point of view, there have been attempts in recent years to use recyclable thermoplastic resin films in electronic circuit board applications. **Table 1** gives the typical physical properties of various thermoplastic resins. For use in electronic circuit board applications, active components like IC chips and passive components like resistors and condensers must be mounted, and at that time connections are made with solder. Therefore, there is a need to be able to use these with lead-free solder reflow (approximately 260°C) because of environmental problems in recent years. Therefore, the only ones that can be used when viewed in light of

Table 1 Physical Properties of Various Themoplastics

	LCP (Type I)	PI (Thermotropic)	PEEK	PES	PPS	SPS
State Classification	LC	Amorphous	Crystal	Amorphous	Crystal	Crystal
Melting Point (°C)	340	—	334	—	278	270
Tg (°C)		250		220		
Moisture Absorption (%)	0.04%	0.34%	0.14%	0.43%	0.04%	0.02%
Flammability UL94	V-0	V-0	V-0	V-0	V-0	HB
Resistance of Hydrolysis	○	○	◎	○	○	○
Dielectric Constant 1GHz	3.0	3.0	3.3	3.4	3.4	2.6
Dielectric Tangent 1GHz	0.003	0.003	0.003	0.004	0.002	0.001

melting point and Tg are LCP and PEEK. An important factor in assuring a market as an electronic material is cost, and of these, PEEK is produced using expensive monomers, so it is much more expensive than LCP. Therefore, from the aspects of both cost and properties, liquid-crystalline polymers are presently the thermoplastic materials most suitable for electronic circuit boards.

Classification of Liquid-crystalline Polymer Films and Applicability for Electronic Circuit Boards

Roughly classifying liquid crystals, we can divide them into thermotropic liquid crystals where the liquid crystal phase is expressed with heat and lyotropic liquid crystals where the liquid crystal phase is expressed by dissolution in solvents, such as cellulose and polyamino acid, and aramids. Of these, the only ones that have been used industrially as electronic component materials are the wholly aromatic polyesters that belong to the thermotropic liquid crystals group because of their heat resistance and flame resistance. For convenience wholly aromatic polyesters are classified into type I, type II and type III according to their heat resistance. These classifications are summarized in **Table 2**, including typical molecular structures. The only ones of these that make it possible to use lead-free solder (approximately 260°C), which is an important factor for usability in electronic circuit boards as mentioned above, are types I and II.

Since these wholly aromatic polyesters express the liquid crystal phase specifically, there is a problem that it is very easy for the molecular chains to become ori-

ented in the direction of flow, and we do not get a usable level by simply forming a film. In the following we will discuss liquid-crystalline polymer film formation technology.
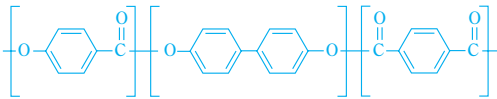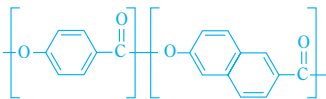
Conventional Liquid-crystalline Polymer Film Formation

Since, in terms of processing, liquid-crystalline polymer films have the characteristic of very easily being oriented, they are easily oriented unidirectionally, and there is said to be a problem in that it is extremely difficult to fabricate films drawn along two axes.[5]

For example, fabrication using extrusion, which is a typical manufacturing method for plastic films is extremely difficult. Liquid-crystalline polymers have the characteristic of the apparent molten viscosity falling in the direction of the external force when an external force is applied, and if the extrusion devices that are normally used with polyethylene terephthalate (PET) and the like are used, the molten polymer body that is extruded from the die (film extrusion slit) immediately draws down, and is not extruded as planned. In addition, if a LCP film that has been drawn vertically is drawn horizontally, the extruded film has already been oriented. Since, with the fiber bundles in this state, the interaction of the molecular chains (fibers) in the horizontal orientation is very weak, the edges of the film break off when the film is grabbed (the image being like packaging string).

Furthermore, there is the problem of not being able draw the film because only the part that is grasped has a molten flow and breaks off because of the external force, even if there is strict heating control for drawing

Table 2 Typical LCP Classified into Heat-Resistant Group

Type	LC Transition Temp. (°C)	Solder Resistance (°C)	Molecular Structure
I	330 ~	280 ~	
II	280 ~ 320	230 ~ 270	
III	~ 240	~ 190	

it. In addition, even though two-axis drawn films have been processed through such great effort and even though coatings and adhesives have been developed, there have been problems with separation of the layers when a strong external force is applied.

