Effects of State Change of Liquid Crystalline Polymer on Dynamic Visco-Elasticity of its Blends with Polyethylene-Terephthalate

S.A.R. Hashmi[1] and Takeshi Kitano[2]*

[1] Advanced Materials & Processes Research Institute, CSIR, Hoshangabad Road, Bhopal 462026, India

[2]Polymer Centre, Tomas Bata University in Zlin, T.G.M 275 762 72 Zlin, Czech Republic

* Email: sarhashmi@rediffmail.com
Fax: x91.755.2488323

Received: 9.2.2007, Final version: 16.5.2007

Abstract:
The dynamic viscoelastic properties of liquid crystalline polymer (LCP) and polyethylene terephthalate (PET) blends were studied at two different temperatures: 265°C at which LCP was in solid state and 285°C at which LCP was in molten state. The PET was in molten state at both the temperatures. The storage modulus, *G'*, loss modulus, *G''*, dynamic viscosity, η', of blends with different compositions were evaluated and compared. The morphology of these samples was studied using scanning electron microscope, which exhibited composition dependency. A maxima was observed in the viscosity versus composition plot corresponding to 90/10 LCP/PET blend at 285°C. The *G'* versus *G''* plots demonstrated the composition dependency of LCP/PET blends.

Zusammenfassung:
Die dynamischen viskoelastischen Eigenschaften von Blends eines flüssigkristallinen Polymers (LCP) und Polyethylenterephthalat (PET) wurden bei zwei unterschiedlichen Temperaturen untersucht: 265°C, bei der LCP im festen Zustand war, und 285°C, bei der LCP im geschmolzenen Zustand war. PET war bei beiden Temperaturen im geschmolzenen Zustand. Der Speichermodul *G'*, der Verlustmodul *G''*, die dynamische Viskosität η' der Blends mit unterschiedlichen Zusammensetzungen wurden ausgewertet und verglichen. Die Morphologie dieser Proben wurde mittels Rasterelektronenmikroskopie untersucht und zeigte eine Abhängigkeit von der Zusammensetzung. Ein Maximum der Viskosität als Funktion der Zusammensetzung trat beim 90/10 LCP/PET-Blend bei 285°C auf. Das *G'*-*G''*-Diagramm zeigte ebenfalls eine Abhängigkeit von der Zusammensetzung der LCP/PET-Blends.

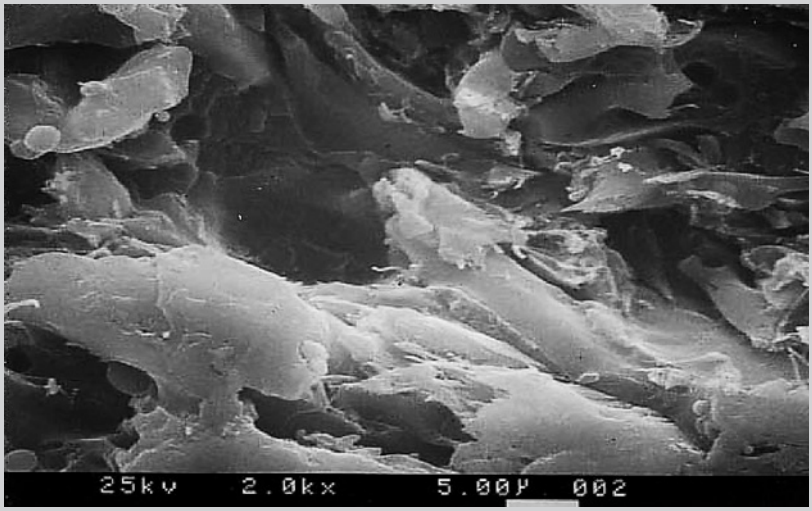
Résumé:
Les propriétés viscoélastiques dynamiques de mélanges de polymère cristal liquide (LCP) et de polyéthylène téréphtalate (PET) ont été étudiées à deux températures différentes : 265°C où le LCP se trouve à l'état solide et à 285°C où le LCP se trouve à l'état fondu. Le PET était à l'état fondu aux deux températures. Le module élastique *G'*, le module de perte *G''*, la viscosité dynamique η' des mélanges de différentes compositions ont été évalués et comparés. La morphologie de ces échantillons a été étudiée à l'aide d'un microscope électronique à balayage, qui a révélé une dépendance de la morphologie avec la composition. Um maximum a été observé dans le graphe de la viscosité en fonction de la composition, qui correspond à un mélange 90/10 LCP/PET à 285°C. Les graphes de *G'* en fonction de *G''* démontrent l'influence de la composition des mélanges LCP/PET.

