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Research paper

# Nanoclay compatibilization of phase separated polysulfone/polyimide films for oxygen barrier

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ABSTRACT

Polyimide (PI) and Polysulfone (PSF) films are used in many applications ranging from electronic film capacitors to membranes for gas separation and water purification, yet their phase separation issues limit many potential synergistic blend film applications. To this end, we examine the potential of nanoclays as non-traditional compatibilizers and re-enforcing agents in these technologically important polymer blend films. Herein, we quantify the effect of a nanoclay, Cloisite 30B on the phase separated blend film morphology compatibilization of PSF/PI and associated changes in its mechanical properties and film surface energy. Addition of as little as 1 mass% of organoclay strongly compatibilized the blend phases at all compositions, reducing the scale of blend phase separation by ~5–10 times, and interestingly, the net discreet surface phase separated domain area converged to that observed in 50% blend composition for other off-symmetric blend compositions. Clay compatibilization effects also induced a notable reduction of aspect ratio of surface phase separated domains in thin film blends, attributed to a high degree of exfoliation of the nanoclay by the PSF component so that the effective PSF domain interfacial tension with PI is reduced. Surface modification effects on topography leveling and surface energy changes are only qualitatively similar to our previous observations of block copolymer compatibilizer effect on polymer thin film blend phase separation. Thermal decomposition (TGA) measurements of PSF/PI films showed a decrease in thermal stability upon adding C30B due to its surfactant modification, while film mechanical tensile modulus properties improved slightly by adding low concentration of C30B (~1 mass%), but higher nanoclay loading decreased tensile strength and elongation at break. Finally we note that in terms of processing, the viscosities of the polymer solutions dramatically changed with addition 1 mass% and 3 mass% of C30B. We anticipate that more generally, nanoclays can act similarly to traditional polymeric compatibilizers in many aspects in suppressing polymer thin film blend phase separation that can have ramifications for many advanced technological applications such as sensors and membranes. To this end, we present preliminary oxygen barrier properties of adding Cloisite 30B on PSF/PI blend films.



## 1. Introduction

Polymer clay nanocomposites continues to be an attractive area of research, development and innovation, both for academics as well as to the polymer industry because it provides an inexpensive route for enabling versatile property enhancement to pristine polymers. Yet the complexity of meeting their processing requirements for various diverse applications can be quite challenging. Nanoparticles and organic-inorganic materials can potentially improve and modify the properties of not only bulk polymers but also those in the form of membranes and films wherein their mechanical, thermal, and nanoscale properties may be enhanced by molecular level property modifications to the polymers at low clay loading. This is an area of much research, and scholars have found that in general, inorganic fillers, zeolites and ceramics can be used to prepare composite films as well as membranes due to their ability to be exfoliated in polymeric matrices at the nanoscale level. For instance, nanocomposite films can be used as barrier protection coatings to reduce the impact of corrosion, wherein the

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**Table 1**
The blend films compositions preparation of C30B/PSF/PI.

| 20 mass% polymer in NMP | 30PSF/70PI | 50PSF/50PI | 70PSF/30PI |
|---|---|---|---|
| Cloisite 30B mass% in solution | 0, 1, and 3 mass% | 0, 1, and 3 mass% | 0, 1, and 3 mass% |

nanofilled polymeric coating film is used as a shell to protect metals from the environment (Monticelli et al., 2007; Yeh et al., 2004).

Polysulfone (PSF) is widely used in various applications such as medicine, food processing and mechanical equipment manufacturing, as well as in several electrical procedures, electronic components, gas filtration and piping (Ionita et al., 2014; Musto et al., 2004; Taurozzi et al., 2008; Unsal et al., 2012). Notably, important applications of polysulfone involve membranes in gas separation, batteries and fuel cell at low cost and high availability (Anadão et al., 2010; Kim et al., 2006). Polysulfone is one of the most commercially used high-performance polymers due to its clear and rigid nature, high thermal stability across a wide range of temperature and high glass-transition temperature (Bakhtiari et al., 2011; Sur et al., 2001). PSF also possess resistance to basic solutions with high pH values, and is soluble in organic solvents that make it usable for many applications with some modifications (Fan

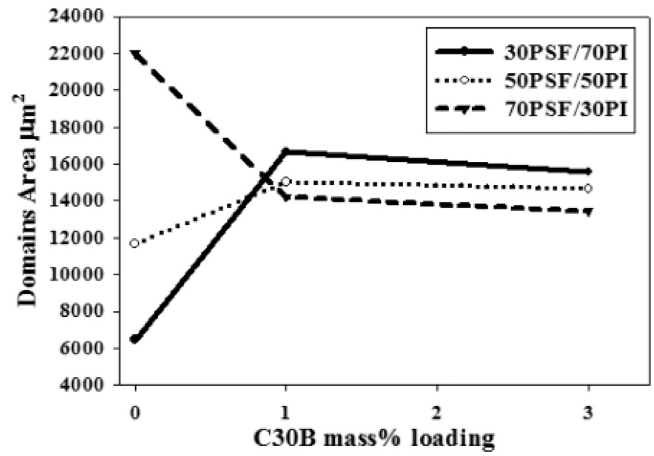


**Fig. 2.** Total PSF domains area in PSF/PI films estimated from images of net total area of 34,355 μm$^2$. The plot illustrates convergence of total domains area to a common total domain area around the 50 mass% PSF sample, with addition of clay at 1 and 3 mass%. Regardless of initial composition of PSF/PI blend ratio, with addition of clay the total domain area converges to a common value ~15,000 ± 1000 (±6%) μm$^2$.