These problems are all caused by the fact that the molecular chains of liquid-crystalline polymers have rigidity and little flexibility (**Fig. 1**).
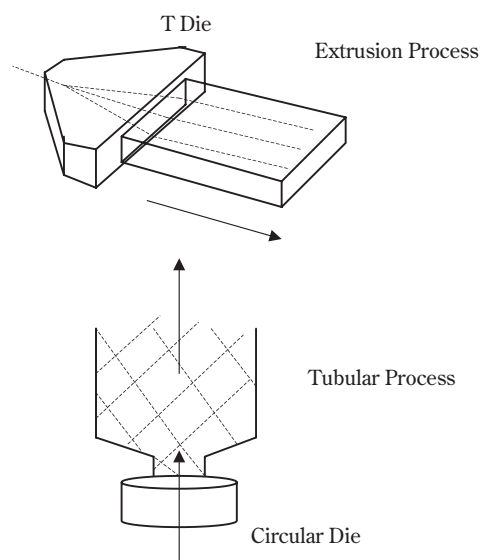

	LCP		Crystalline Polymer

Melt

Injection Molding

Solidify
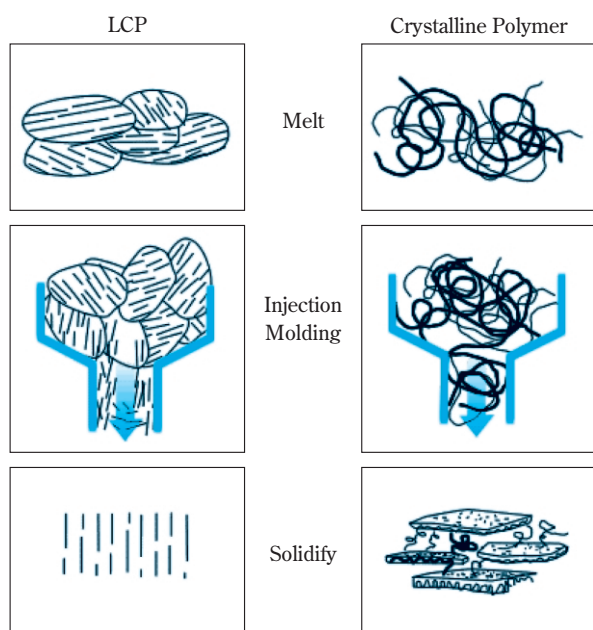
Fig. 1　Schematic representation of injection molding process

Normal polymers have flexibility, becoming entangled like boiled spaghetti. Even if the entanglement comes undone and there is elongation when a film is drawn at high temperatures, there is resistance to the drawing force with sufficient friction. However, there is no entanglement of the molecular chains of liquid-crystalline polymers with their rigidity, just like dry pasta, and they are characterized by forming a complete liquid lacking viscosity when melted (low molten viscosity). The ability to manufacture films is low because it is difficult to form a film, and lateral drawing is impossible unless it is supported by sandwiching with another film for support. Furthermore, since, with their rigidity, the molecules easily orient in the direction of a shear stress when one is applied with melting, the film produced cracks very easily, and this is the cause of its easily peeling off in thin layers like mica with its low interlayer peel strength.

With these problems, we can assume that various companies have used a variety of ingenuity in the pro-

duction of liquid-crystalline polymer films. For example, there is orientation in one direction (vertical) no matter what with the normal T die film forming for extruding molten resin in one direction, but a production method for obtaining a non-anisotropic liquid-crystalline polymer film by layering this on a fluorine based heat resistant film and carrying out supported lateral drawing has already been reported.[6] In addition, attempts are being made at two-axis drawing in the direction of extrusion (vertical) and the direction perpendicular to it (horizontal) using a tubular process where the molten resin is extruded in a cylindrical shape and the cylinder directly inflated in the lateral orientation by internal air pressure (**Fig. 2**). Whether extruded upwards or downwards, the molten viscosity is too low, and liquid-crystalline polymers easily change to draw down. Even if the tubular process is used for forming the film, it cannot be thought of as being easy, but there has already been a report of a manufacturing method for a liquid-crystalline polymer film that controls molten drawing down producing a vertically non-anisotropic film.[7]


Fig. 2　LCP film fabrication process

Film Formation Using the Liquid-crystalline Polymer Solvent Casting Method (New Method)

With films formed by the extrusion and tubular process mentioned above, where the LCP is substantially melted, it is very difficult to solve the problems of vertical anisotropy and interlayer peeling of the film

because of the peculiar alignment characteristics. Therefore, we thought that if we used a solvent casting method, like that used in the production of polycarbonate, polyimide and other plastic films, where, after dissolution in a solvent, the solvent is eliminated to obtain the product, we could obtain a non-anisotropic film because the film could be produced without melting the liquid-crystalline polymer, and we started research and development.[8]