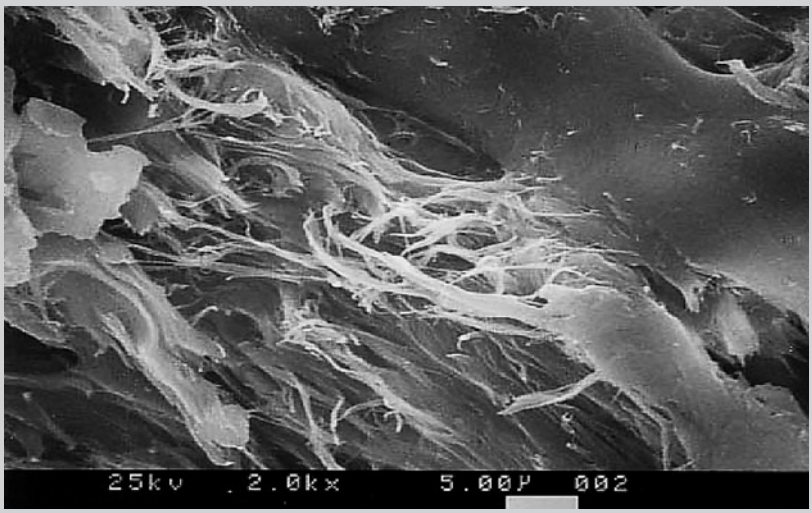
Key words: LCP/PET blend, storage modulus, loss modulus, dynamic viscosity

1 INTRODUCTION

The high performance engineering-material coupled with low melt-viscosity and the tendency to form fibrous structure makes liquid crystalline polymers (LCPs) useful for various industrial applications. They are known for high strength and stiffness, high chemical resistance, good dimensional stability and low linear thermal expansion coefficient. While blended with other thermoplastics polymers, the LCPs improve mechanical properties of composites at reasonably low cost [1, 2]. LCPs display different morphologies when mixed with other thermoplastics [3, 4]. The shape of dispersed LCP varies from spherical, elliptical, layered to fibrous shape and depends upon the volume fraction of LCP, vis-

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org





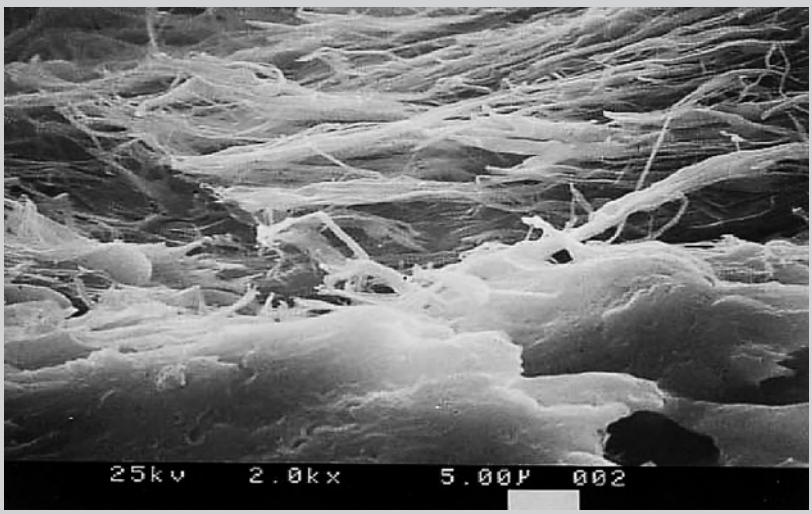


Figure 13 (above): Cryogenic fractured surfaces of LCP/PET:30/70 blend.

Figure 14 (middle): Cryogenic fractured surfaces of LCP/PET:50/50 blend.

Figure 15 (below): Cryogenic fractured surfaces of LCP/PET:90/10 blend.

anced by the interfacial tension [25, 26]. The LCP's are incompatible with the thermoplastics because the melt of LCP displays anisotropy whereas the latter show isotropy. Figure 13 shows a fractured surface in which PET dominating morphology can be observed. Figure 14 is slightly different than Figure 13 as the layers and fibres of LCP were also observed along with PET smooth surface. The formation of layers and fibres may be attributed to the increased number of LCP particles with the increased LCP content and possible coalesce of these particles combined with the sheared flow inside the capillary. Figure 15 shows the microstructure where in the morphological features of LCP dominate over that of PET and hence fibrous structure can be seen in this micrograph. The morphology of LCP/PET samples strongly exhibits the composition dependency.

4 CONCLUSION

Visco-elastic parameters G', G'', η' are composition dependent at both states; the solid as well as fluid state of LCP in LCP/PET blends. The value of η' of blends containing more than 50% of LCP in LCP/PET blend is higher than that of either of the blend constituents at 285°C. The increased amount of LCP in the blend reduced the sensitivity of G'' with respect to ω. PET displayed near Newtonian behaviour beyond the ω value 1 rad/s. This behavior was dominated by shear thinning effect in all composition of LCP/PET blends. The G' versus G'' plots demonstrated the composition dependency of LCP/PET blends at both temperatures 265 and 285°C.

ACKNOWLEDGEMENTS

SARH is thankful to N. Ramakrishnan, Director RRL Bhopal, for granting permission to publish this work.