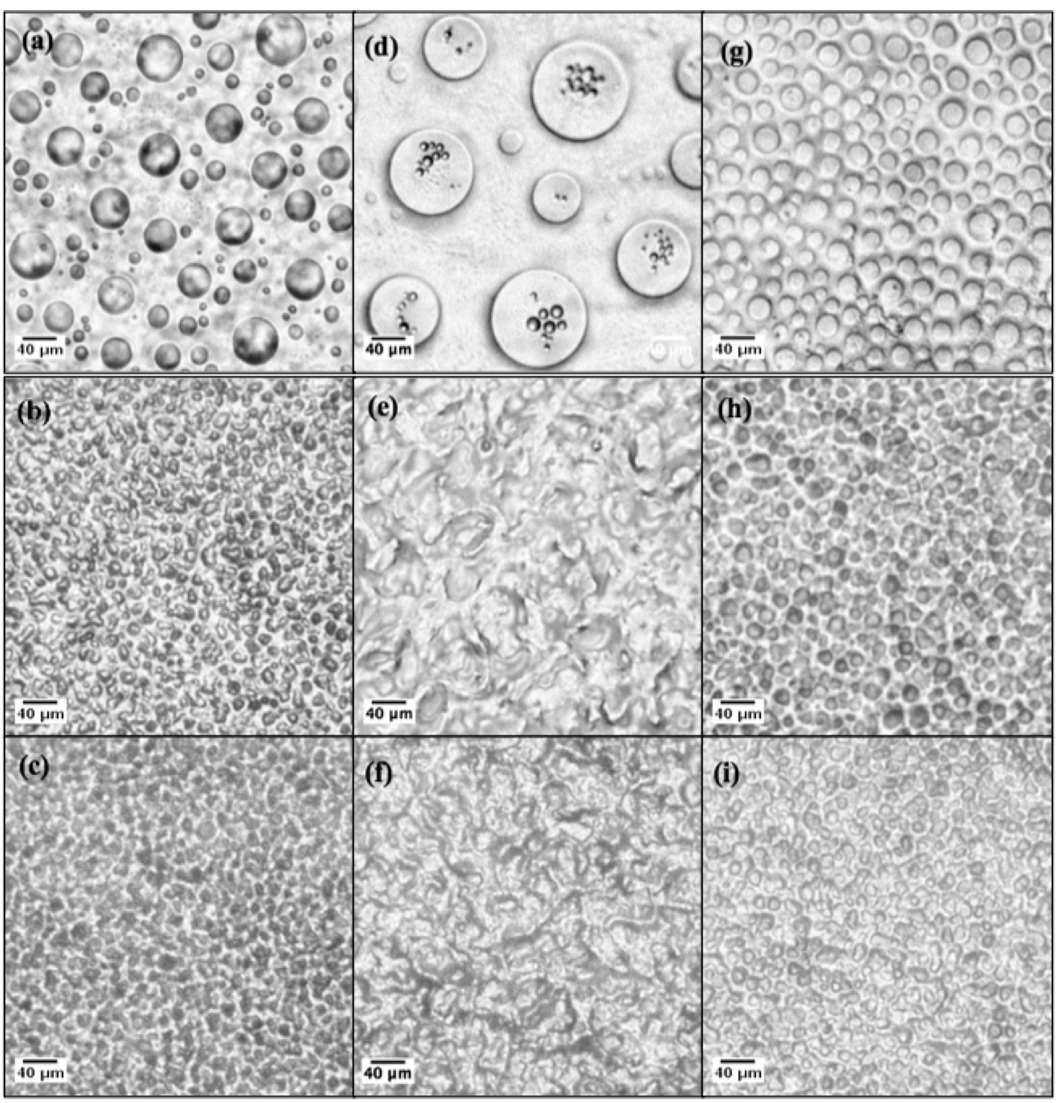


**Fig. 1.** Phase separation morphology images for different concentrations of PSF/PI nanocomposite films taken by optical microscopy, OM. (a, b, and c) represent 30PSF/70PI with (0, 1, and 3%) mass% of C30B respectively. (d, e, and f) represent 50PSF/50PI with (0, 1, and 3%) mass% of C30B respectively. (g, h, and i) represent 70PSF/30PI with (0, 1, and 3%) mass% of C30B respectively.