When solvent-casting method has been used conventionally, the liquid-crystalline polymer is first dissolved and used, the liquid-crystalline polymers that are on the market will only dissolve in extremely expensive fluorine phenol solvents that are difficult to handle, such as those shown in **Fig. 3**. Therefore, the industrialization of this idea has been thought to be fundamentally impossible. In addition, even if it is dissolved in some solvent for a substantial period, the length of the molecules with rigidity (Kuhn length) is short, and the concentration of parts with rigidity becomes too low when dissolved. It turns into a normal liquid and a solution without liquid crystals, so it has been thought we cannot expect the properties unique to liquid crystals. To verify this, we examined the forming of a film by dissolving a polymer with the same skeleton as the famous liquid-crystalline polymer (X7G) developed by Eastman Kodak Co. for a semi-aromatic liquid-crystalline polymer in trifluoroacetic acid. The film obtained was a spongy film with the liquid-crystalline polymer molecules having rigidity being oriented in arbitrary directions, so brittle that it could be broken by blowing on it, and it was certainly not of a level that would be useful.[5]
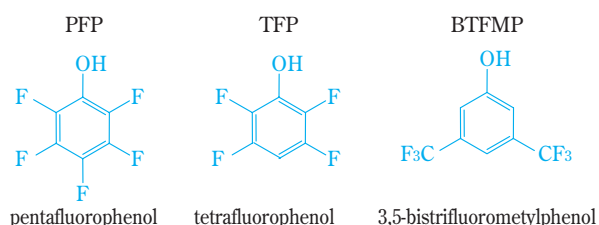
Fig. 3   Standard solvents for LCP

However, as a result of continued investigations at Sumitomo Chemical, we found that solvent-cast films that were flexible and had sufficient strength were obtained by dissolving LCP with a specific monomer composition in a specific solvent. The molecular design

of the liquid-crystalline polymer is originally one where the crystallinity of a homopolymer formed from insoluble, non-melting para hydroxyl benzoic acid as shown in **Fig. 4** is broken down through the introduction of copolymer components, and the liquid crystallinity, which is an intermediate state, is obtained. Since it is dissolved in the specific solvent at Sumitomo Chemical, we reassessed our thinking about this molecular design from the origins for the investigation.
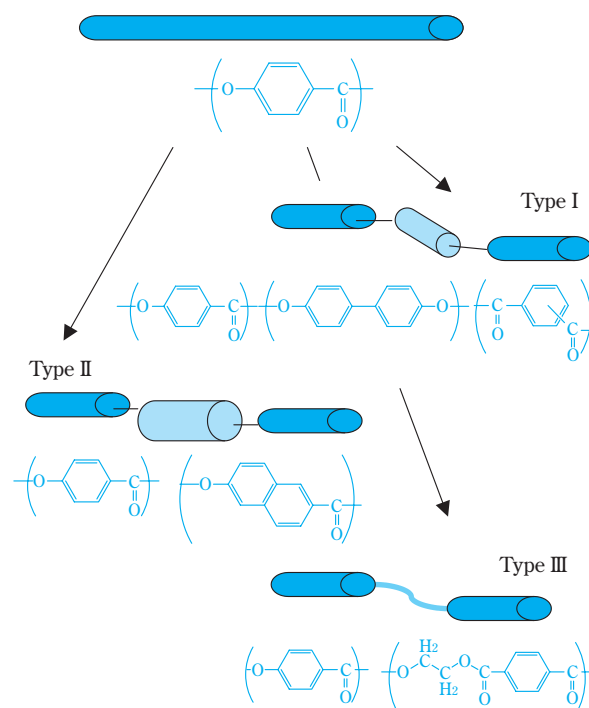

Fig. 4   Conceptual origin of molecular design of LCP

The liquid-crystalline polymer solution obtained in this manner is casted on a supporting body, and solvent drying is carried out at a low temperature of 100°C.

At this point, the liquid-crystalline polymer is in an amorphous (non-crystalline) state, and the film is transparent. This is further heat treated at high temperatures to orient the liquid crystals, and a semitransparent to opaque film is obtained (**Fig. 5**). The gas barrier properties (water vapor penetration and oxygen penetration) and the like that characterize the liquid-crystalline polymer in the transparent film from the initial drying being approximately 1/10 of the expression in the oriented liquid crystal semi-transparent to opaque film has been reported.[9] Therefore, if it is actually to be used as a film with the characteristics of conventional liquid-crystalline polymers for electronic materials, it

must be processed at high temperatures. To optimize the heat treatment temperature for this liquid-crystalline polymer solvent-cast film, we carried out investigations using positron annihilation methods in this research and development.
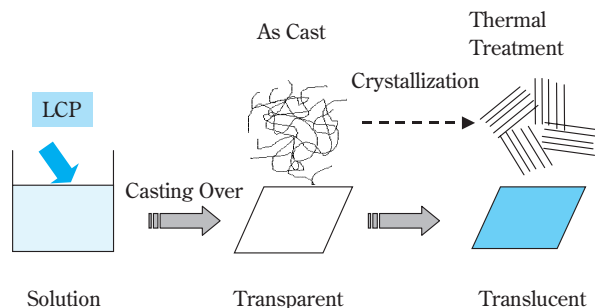
Dry-up process of LCP solvent-casting film

