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Thermal and optical behavior of poly(ethylene-b-ethylene oxide) block copolymer dispersed liquid crystals blends

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ABSTRACT

Different block copolymer dispersed liquid crystals blends based on poly(ethylene-b-ethylene oxide) (PE-b-PEO) and modified with low molecular weight nematic liquid crystals, 4′-(hexyloxy)-4-biphenylcarbonitrile (HOBC) and N-(4-ethoxybenzylidene)-4-butylaniline (EBBA) were prepared and characterized. The miscibility between each block of PE-b-PEO block copolymer and nematic liquid crystals was studied using differential scanning calorimetry (DSC). DSC results were in good agreement with the miscibility prediction supported by the solubility parameters and miscibility effect in polymer dispersed liquid crystals blends based on polyethylene oxide (PEO) homopolymer. Thermal stability of PE-b-PEO/HOBC and PE-b-PEO/EBBA blends was also studied. Block copolymer dispersed liquid crystals blends maintained the nematic/isotropic transition in function of the ratio between PE-b-PEO block copolymer and nematic liquid crystals indicating the potential application of the designed materials.

1. Introduction

Polymer blend technology is one of the main areas of research and development in polymer and material science. This technology leads to combine synergistically different polymeric materials. The mixture of polymers offers opportunities to create novel materials with tailored properties, which can improve the properties of the neat components in the polymer blends [1–8].

In order to control the miscibility between components, one can control physical interactions between polymers such as hydrogen bonding, dipole–dipole or ion–dipole interactions [2,3]. Simultaneously, the miscibility between polymer blends can be controlled by studying the phase separation between components, which is strongly related to the morphology and their final properties such as thermal, mechanical and others [1,2,5,9–14].

As it is well-known, one of the effective ways to improve the miscibility between polymers is the addition of block copolymers, which are able to reduce the interfacial tension between components leading to higher miscibility [1,10,15–18]. Moreover, block copolymers are one of the components that allow to control the phase separation and consequently promote higher miscibility between components [17–23]. In this research field different block copolymers such as poly(styrene-b-(ε-caprolactone)) (PS-b-PCL) [17], poly(ethylene-b-ethylene oxide) (PE-b-PEO) [18], poly(styrene-b-ethylene

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oxide) (PS-b-PEO) [20], poly(styrene-b-isoprene) (PS-b-PI) [21], poly(ethylene oxide-b-(ε-caprolactone)) (PEO-b-PCL) [22] and poly(styrene-b-methyl methacrylate) (PS-b-PMMA) [23] among others were explored.

In the last decade, polymer dispersed liquid crystals (PDLC) blends were also investigated due to their wide range of applications in the field of thermal and electro-optical devices such as optical switches (light shutters), smart windows, reflective displays and others [24–32]. Nematic liquid crystals (NLC) with their optical anisotropy and dielectric properties allow to design PDLC materials, which can switch from a state of high dispersion of light (OFF state) to a transparent state (ON state) by applying an external field such as thermal gradient, electrical voltage or magnetic field [20,24–32].

Rodrigues et al. [33] reported the microscopic behavior of polymeric blends of poly(ethylene oxide) (PEO) with two different low molecular weight liquid crystals. The authors proved the miscibility between PEO homopolymer and both liquid crystals. Similar studies were carried out by Filip et al. [34,35] employing poly(ether sulfone)s (PS), poly(ethylene adipate) (PEA) and polytetrahydrofuran (PTHF) blended with low molecular weight cholesteryl palmitate (CP) liquid crystal. They proved the evidence of strong interactions between components in PS/CP blends by means of thermogravimetric analysis. Additionally, they also reported that PEA/CP and PTHF/CP blends showed interaction between components confirmed by their thermal behavior and thermal stability. Moreover, Hoppe et al. [28] studied the phase diagram of PDLC blends based on polystyrene (PS) and N-(4-ethoxybenzylidene)-4-butylaniline (EBBA) liquid crystal using differential scanning calorimetry (DSC) and optical microscopy (OM) with crossed polarizers. They concluded that the fast cooling rate led to PDLC blends with smaller nematic domains with a narrow size distribution. On the contrary, the slow cooling rate led to the coexistence of very large and small nematic domains.

As mentioned above, one attractive strategy for the preparation of PDLC is the use of block copolymers as matrices instead of homopolymers [20,29–32]. Block copolymers consist of two or more covalently linked polymers, which can self-assemble offering nanostructured templates for dispersion of NLC. Consequently, NLC can be positioned in one block of the block copolymer leading to PDLC materials with tunable properties.

However, based on our knowledge only a few works have been reported on PDLC blends based on block copolymers [20,28,29].

In the present work, two low molecular weight nematic liquid crystals, 4′-(hexyloxy)-4-biphenylcarbonitrile (HOBC) and N-(4-ethoxybenzylidene)-4-butylaniline (EBBA), were used to fabricate blends with poly(ethylene-b-ethylene oxide) (PE-b-PEO). The miscibility of the PE-b-PEO/HOBC and PE-b-PEO/EBBA polymer blends was studied using different advanced techniques such as infrared Fourier transform spectroscopy (FTIR), differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). The ability of the liquid crystals to maintain their nematic–isotropic transition was investigated by means of optical microscopy (OM).

2. Experimental details

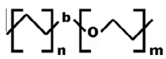
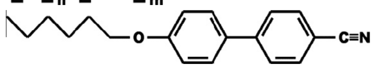
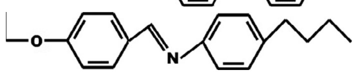
2.1. Materials

Two different nematic liquid crystals 4′-(hexyloxy)-4-biphenylcarbonitrile (HOBC) with 96% purity and N-(4-ethoxybenzylidene)-4-butylaniline (EBBA) with 98% purity as well as poly(ethylene-b-ethylene oxide) diblock copolymer (PE-b-PEO) with an average molecular weight (M_n) of 920 g mol^{-1} and 50 wt.% PEO block content were purchased from Sigma–Aldrich and were used as received. Additionally, poly(ethylene oxide) (PEO) homopolymer with a molecular weight (M_n equal to 950–1050 g mol^{-1}) similar to this block in the PE-b-PEO block copolymer supplied by Sigma–Aldrich was used without purification. The chemical structures of the used materials are shown in Table 1.

2.2. Sample preparation

PE-b-PEO block copolymer dispersed liquid crystals blends were prepared by melting different weight percentages of PE-b-PEO block copolymer, 25, 50 and 75 wt.% with two different low molecular weight nematic liquid crystals, HOBC and EBBA,

Table 1
Chemical structure of PE-b-PEO block copolymer and HOBC and EBBA liquid crystals. For comparison the chemical structure of PEO homopolymer was also added.

Materials	Chemical structure
Poly(ethylene-b-ethylene oxide) block copolymer (PE-b-PEO)	
4′-(Hexyloxy)-4-biphenylcarbonitrile (HOBC)	
N-(4-ethoxybenzylidene)-4-butylaniline (EBBA)	
Polyethylene oxide (PEO)