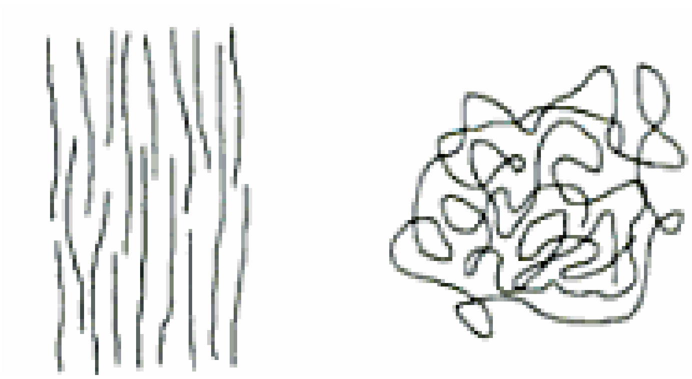
Liquid Crystal Polymers

Liquid Crystal Polymers (LCPs) make up a family of thermoplastics which have a unique set of properties. They perform very well in harsh environments, including high heat resistance and tolerance, high electrical resistance, and high chemical resistance. Unlike other polymers such as ABS or nylon, LCPs show a high degree of anisotropy in both solid and liquid crystal phases. This means that the strength, stiffness, and thermal expansion will be greater in one direction, not the same in every direction. The three most commonly used LCPs are PET copolyester, copolyamide, and polyester-amide, however others are also possible.

LCPs have a highly crystalline molecular chain in comparison to most common polymers such as ABS and nylon. They exhibit a semi rigid, nearly linear, stacked orientation of molecules which stay highly ordered even in the liquid crystal phase as shown in Fig. 1 (a) below. This is in comparison to the molecular structure of ABS and nylon which have intertwining molecular chains, shown in Fig. 1(b). This special stacked molecular architecture of LCPs creates anisotropic tendencies which introduce many fascinating properties.



(a) (b)

Fig. 1: (a) Stacked molecular interaction of LCPs. (b) Intertwined molecular interaction of most thermoplastics such as ABS and Nylon

The reason for anisotropy is the primary bonds within the molecule, causing a high attractive force within the molecule itself. The molecules are bonded together by less attractive secondary bonds, making them more susceptible to separation. When a force is applied transverse to the molecular orientation the secondary bonds receive the majority of the load resulting in easier separation. Conversely, a load in the longitudinal direction more heavily loads the primary bonds of the molecules resulting in a higher difficulty of separation.

LCPs are most easily injection molded, although it is possible to use other processing techniques to accommodate the material. The melt temperature of LCPs is between 280-330ºC, and mold temperatures should be between 70-130ºC. The molecular chains in the melt are highly oriented along the direction of the resin flow. For this reason, careful attention needs to be given to the gating locations on the mold to achieve the desired resin flow, which will dictate final molecular orientation and anisotropic properties. This has a significant effect on the final part, as anisotropic dependent properties such as tensile strength, thermal expansion, and elastic modulus, can be up to three times greater in the longitudinal versus the transverse direction.

LCPs demonstrate good cycle repeatability due to their high melt flow and low thermal expansion in the direction of molecular orientation. This allows thin walled parts be easily molded without the part warping. LCPs also show a high resistance to heat, burning, weather and UV rays, and very good electrical insulation properties. LCPs are very resistant to hydrolysis, weak acids and bases, alcohols, aromates, chlorinated hydrocarbons, esters, and keytones throughout a wide range of temperatures. They also display good mechanical properties, with high strength, modulus of elasticity, and toughness. Table 1 below illustrates the difference between longitudinal and transverse thermal expansion in LCPs, and also compares it to the thermal expansion of 2 other common polymers. The coefficient of thermal expansion given in Table 1 measures the meters of expansion per degree Celsius per meter.

	DuPont Zenite (LCP)	Generic ABS	Generic Nylon
Linear (10^{-6}/ ºC)	0-.007	0.074-0.123	0.080-0.120
Transverse (10^{-6}/ ºC)	0.022-.062	0.072-0.116	0.090-0.150

Table 1: Linear and Transverse Coefficients of Thermal Expansion for LCP, ABS, and Nylon

Although LCPs have many unique advantages, they also have disadvantages which are important to be aware of. The anisotropic nature of the material causes weakness at weld lines where the material meets in different molecular orientations. Also, because the direction of thermal expansion is influenced by the orientation of the molecules, warpage can occur in parts which have different degrees of molecular orientation. Both of these issues are easily remedied by choosing appropriate gate locations. The cost of LCPs is also somewhat higher than more traditional polymers, but because of its superior properties it stays competitive in many applications. A cost comparison for LCP, ABS, and Nylon can be seen in Table 2.

	DuPont Zenite (LCP)	Generic ABS	Generic Nylon
Approx. Cost per Pound	$16.25	$1.50	$3.25

Table 2: Cost Comparison of LCP, ABS, and Nylon

LCPs are used in many applications that would not be feasible with other polymers. Because of their high operating temperature (often over 200 ºC), LCPs are often used for oven handles and engine shields. Chemical resistance and high strength makes them well suited for modern high pressure fuel line connectors in the automotive industry. And because of their electrical insulating properties, LCPs make excellent electrical device housings and semiconductor components.

References:

[1] Campo, E. Alfredo, *the Complete Part Design Handbook*, Hanser, 2006

[2] Osswald, et al, *International Plastics Handbook*, Hanser, 2006