Optimization of Heat Treatment Conditions for Liquid-crystalline Polymer Film (Using Positron Annihilation)

The liquid-crystalline polymer is a wholly aromatic copolymer polyester as shown in Table 2, and it is difficult to obtain the quantitative changes in the pseudo-crystalline phase formed from part of the monomer expressed with heat treatment through methods such as the X-ray diffraction used to analyze conventional polymers. Therefore, in this research, we investigated the heat-treatment conditions using a method known as positron annihilation, which is extremely sensitive to structural changes, along with conventional thermal analysis (DSC and DMA).

1. Positron Annihilation

The positrons used in positron annihilation are extremely unstable antiparticles, and they are obtained through the production of pairs due to the interaction of the β^+ breakdown and high energy γ rays from radioisotopes (RI) with substances. When used for analysis of polymer materials, there is an interaction with the orbital electrons in the atoms and molecules and the free electrons after the positrons having high energy lose energy to heat conversion with the incidence of the positrons, and pair annihilation occurs. At this time, the radiated pair annihilation γ rays carry the information on the annihilated companion electrons, and the characteristics of the polymer material can be analyzed from this information. The method for doing

so is positron annihilation. Measurements of the positron annihilation lifetime and measurements of the Doppler spread of the pair annihilation γ rays are typically made in positron annihilation. Positron annihilation lifetime measurements were used in this research.

2. Positron Annihilation Lifetime Spectroscopy (PALS)[10]

^{22}Na (half life 2.6 years) was used as the positron beam source.

The positrons for this beam source exhibit an energy distribution in the range of 0 – 500 keV with a peak in the neighborhood of 200 keV. At the same time as the emission of positrons due to the β^+ destruction from ^{22}Na, 1,247 keV γ rays are emitted, but these γ rays show the time of emergence of the positrons. The positron lifetime is obtained by measuring the time lag to the 511 keV γ rays emitted due to pair annihilation. **Fig. 6** shows a schematic of the test apparatus. The γ rays are detected by the detector on one side, and using an energy differentiating constant fraction differential discriminator (CFDD), the 1,274 keV γ rays can be selected. In addition, the 511 keV γ rays are detected by the CFDD for the other detector, and these signals are sent to a time to amplitude converter (TAC) as Start and Stop signals. The output of this is input to a multi-channel analyzer (MCA). In a PALS test for polymer materials like that shown in **Fig. 7**, a lifetime curve is obtained.

In most cases, positronium (Ps) is formed in the polymer. Ps has a structure formed from positrons and
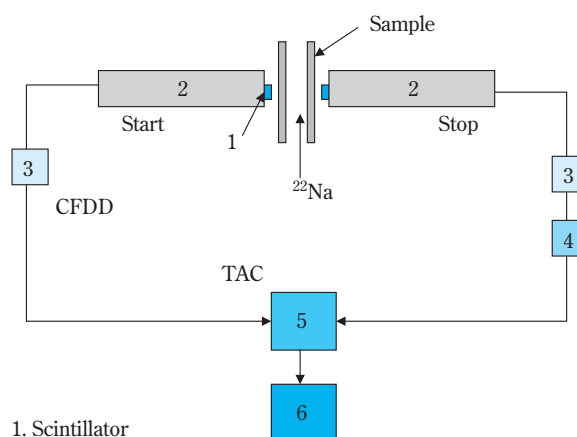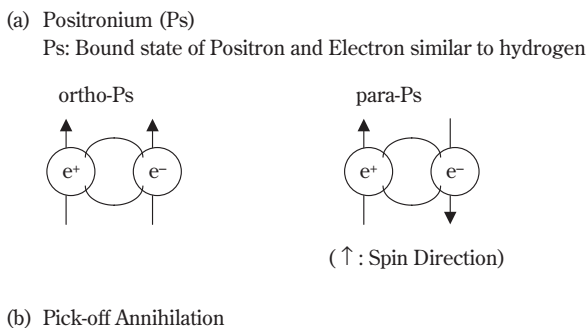