REFERENCES

[1] Tjong SC: Structure, morphology, mechanical and thermal characteristics of the in situ composites based on liquid crystalline polymers and thermoplastics, Mater. Sci. Eng. Rev. 41 (2003) 1.

[2] Kiss G: In situ composites: Blends of isotropic polymers and thermotropic liquid crystalline polymers, Polym. Eng. Sci. 27 (1987) 410.

[3] Kyotani, M, Kaito A, Nakayama K: Thermal, Structural, and Mechanical Properties of Strands of Blends of Liquid-Crystalline Copolyester and Copolyesteramide with Poly(ethylene terephthalate), Polym. Polym. Compos. 3 (1995) 205.

[4] Song CH, Isayev AI: LCP droplet deformation in fiber spinning of self-reinforced composites, Polymer 42 (2001) 2611.

[5] Shimizu H, Kitano T, Nakayama K: Morphological control of LCP/PET blends using a melt mixer equipped with a milling part, Mater. Lett. 58 (2004) 1277.

[6] Kaito A Kyotani, M and.Nakayama K: Orientation distribution of liquid-crystalline polyester sheets

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

studied by polarized infrared spectroscopy, J Polym. Sci. Part B Polym. Phys. 31 (1993) 1099.
[7] Kyotani M, Kaito A, Nakayama K: Structural, mechanical, and thermal properties of extruded sheets of a liquid crystalline co-polyester, J. Appl. Polym. Sci. 47 (1993) 2053.
[8] Marrucci G: Thermotropic Liquid Crystal Polymer Blends, Mantia La FP (Ed.), Technomic, Lancaster (1993) 43-58.
[9] Hashmi SAR, Kitano T: Rheology of LCP/PET blends at solid and molten states of LCP, Appl. Rheol. 16 (2006) 152.
[10] Kataoka T, Ohnishi S, Kitano T, Nakama K and Takayama H: Mixing effect of filler and polymer by an elastic melt extruder, Rheol. Acta 15 (1976) 268.
[11] Yano S, Kitano T: Handbook of applied polymer processing technology, Cheremisinoff NP, Cheremisinoff NP (Eds.), Marcel Dekker Inc., New York (1996).
[12] Coppola L, Nicotera I, Oliviero C: Dynamic rheological analysis of MLVs and Lamellar Phases in the System, Appl. Rheol. 15 (2005) 230.
[13] Fisher DT, Boger DV, Scales PJ: Measurement errors in yield stress rheometry that arise from torque offset correction Appl. Rheol. 16 (2006) 206.
[14] Lin Li: Viscoelastic properties of particle filled polymers in the molten state, Ph.D. thesis, Kyoto University, Japan (1989).
[15] Chand N, Hashmi SAR: Mechanical and rheological characteristics of Poly-propylene/Polyethylene/Red Mud, Compos. Res. & Industry 40 (1995) 193.
[16] Lobe VM, White JL: An experimental study of the influence of carbon black on the rheological properties of a polystyrene melt Polym. Eng. Sci. 19(1979) 617.
[17] Meitz DW, Yen L, Berry GC, Markovitz H: Rheological Studies of Dispersions of Spherical Particles in a Polymer Solution, J. Rheol. 32 (1988) 309.
[18] Hashmi SAR, Kitano T: Shear rate dependence of viscosity and first-normal-stress-difference of LCP/PET blends at solid and molten states of LCP, J Appl. Polym. Sci. 104 (2007) 2212.
[19] Han CD, Lem KW: Temperature independent correlation of elastic responses of viscoelastic liquids, Polym. Eng. Rev. 2 (1983) 135.
[20] Han CD, John MS: Correlations of the first normal stress difference with shear stress and of the storage modulus with loss modulus for homopolymers J Appl. Polym. Sci. 32 (1986) 3809.
[21] Rong S, Chaffey CE: Composite viscoelasticity in glassy, transitional and molten states, Rheol. Acta 27 (1988) 179.
[22] Hashmi SAR, Chand N, Kitano T: Dynamic viscoelasticity of redmud filled polypropylene/low-density polyethylene blends, Ind. J Eng. & Mater. Sci. 5 (1998) 312.
[23] Han CD, Baek DM, Kim JK, Chu SG: Rheological behaviour of block copolymers in the disordered state: effects of molecular weight and block length ratio, Polymer 33 (1992) 294.
[24] Kraus G, Rollmann KW: The entanglement plateau in the dynamic modulus of rubbery styrene-diene block copolymers. Significance to pressure-sensitive adhesive formulations J Appl Sci. 21 (1977) 3311.
[25 Plochocki AP, Dagli SS, Andrews RD: The interface in binary mixtures of polymers containing a corresponding block copolymer: Effects of industrial mixing processes and of coalescence, Polym. Eng. Sci. 30 (1990) 741.
[26]. Fortelny I, Zivny A: Theory of competition between breakup and coalescence of droplets in flowing polymer blends, Polym. Eng. Sci. 35 (1995), 1872.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org