

Tribological enhancement effect of main-chain thermotropic liquid crystalline polymer

Fanglin Xu, Yuanshi Xin, Tongsheng Li*

State Key Laboratory of Molecular Engineering of Polymers, Department of Macromolecular Science, Fudan University, Shanghai 200433, China



ARTICLE INFO

Keywords:

- A. Polymer-matrix composites (PMCs)
- B. Interface/interphase
- B. Microstructures
- B. Wear

ABSTRACT

Although main-chain thermotropic liquid crystalline polymer (LCP) has been extensively investigated as self-reinforcing composites, tribological application is rarely reported. This paper explores tribological enhancement effect of LCP on representative matrix poly(vinylidene fluoride) (PVDF). Moreover, structures of PVDF/LCP blends are assessed in detail. Due to immiscibility, LCP in blends is uniformly dispersed in the form of particles or microfibrils, dependent on LCP content. Besides, LCP improves storage modulus of PVDF. Most importantly, tribological performance of PVDF is obviously promoted. Compared with neat PVDF, the wear rate, coefficient of friction and oscillation amplitude of blend containing 20 wt% LCP simultaneously decrease by 97.7%, 80.7% and 80.2%, respectively. In particular, frequency-enhancement phenomenon is observed. By probing worn PVDF domains with nanoindentation test and atomic force microscopy (AFM), preliminary tribological enhancement mechanism of LCP is unveiled. Overall, this finding provides a new, but promising lubrication route of polymer.

1. Introduction

Complexity, cost, contamination and environmental constraints of systems preclude alternative lubrication strategies, e.g. fluid and grease lubrication. Hence, polymers are increasingly necessary in many tribological applications, such as gears, compressor, and bearing components [1–3]. The most commonly used polymers include high-density polyethylene (HDPE), acetal, polyamide (PA), polyimide (PI), polytetrafluoroethylene (PTFE) and polyphenylene sulfide (PPS) due to superior properties of self-lubricating, ease of manufacturing, and lightweight, compared with ceramic and metal couples [4–6]. The low shear strength of lamellae enables PTFE to be a type of superb self-lubricant [7]. Besides, HDPE also exhibits low coefficient of friction due to obvious chains orientation under friction [8]. To further reduce coefficient of friction, additional solid lubricants (e.g. graphite) are commonly needed [9]. On the other hand, the wear resistance is correlated with strength and stiffness, frequently enhanced by introducing reinforcing fillers (e.g. carbon fiber, glass fiber) [10]. However, higher coefficient of friction is often observed. Conventionally, solid lubricants and reinforcing fillers are needed to be simultaneously introduced to lower friction and wear rate, respectively.

Thermotropic liquid crystalline polymer (LCP) has attracted more and more interest, owing to excellent dimensional stability, low melt viscosity and high strength, stiffness and chemical resistance [11–15]. In general, thermotropic LCP is classified into two groups, i.e. main-

chain LCP and side-chain LCP, in terms of the sites of liquid crystalline moieties. With respect to main-chain LCP, more effective approach is to use it as a minor component to enhance thermoplastic polymer (TP) blends due to anisotropic properties and high cost. In this case, there are two advantages [11,12]. On one hand, LCP obviously reduces processing viscosity of TP blends, arising from high shear thinning and orientability properties of LCP. On the other hand, the formation of LCP microfibrils is often achieved in TP/LCP blends under suitable processing conditions, which is mainly attributed to high long-range order of chains along the flow or drawing direction during injection and extrusion. Consequently, LCP microfibrils drastically enhance TP blends and give rise to *in situ* or self-reinforcing composites. The poly(L-lactide) (PLLA)/LCP blend system was studied by injection [14]. As regards blend system containing 30 wt% LCP, dynamic storage modulus (E') reached 10.7 GPa at the room temperature, which even surpassed that of pure LCP. Moreover, the large decrease of E' in the vicinity of PLLA α -relaxation temperature was also absent. The authors attributed the enhancement behavior to self-reinforcement of LCP microfibrils formed in the blend.

In principle, friction is the resistance to slide as relative sliding of contact interfaces occurs [16]. With respect to polymers, friction is always associated with energy dissipation almost arising from viscoelastic relaxation behavior [17,18]. In this regard, the dependence of friction force on sliding frequency corresponds well to that of viscoelastic loss factor on frequency, which is often employed to explore

* Corresponding author.

E-mail address: lits@fudan.edu.cn (T. Li).

Table 1
Properties of PVDF (FR902) and LCP (Vectra A950).

Sample	Density (g/cm ³)	MFI (g/10 min)	T_g (°C)	T_m (°C)	T_i (°C)	Tensile strength (MPa)
PVDF	1.77	10	-45	160	N/A	44
LCP	1.4	N/A	130	280	325	182

MFI: melt flow index.