1. Scintillator
2. Photo-Multiplier
3. Constant Fraction Differential Discriminator
4. Delay
5. Time to Amplitude Converter
6. Multi Channel Analyzer

PALS System

6

Digital
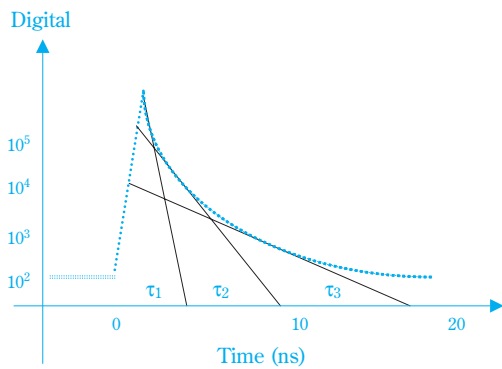
Fig. 7 Typical lifetime spectrum of polymer material for PALS system

electrons similar to hydrogen atoms, and it forms two states according to the spin state, para (p-Ps) and ortho (o-Ps) in a proportion of 1:3. p-Ps is annihilated with the emission of two photons, and its intrinsic life is 125 ps (usually shown as τ_1). The intrinsic life of o-Ps in a vacuum is 140 ns, and it is captured in the voids in the polymer. It interacts with the electrons in the vicinity of the voids and undergoes pick-off annihilation, with a short life of several ns (τ_3). The life (τ_2) for annihilation of free positrons without the production of Ps is 300 – 400 ps (**Fig. 8**).

(a) Positronium (Ps)
    Ps: Bound state of Positron and Electron similar to hydrogen

ortho-Ps   para-Ps

($\uparrow$: Spin Direction)

(b) Pick-off Annihilation

Fig. 8 Schematic illustration of positronium (a) and positronium reaction (b)

Of the lifetimes used with PALS, τ_3 shows the lifetime to annihilation correlated with the size of the voids where o-Ps is dispersed within the polymer and selectively trapped in voids. Therefore, the relationship with the void is given by Equation (1).

Along with this information about the voids, it is possible to estimate structural changes in combination with DSC, DMA and other thermal behavior analyses.

$$1/\tau_3 = 2 \times (1.0 - R/R_0 + \sin(2\pi R/R_0)/2\pi) \quad (1)$$

$$\begin{bmatrix} R_0 = R + \Delta R \ (nm) \\ \Delta R = 0.166 \ (nm) \end{bmatrix}$$

Here, an infinitely large walled well potential (radius R_0) is assumed, and Equation (1) is found by calculating the overlap of the electron layer (thickness of ΔR) running from the wall and the wave function for o-Ps.

3. PALS Measurements on LCP Cast Film[11)]

In **Fig. 9** a) and b) ●, the solid dots show the lifetimes τ_3 for the case where the as-cast liquid-crystalline polymer film was heated raising the temperature 2.5°C/hour from 40°C to 250°C, and the corresponding changes in intensity I_3 for those lifetimes are shown.

Four temperatures (140°C, 170°C, 200°C and 235°C)
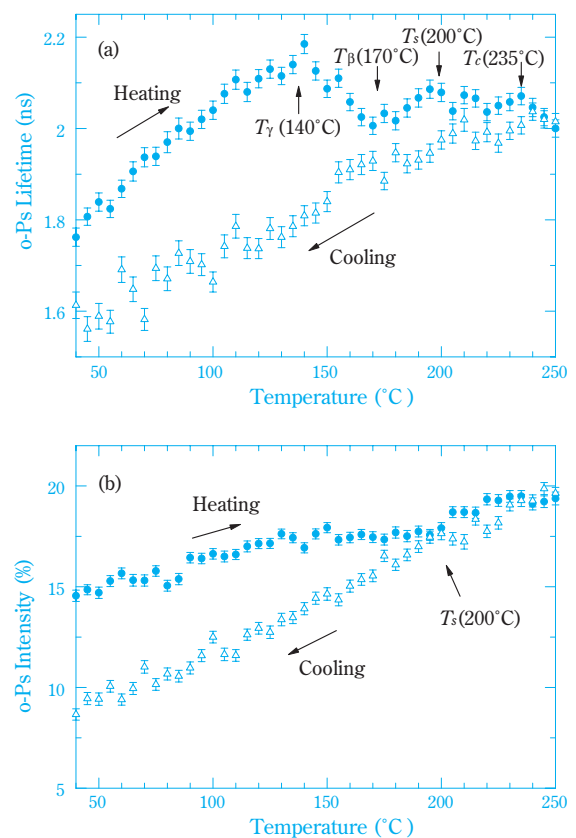
Fig. 9 The temperature dependencies of the ortho-positronium lifetime T_3 (a) and intensity I_3 (b) of the as-cast film over the high temperature range from 40 to 250°C at the heating and cooling rate of 2.5°C/h

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exhibiting characteristic behaviors can be observed.

