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Change in surface properties of polydimethylsiloxane/polyurethane/carbon nanotubes elastomeric coatings

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ABSTRACT

Addition of polydimethylsiloxane (PDMS) to polyurethane (PU) improves mechanical, surface and bulk properties. PDMS plays the role of a soft segment in PU because of its low surface tension and glass transition temperature. This polymer blend shows highly segregated morphology allowing production of thermoplastic elastomers with properties in between a crosslinked elastomer and thermoplastic depending on composition. In this study, PDMS/PU blends were synthesized in situ and the effects of PDMS composition, the type and content of catalyst, solvent and isocyanates molecular weight as well as carbon nanotubes (CNTs) incorporation on the surface properties of the resulting elastomeric coatings were discussed. Different measurements including contact angle, SEM, AFM, FTIR and elemental composition analyses were used for interpretations. The competition between OH terminating groups of PDMS and polycaprolactone was the key controlling over the hydrophilicity of the resulting PDMS/PU coatings. Such effect was studied by monitoring the changes in surface properties of the cured coatings. The results revealed that by adjusting the above-mentioned parameters, surface chemistry of the cured films were changed. PDMS introducing to PU resulted in a rise in water contact angle from 93° to 113°, which indicated a considerable surface hydrophobicity. Moreover, solvent selection exhibited a crucial role on surface roughness. CNTs incorporation resulted in surface hydrophobicity enhancement, as featured by a rise in water contact angle from 100 to 135°, suggesting the possibility of surface tailoring by optimizing PDMS and CNTs concentrations.

1. Introduction

As long as polydimethylsiloxane (PDMS) entered the world market as an elastomer, it has been considered for manufacturing biomedical materials thanks to its unique properties such as acceptable thermal and oxidative stability, low toxicity, low surface tension and low glass transition temperature [1–3]. Polyurethanes (PU) due to its desired mechanical properties and wide range availability of physical properties have been used as a versatile polymer in different fields such as coatings, composites, and particularly as biomedical material [4–6]. Blend of PDMS and PU give rise to a variety of properties needed for a range of engineering applications. There was an idea that addition of PDMS to PU in the course of urethane polymerization at different ratios could be considered as a tactic to tune the softness of the resulting coating [7,8]. Outstanding mechanical properties of PU from one side and the inertness and biocompatibility of PDMS from the other side could end in engineering elastomers for biomedical uses [9,10].

PDMS has been used frequently in the synthesis of PU to achieve excellent mechanical properties with desired resiliency, antifouling and low-temperature flexibility [11,12]. For example, PDMS was used as a soft segment component in PU synthesis due to its low surface tension, low toxicity, low glass transition temperature, and biocompatibility [13,14]. The resulting blend showed obvious phase separation due to the incompatibility of polar hard and soft segments though could have potential advantages [15,16]. Since the resulting blend was a thermoplastic elastomer (TPE), depending on composition, properties of a crosslinked elastomer together with processability in injection molding or extrusion were comparative. Though bulk properties of such elastomeric blends were thoroughly discussed, a few might know that the surface characteristics of such blends could be tailored depending on composition and hydrophobicity when PDMS/PU blends were used as coating.

Water repellency and hydrophobicity are critical factors in functional coating for advanced uses. It is well-documented that PDMS has been considered in many coating formulations thanks to its low surface tension that could make possible surface properties modification [17,18]. There was also evidence that PDMS could easily migrate to the surface of the cured film that was liable for changing the surface

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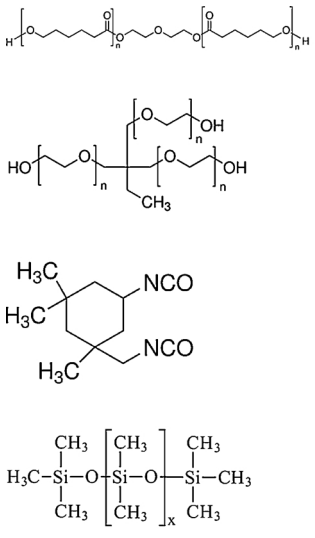

Fig. 1. Chemical structure of the materials used in this work.

properties of coating by making the surface hydrophobic through minimizing the interfacial energy [19,20]. Thus, engineering of surface properties of PDMS/PU elastomeric coatings attracted a great deal of attention.

