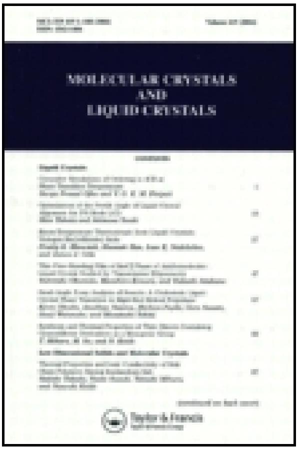

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The Application of Liquid Crystal Polymer Properties

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THE APPLICATION OF LIQUID CRYSTAL POLYMER PROPERTIES

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Abstract

Liquid crystal polymers offer a unique combination of properties to the end user. These typically include low melt viscosity, fast cycle times, moulding to tight tolerances, very low mould shrinkage/warpage/sinking, excellent mechanical properties, good solvent resistance, low flammability, high continuous use temperature, excellent solder resistance, low thermal expansion, excellent barrier properties, and low water absorption. Some of these properties are exhibited by conventional amorphous polymers, others by conventional crystalline polymers, but only liquid crystal polymers can provide this complete range of advantages. Many of these properties are common to all liquid crystal polymers. Differences arise primarily in processing conditions, high temperature performance, mechanical properties and cost. Potential applications of liquid crystal polymers arise directly from this unique combination of properties. These include precision moulded small components, complex extrusion profiles, film exhibiting excellent barrier properties, high strength/modulus fibres, and novel composites.

1 INTRODUCTION

Both thermotropic and lyotropic liquid crystal polymers (LCP's) have been intensively studied and developed for commercial applications. Lyotropic polymers decompose before the melting point is reached and are processed from solution into fibre and film. Thermotropic polymers can be melt processed, permitting the production of injection mouldings in addition to fibre and film. Current industrial activity is concentrated on main chain thermotropic LCP systems for injection moulding applications.

2 DESIGN CONSIDERATIONS

Anisotropy, the skin/core morphology, and weakness at a weld line all need to be considered when designing components in LCP's.

Anisotropy of articles arises from the ready molecular orientation (by flow, electric or magnetic fields or surface interaction) and relatively long relaxation times. During melt processing, orientation is primarily produced by extensional flow in fountain flow at the advancing front in injection moulding, and in draw down during fibre spinning. The addition of fibrous and particulate fillers reduces the anisotropy of LCP mouldings. This is the reverse of that experienced with conventional thermoplastics, where the addition of reinforcing fibres introduces/ increases anisotropy.

The skin/core morphology produces a 'composite' moulding for which the properties can be approximately calculated from the contributions of the skin and core. Molecular orientation at the advancing front during injection moulding produces an oriented skin, in the direction of flow, whereas the core is essentially disordered. The skin macrolayers exhibit superior properties to the core, the latter being more typical of a conventional thermoplastic. The relative proportions of skin and core depend on the polymer, processing conditions and thickness. Decreasing the thickness of the sample increases the relative proportion of skin in the moulding and therefore improves the mechanical properties.

A weld line is produce in a moulding when two flow fronts meet, and is a point or weakness. Seam type weld lines are stronger than butt (head-to-head) weld lines. This effect is observed with fibre reinforced conventional thermoplastics. Moulds should be designed to minimise the effects of weld lines by locating them in non-critical positions.

3 PROPERTIES/APPLICATIONS

Liquid crystal polymer can be classified into three basic structural types, which can be considered to be targeted at different application areas.

Type	Structure	
		↓ Decreasing processing temperature, heat distortion temperature, continuous service temperature
I	Aromatic, rigid, linear	
II	Aromatic, rigid, disrupted	
III	Semi-rigid	

Essentially all LCP's will exhibit the fundamental properties of low melt viscosity, low mould shrinkage, low thermal expansion and good solvent resistance. Differences arise primarily in processing conditions, high temperature performance (heat distortion temperature, HDT, and continuous use temperature), mechanical properties, and cost. Applications den nding the highest temperature performance generally require type I LCP's. Lower temperature application requiring a less fibrillating LCP favour type III LCP's. Type II LCP's are expected to be potential candidates for the largest volume of LCP applications.

3.1 Low melt viscosity

The low melt viscosity of LCP's enables their use:

a) to injection mould components with long or complex flow paths and thin sections.

b) at very high filler loadings (up to 70% w/w).

c) as processing aids; addition of 10% w/w LCP approximately halves the melt viscosity of a conventional thermoplastic. Obviously, the processing temperatures of the two polymers must overlap.

