Studies on TPU/PP Blend and Comparing it with PVC Used as Blood Bag

Shadi H. Ajili,, Nadereh Golshan Ebrahim,," and Mohammad T. Khorasani†

(1) Department of Polymer Engineering, Tarbiat Modarres University, P.O. Box: 14115/317 Tehran, I.R. Iran
(2) Department of Polymeric Biomaterials, Iran Polymer and Petrochemical Institute P.O. Box: 14965/159, Tehran, I.R. Iran
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A B S T R A C T

In this work, blends with different ratios of thermoplastic polyurethane-polypropylene (TPU-PP) were prepared using a Haake internal mixer and studied by SEM micrographs of cryofractures. The polymers, their blends and PVC blood bag were characterized by measuring their mechanical properties (modulus, tensile strength and elongation-at-break), water absorption and blood compatibility. According to the obtained results, although the blends are immiscible, the mechanical properties of the blends except TPU/PP = 50/50 are comparable with commercial blood bag material. Results showed that the physical properties of TPU/PP = 80/20 blends are nearly similar or even better than those of PVC blood bag. The comparison of behaviour of platelet adhesion onto the surface of the best sample (TPU/PP = 80/20 blend) with the commercial blood bag surface showed the less tendency of the blend than the second one to interact with platelets.

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thermoplastic polyurethanes; polypropylene; blend; blood bag; biomaterials.

INTRODUCTION

Blood bag system is a disposable biomedical device used for collection, storage, transportation and transfusion of human blood and blood components [1]. Until now, the most widely used blood bag material has been plasticized polyvinyl chloride (PVC) [2]. PVC is a relatively rigid and brittle polymer. Plasticizers are added to PVC to facilitate processing and increase flexibility and toughness in the final product by internal modification of the polymer molecule [3]. The main
plasticizer used in blood bags is di-2-ethylhexyl phthalate (DEHP) [2]. It is a lipophilic or fat-loving compound and so it tends to concentrate in fatty tissues [4]. In vivo and invitro research links DEHP or its metabolites to a range of adverse effects on the liver, reproductive tract, kidneys, lungs and heart. It also appears to pose a relatively low risk of hepatic cancer in humans [3]. As a result of such problems, several efforts have been made to develop plastic materials suitable for storage blood components from non-PVC plastics [5]. Among the materials investigated were polymers such as thermoplastic polyurethanes [6], silicone polycarbonate block copolymers, ethylene-vinyl acetate copolymers [7], flexible polyesters and various thermoplastic elastomers and polyolefin blends [8]. We also tried to solve the problem of toxicity of the plasticized PVC by use of the polyurethane and polypropylene blend as a blood bag material. Polyurethanes are one of the few synthetic materials with good biocompatibility and other performance characteristics which make them suitable for a wide range of medical applications as blood bags and surgical gloves through to wide range of high risk applications such as catheters, synthetic veins and more recently wound dressings [9]. Polypropylene is also one of the polymeric biomaterials that is extensively used for biomedical applications such as sutures and finger joint implants due to its low cost, good mechanical properties and inertness in living system [10].

This paper presents the results of the physical and mechanical investigations of thermoplastic polyurethane/polypropylene blends as a material for PVC replacement in blood bag. TPU/PP blends provide inert, strong and elastic composition which is desirable for blood bag manufacturing.

In this study, TPU/PP blends with different ratios were prepared, then their morphology and bulk properties (modulus, tensile strength, elongation-at-break and water absorption) were examined to compare them with those of commercially available blood bags. To further study about blood compatibility, the behaviour of platelet adhesion onto the best sample surface was also compared with that of PVC blood bag surface.

It is required to mention that in the case of blood bag material, its cytocompatibility should be distinguished. For this purpose, in vitro cell culture test was done on the blend surfaces which showed good cell response due to supporting of attachment and growth of the cells on them [11].

**EXPERIMENTAL**

**Materials**

Medical grade thermoplastic polyurethane (LARIPUR 7025) was obtained from Coim Co. (Italy) with hardness 70, shore A. It is a block copolymer consisting of hard segments with soft segments of polyester.

Medical grade polypropylene was supplied by Arak Petrochemical Co. (Iran), known as V30GA type with nominal melt flow index (MFI) of 16.

Blood bag samples made from plasticized PVC were purchased from Green Cross Medical Co. (Korea).

**Preparation of Blends**

Before processing, the thermoplastic polyurethane was dried for at least 3 h in a vacuum oven at 100 C.

Blending of components was done in Haake mixer (Buchler Rhecord 90) at 190 C with rotor speed of 60 rpm for 5 min.

Pressure moulding was used to produce specimens of PP, TPU, its blend and PVC (blood bag material) for tests. The residence time in the molten state was up to 5 min at 190 C. The moulding pressure was about 100 bar with rate of cooling 5 C/min. The moulds employed were teflon-coated to provide a non-adhesive surface.

**Bulk Characterization**

Morphology studies were done using a scanning electron microscope (SEM) model XL30 made by Philips Company. Prepared blends were cryogenically broken and fractured surface was coated with gold-platinum alloy before scanning.

The mechanical properties (tensile strength and modulus) of the PP, TPU and blends were evaluated at room temperature in a tensile testing machine (Instron 6025) at a cross-head speed of 200 mm/min and compared with those of the commercial blood bags.