It can be seen that the lifetime τ_3 suddenly drops at 140°C (T_r) in the process of raising the temperature, but this indicates that the free volume has suddenly been reduced. From the DSC measurement results in **Fig. 10**, this transition can be thought of as being a reorientation process because of crystallization of the unstable noncrystalline structure obtained when the solvent volatizes.
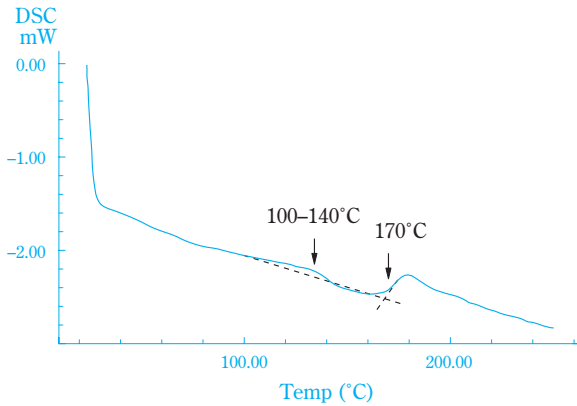
**Fig. 10**   DSC thermogram of the as-cast film on the 1st heating process at rate 10°C/min.

With a further increase in temperature, the decrease in the lifetime τ_3 stops temporarily at 170°C (T_β). From the DSC measurement results, we can assume that this 170°C corresponds to the glass transition temperature (T_g). Further increasing the temperature, τ_3 increases at 200°C (T_S) and remains almost constant. As a result of carrying out DMA measurements (**Fig. 11**) to clarify these subtle changes, it was found that T_S is the tem-
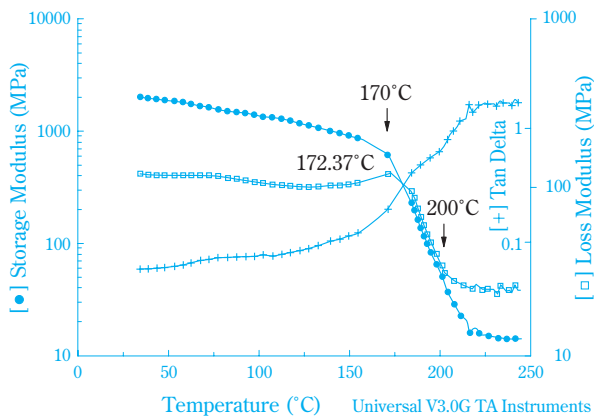
Fig. 11   DMA data of the as-cast film on the 1st heating process at rate 10°C/min at frequency 10Hz

perature where the coefficient of elasticity decreases remarkably. If the temperature is raised further above 200°C, τ_3, which was almost constant, begins to drop again at 235°C. It is thought that this temperature is the temperature where crystallization initiates.

On the other hand, for the lifetimes τ_3 during the temperature reduction process for a film heated to 250°C and the corresponding changes in intensity I_3 for those lifetimes are shown by the triangles in Fig. 9 a) and b) △. Transitions as clear as those seen in the process of increasing the temperature were not seen in the temperature reduction process. In addition, the lifetime τ_3 exhibited a relatively small value compared
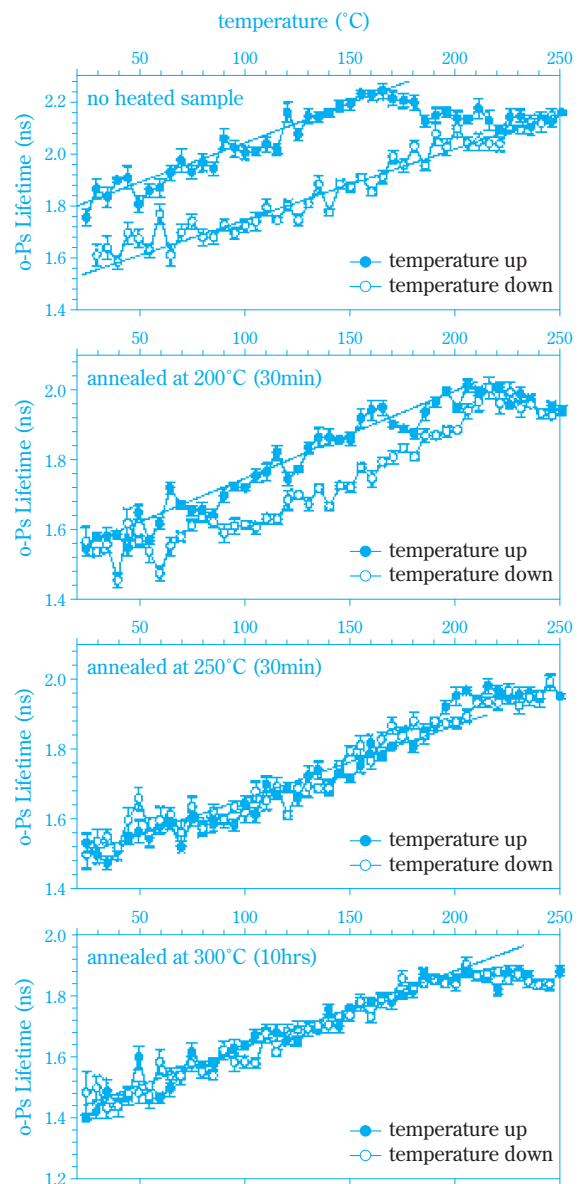
Fig. 12   The temperature dependencies of the ortho-positronium lifetime T_3 of the as-cast film over the high temperature range from 40 to 250°C at the heating and cooling rate of 2.5°C/h