T_g : glass transition temperature. T_m : melting temperature. T_i : isotropy temperature.

surface relaxation behavior of polymers [18]. Under friction, the most direct and predominant responses of polymers are chains disentanglement and orientation parallel to sliding direction at friction interfaces [8,19], accompanying chains relaxation. As a general trend, low entanglement and ease of orientation favor to depress friction [20], like PTFE and HDPE. Besides, friction heat is an important dissipation form of energy, accounting for rising temperature of friction surface often comparable to melting temperatures of polymers [16]. On the other hand, as to wear, the adhesion at contact interfaces are most commonly observed trigger during sliding [16,21]. As sliding proceeds, the fragments detachment and wear of bulk polymers occur if shear strength of

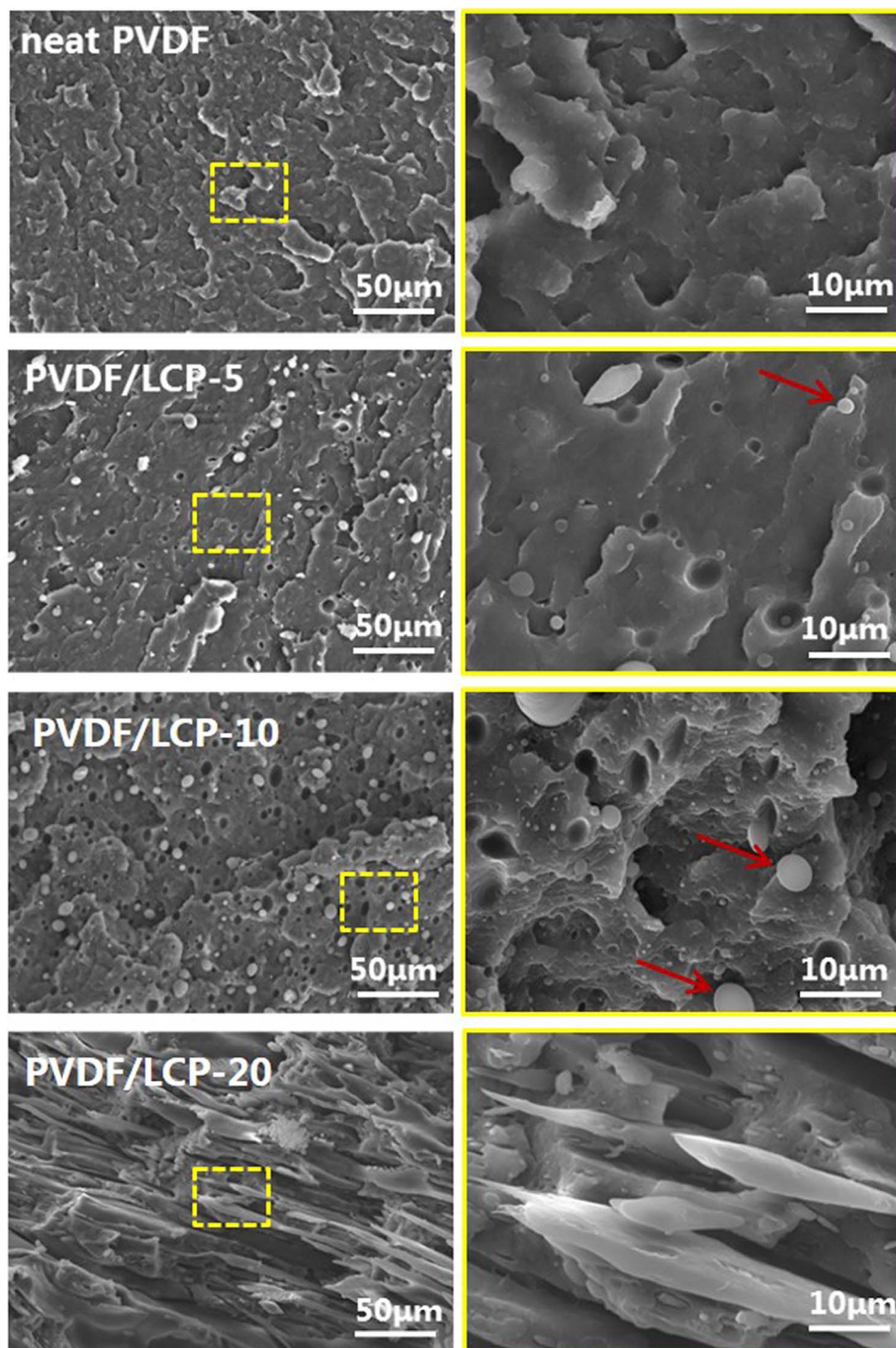


Fig. 1. Morphology of PVDF with various LCP contents observed with SEM. LCP particles are identified by red arrows. The right side was higher magnification, corresponding to the marked areas. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Download English Version:

<https://daneshyari.com/en/article/7889563>

Download Persian Version:

<https://daneshyari.com/article/7889563>

[Daneshyari.com](https://daneshyari.com)