The swelling property of the blends were examined by measuring the water absorption content. The prepared samples were weighed after drying (dry weight) and immersed in purified water. The swollen films were taken out of water after 1 day, the surfaces wiped with filter paper, weighed (wet weight). The swelling capacity was calculated as follows:

\[
\text{Swelling (\%) = } \left[ \frac{(\text{wet weight-dry weight})}{\text{dry weight}} \right] \times 100
\]
Surface Characterization

Platelet Adhesion

Venous blood from healthy human volunteers was collected with vacuum syringe containing 5% citric acid. The blood was centrifuged at 800 rev min\(^{-1}\) for 10 min at 25°C and the platelet rich plasma (PRP) was withdrawn with a PE pipette and placed in clean vials. The residue of the blood was centrifuged at 3000 rev. min\(^{-1}\) for 10 min to obtain platelet poor plasma (PPP). The platelet count of PRP was determined with Coulter counter (type 4) and adjusted to 150,000 platelets in mL with addition of PPP to PRP. One millilitre PRP was placed on the films of 1 cm\(^2\) and allowed to stand for 1 h at 37°C. The samples were then vigorously washed with phosphate buffered saline (PBS). The samples were then dehydrated with ethanol (50-100%) and dried up to the critical point.

RESULT AND DISCUSSION

Morphology

Blends of thermoplastic polyurethanes and polypropylene are highly incompatible because of large differences in polarities and high interfacial tension [12]. The differences in surface free energies induce incompatibility. Due to this fact, SEM micrographs of cryofractures (Figures 1-3) have revealed no sign of interfacial adhesion.

From these Figures it was also found that all the blends exhibited a two-phase morphology. As shown in Figures 1 and 2, one phase as spherical particles is dispersed in another phase. Lambardo et al. [13] already showed that blend components with lower viscosity have tendency to form the matrix. For the blend studies, TPU has lower viscosity (according to torque ratio in Figure 4, which is an estimation of viscosity ratio among TPU-PP components), therefore, TPU should be used as matrix phase.

It was also found from Figures 1 and 2 that the size of dispersed phase (PP) can be related to its composition in the blend. It was observed that the size of dispersed particles (PP) have become coarser in TPU/PP=70/30 blend than TPU/PP=80/20 blend.

This is because of coalescence. Coalescence manifests itself in the first blend more than that in the second one due to higher probability of collision.

As shown in Figure 3, the blend morphology of
TPU/PP=50/50 blend is similar to a co-continuous type. The change from disperse morphology in the blends with 20 and 30 wt% PP to co-continuous one in TPU/PP=50/50 blend is because of coalescence and lack of an adequate mixing shear energy to break up the PP particles. This structure, because of non-homogeneity of the blend, is not good for our purpose.

**Mechanical Properties**

Mechanical behaviour (modulus, tensile strength and elongation-at-break) of the blends and commercial blood bag are reported in Table 1. All blends except TPU/PP=50/50 have higher tensile strength than those of the blood bag.

Comparison between the results shows the decrease in tensile strength and elongation-at-break with addition of a second polymer, because the disperse phase in incompatible blends reduces the cohesive strength of the matrix. The extent of reduction in polymer properties is related to blend morphology, with blends having finer dispersity show less reduction in properties [14]. Due to this fact, TPU/PP=80/20 blend has higher tensile strength than that of TPU/PP = 70/30 blend.

Results also show that the increasing of TPU content decreases the modulus of the blend, due to lower modulus of TPU than PP.
Water Absorption

The swelling property of the films of PP, TPU, TPU/PP blends and commercial blood bag films was evaluated by measuring the water absorption content after immersion in distilled water for 24 h. As seen in Figure 8, the water absorption of TPU is higher than that of PP, which relates to polar nature and hydrophilicity of polyurethane. Due to this fact, the water absorption of prepared films has been reduced with addition of PP to TPU matrix, except in TPU/PP=50/50 blend that shows high swelling due to intensive surface roughness of the blend. Such structure is the result of co-continuous phases in this ratio, that increase water permeation towards TPU/PP=50/50 blend film.

As it can be seen from Figure 5 the water swelling of TPU/PP =80/20 blend is slightly higher than that of PVC blood bag. This advantage is good for our purpose; because it reduces the friction of film surface and damages to the blood cells.

The obtained results show that among prepared blends, TPU/PP =80/20 blend has the best properties (morphology, tensile strength, elongation-at-break and appropriate water swelling). Therefore, this blend has been chosen for platelet adhesion experiment in order to compare it with blood bag.

Platelet Adhesion Study onto the Film Surfaces

To evaluate blood compatibility, in vitro platelet adhesion experiment was carried out using the platelet rich plasma (PRP) [15]. Optical microscopy was used to study the morphology of adherent platelets. Figures 6a-6c show the attachment of platelets on the polymer films. As it can be seen, not only the platelet adhesion on the PVC blood bag surface (Figure 6a) is significantly the highest among the samples of Figure 6, but also, the completed activation and aggregation of attached platelets were observed on the PVC blood bag film.

The good blood compatibility of polyurethanes was discovered by Boretos et al. [16]. As reported [17], grafting of long alkyl side chain onto a polyurethane has been shown to reduce platelet deposition. Therefore, if we compare Figure 6b (TPU/PP= 80/20) with Figure...
6c (TPU), it seems PP chains play the role as alkyl chains grafted on TPU; hence, the presence of PP in the blend is supposed to suppress platelet adhesion on the surface and improves its blood compatibility. So the surface characteristics of TPU/PP=80/20 blend makes this material more desirable than PVC or even TPU for blood bag application.

CONCLUSION

In the blend system of TPU/PP, no interaction between the blend components can be detected by SEM. TPU/PP=80/20 blend has a finer dispersed morphology than the others.

The tensile strength of compositions show a U-shaped curve with a minimum between 40 and 50 wt % of TPU. All the blends except TPU/PP=50/50 have higher tensile strength and elongation-at-break than PVC blood bag.

From the results of this study, the most suitable blend for blood bag application seems to be TPU/PP=80/20, because of the appropriate mechanical strength, slightly higher water swelling and effective suppression of platelet adhesion than those of PVC blood bag.

REFERENCES