with the process for increasing the temperature, and the film that has been heated to 250°C has reduced free volume. Therefore, this shows that irreversible crystallization progresses with heat treatment at 235°C or higher.

To back up the above results, **Fig. 12** shows the lifetime τ_3 for samples of liquid-crystalline polymer film where the heat treatment conditions have been changed and the corresponding changes in intensity I_3. The differences between the behavior in the processes of increasing the temperature and lowering the temperature in heat treatment at 250°C or higher can mostly be seen. From this it was found that a film with stable characteristics could be obtained if heat treatment was carried out on liquid-crystalline polymer films at 235°C or higher.

Characteristics of Liquid-crystalline Polymer Cast Films

Liquid-crystalline polymer solvent-cast films obtained in this manner with heat treatment at 235°C move from an amorphous state to the film that is applied with heat treatment, so the anisotropy that was a problem in the processing of liquid-crystalline polymer films does not occur, as is shown in **Fig. 13**, and they are films superior for use in isotropic electronic materials. In addition to exhibiting the following characteristics that are equal to films obtained through extrusion and tubular process, they are characterized by exhibiting a tear strength with a value of approximately 1.5 times that of films obtained through the melting obtained in tubular process and the like
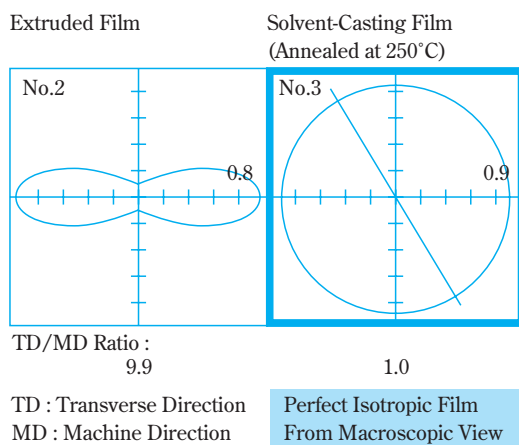
Fig. 13 Orientation Characteristics measured by Microwave Orientationmeter
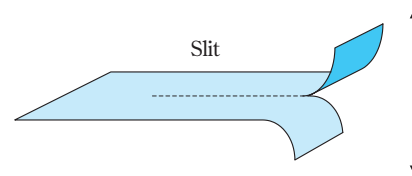
	Solvent-Casting	Tubular Process
Tear Propagation Resistance (mN)	62	39

Fig. 14 Tear property of LCP films

because they are not anisotropic (**Fig. 14**).

1. Water Absorption

The results of water absorption evaluations are given in **Table 3**. In terms of water absorption, a comparison with the polyimide in Table 3 shows that the values are approximately 1/10. Because of this, change due to the environment is more difficult and superior dimensional stability with water absorption is exhibited.