3.2 Outstanding dimensional stability/low thermal expansion

LCP's exhibit very low mould shrinkage (Figure 1) and minimal sinking and warpage, permitting precision moulding of components. In addition, low moisture absorption and thermal expansion produce very low post moulding changes in dimension. The low thermal expansion of LCP's is similar to metals and glass (Figure 2). Therefore in components with an LCP and metal (or glass) in contact, thermal cycling or shock of the part causes similar expansion of both materials and prevents separation or cracking. This permits the use of LCP's in applications such as surface mount devices and optical fibre sheathing.

3.3 Excellent mechanical properties

Unfilled LCP's exhibit exceptional stiffness and strength compared with conventional polymers, even when the latter are glass fibre reinforced (Figure 3). Therefore high strength/modulus fibre can be spun, which is used in protective clothing, etc. Mechanical properties decrease with increasing temperature, as for conventional crystalline polymers. However, the excellent room temperature properties ensure useful mechanical properties at temperatures in excess of 200°C. In common with other polymers, LCP's used under load for long periods of time

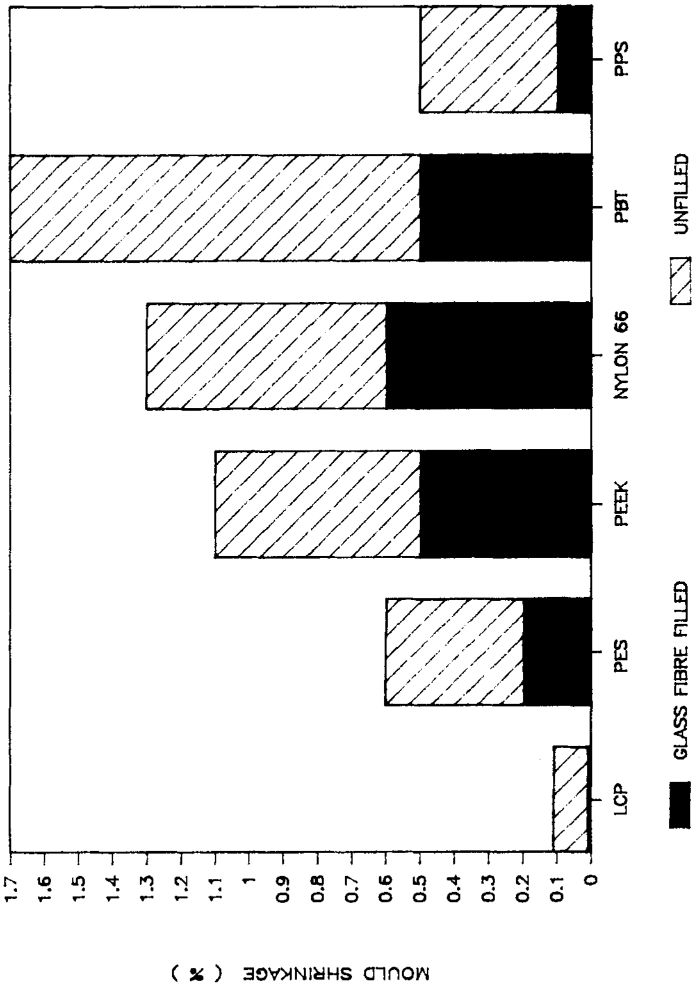

FIGURE 1 Mould Shrinkage of Thermoplastics

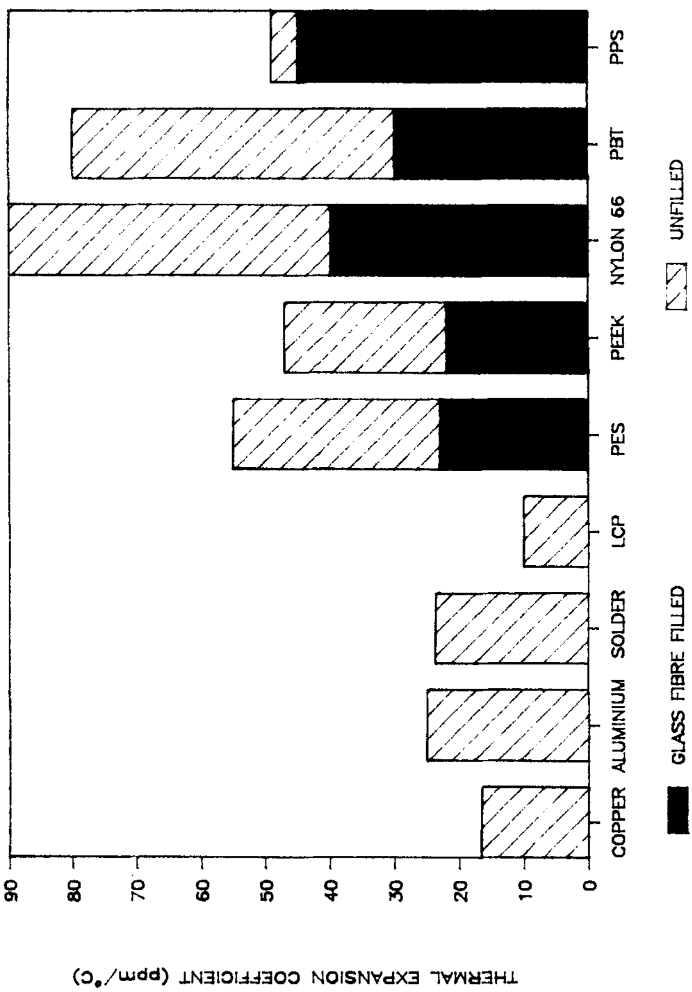

FIGURE 2 Linear Thermal Expansion Coefficient of Thermoplastics

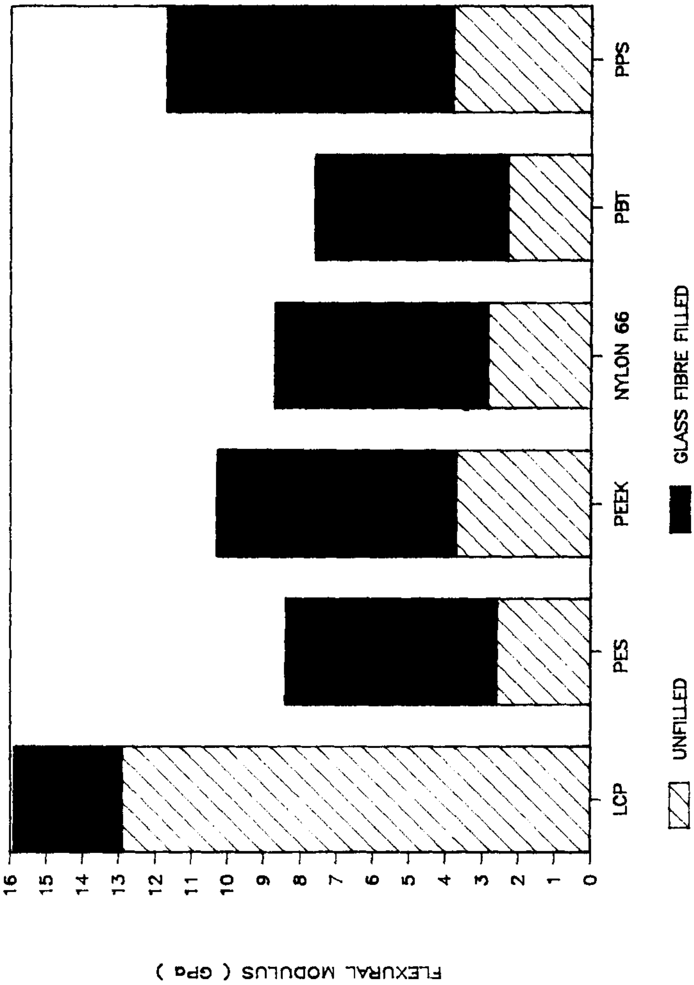

FIGURE 3 Flexural Modulus of Thermoplastics

will exhibit creep. The addition of glass fibre to LCP's significantly increases creep resistance. LCP's exhibit good fatigue resistance, permitting their use in applications involving vibration or cyclical loading.

3.4 Good high temperature properties

LCP's have high heat distortion temperatures (which are increased by the addition of glass fibre) and high continuous use temperatures. This permits use in environments such as under car bonnets.

3.5 Excellent Solder Resistance

LCP components exhibit excellent solder resistance, without drying, permitting their use in a wide range of electronic applications.

3.6 Low flammability

Liquid crystal polymers generally have VO flammability ratings and high limiting oxygen indices, and relatively low smoke and toxic gas emission on burning.

3.7 Excellent environmental resistance

LCP's exhibit excellent barrier properties and resistance to inorganic and organic solvents, weathering (U.V. degradation), and radiation, enabling their use in aggressive environments. Their excellent barrier properties offer potential use in film packaging.

CONCLUSION

The unique property profile of LCP's offers potential solutions to problems which conventional materials are unable to solve. Initial applications arise from this combination of properties, which is of particular interest to the electronic/electrical and automotive markets. However, as with other materials, unexpected applications will also arise. Activity within the chemical industry is high and further announcements of new LCP's are expected.