In this study, PDMS was introduced to the reaction medium of isophorone diisocyanate and polycaprolactone PU moieties. The competition between OH terminating groups of PDMS and polycaprolactone was the key controlling over the hydrophilicity of the resulting PDMS/PU coatings. Such effect was studied by monitoring the changes in surface properties of the cured coatings. Different measurements including contact angle, SEM, AFM, FTIR and elemental composition analyses were used for interpretations.

2. Material and methods

2.1. Materials

In this study PDMS with OH-terminated groups and molecular weight of 1000 was supplied from sigma Company. Isophorone

Table 1
Surface properties of the samples with different content of the PDMS.

	PDMS%	contact angle	surface energy	image
1	0	93.3	42.1	
2	7.1	97.5	38.5	
3	9.4	114.4	29.93	
4	13.1	113.3	29.6	

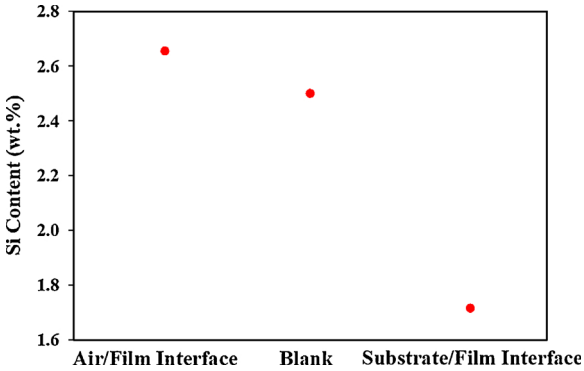

Fig. 3. Si distribution in the film containing 9.4 wt% PDMS.

Table 2
Surface tension values of water and diiodomethane.

	Y1.(mJ/m2)	YL^P (mJ/m2)	Yl^d (mJ/m2)
Deionized water	72/2	22	22
Diiodomethane	50/8	50/8	50/8

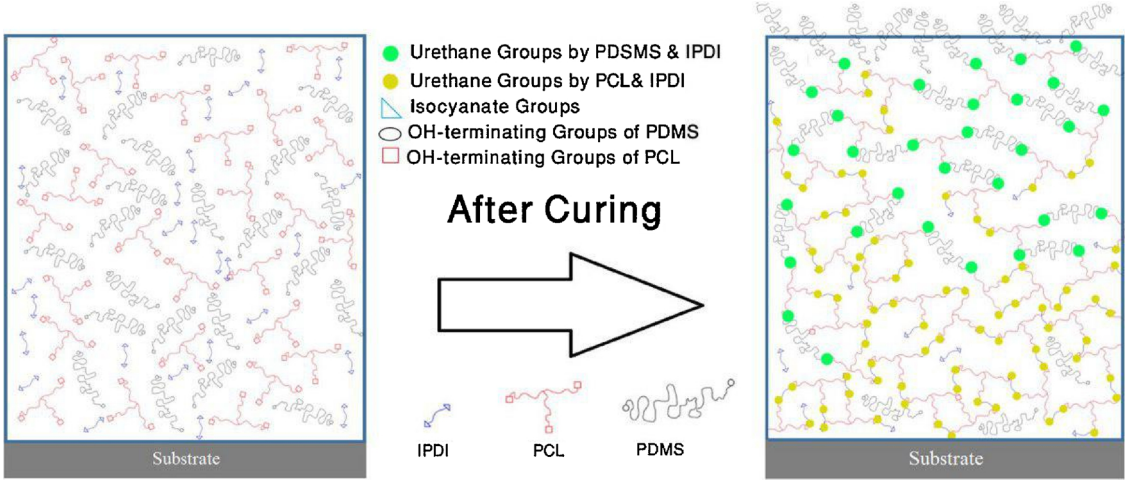

Fig. 2. The schematic illustration of the competition of PDMS and PCL to react with the IPDI.