Table 3 Moisture Absorption Property

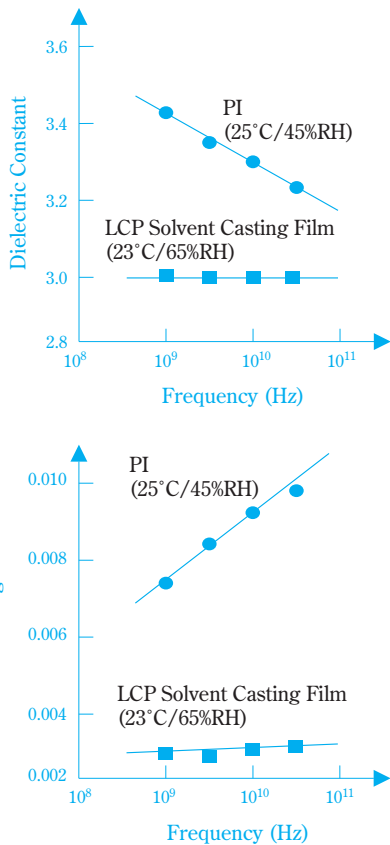|	LCP Solvent – Casting Film	Polyimide Film
85°C / 85%RH 168Hr	0.1%	1.2%

2. Electrical Properties

Fig. 15 shows a comparison of the 1 – 25 GHz dielectric properties for the LCP solvent-cast film and polyimide. We can see that LCP has dielectric stability over a wide range of frequencies and superior low dielectric loss characteristics.

3. Thermal Properties

Table 4 gives the results of evaluations of the thermal properties of the LCP cast film. The LCP solvent-cast film exhibits the excellent solder heat resistance from 260 – 280°C for a thermoplastic films. In addition, the thermal conductivity is of the highest level, and we can expect an improvement in heat dissipation when IC chips are mounted to the insulation film.

4. Mechanical Characteristics

The results of evaluations of mechanical characteristics are given in **Table 5**.

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Fig. 15 Dielectric property of LCP solvent-casting film

Table 4 Thermal Properties of LCP Solvent – Casting Film

	LCP Solvent – Casting Film	Polyimide Film
Solder Resistance 260°C × 120sec	OK	OK
Melting Point	300~380°C	—
Tg	170°C	> 500°C
Thermal Conductivity	0.4mW/K	0.2mW/K

Table 5 Mechanical Properties of LCP Solvent – Casting Film

	LCP Solvent – Casting Film	Polyimide Film
Tensile Strength (MPa)	120	250 – 400
Tensile Modulus (GPa)	3.6	3.5 – 9
Elongation at Break (%)	10	30 – 80
Holding Endurance R=0.38	20000	5000 – 10000

While the tensile strength and tensile modulus are inferior to polyimide, it has the flexibility peculiar to thermoplastic films, and the flexibility is superior at two times or more that of polyimide.

Applications for Liquid-crystalline Polymer Cast Films in Electronic Circuit Boards

The present development of applications for liquid-crystalline polymer solvent-cast films is moving forward centered on the following two themes.
– FPC boards (single layer and multi-layer circuit boards)
– Embedded Circuit Board (components embedded into substrates)

The development of these applications is gathering strength, and the strength of LCP solvent-cast films versus other materials and other companies' (obtained from extrusion and inflation processes) LCP films is as follows.

Versus other materials such as polyimide and epoxy resins
– Law water absorption
– Excellent heat resistance
– Storage stability
– Self fusing properties (capable of lamination without adhesives or prepreg)
– Various characteristics in moisture absorbing environments (dimensional stability, insulating properties and high frequency characteristics)
– Flexibility
– Thermal conductivity
– Environmental compatibility
– Recyclability

Versus other companies' (other methods) LCP
– Less anisotropy
– Less inner layer peeling (adherence with metal)
– Thin film compatibility
– High Loading properties of filler
– Impregnation properties for substrates (prepreg and bonded material)

Conclusion

By succeeding in the dissolution of liquid-crystalline polymers and development of solvent-cast films, it can be assumed that Sumitomo Chemical has made applications in substrates incorporated into components which use films with a high level of filler difficult with conventional extrusion and tubular process, applications for heat dissipating substrates, rigid circuit boards based on production of prepreg where glass cloth and the like is impregnated and 2 – 10 μm ultra
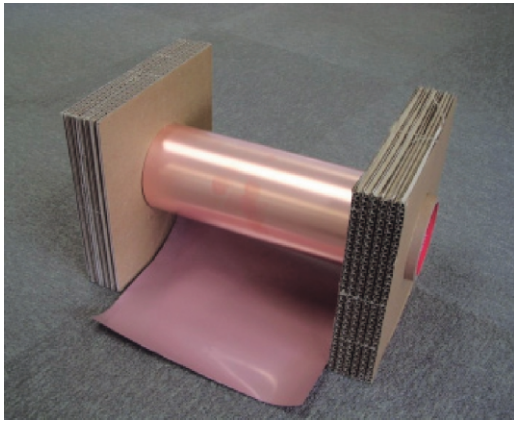
Fig. 16 Our Newly Developed LCP solvent-casting film

thin film formation possible in addition to developing flexible printed circuit boards (FPC) and multi-layer boards for which specific development has already started, greatly expanding applications for liquid-crystalline polymer films (**Fig. 16**).

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