CO-INJECTION OF SANDWICH STRUCTURE XPP/XHDPE/XPP

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1 Introduction

It is known that the fusion of properties achieved by co-injection molding technique range from environment friendly production and cost saving to aesthetics and combinations of engineering properties[1]. In the case of engineering properties improvement, the surface adhesion should be considered for the combination of two different materials. The rule of mixture approaches have been used successfully to predict strength, modulus, and flexural stiffness of sandwich composites that has a good surface adhesion[2]. In this study, sandwich structure obtained by co-injection molding of the crosslinked system of polypropylene(PP) and high density polyethylene(HDPE), namely xPP/xHDPE/xPP, were prepared and investigated by mean of service temperature, mechanical properties, and morphology. The PP skin and HDPE core were crosslinked using dicumyl peroxide(DCP) and vinyl trimethoxysilane(VTMS) system to improve the thermal properties and perhaps the surface adhesion of the sandwich composites[3]. The complete crosslink reaction via silane/water condensation was achieved by sauna treatment after injection molding.

2 Experimental Procedures

2.1 Materials

HDPE and PP used were H5814J and PP700J, both are injection molding grads, obtained from SCG Chemical, respectively. VTMS and DCP are standard laboratory reagents and used as received.

2.2 Sample Preparation

The xPP and xHDPE were prepared in the identical manner. Polymer pellet; PP or HDPE, with all ingredients were melt blended in co-rotation closely intermeshing twin screw extruder (Brabender, model PL2100) at the temperature profile of 160°C, 165°C, 165°C, 170°C, and 170°C from feed zone to pelletized die, respectively. DCP and VTMS were used at 0.3 and 1.0 phr, respectively. They were used to promote crosslink reaction via free radical addition and then in situ condensation reactions. The sandwich specimens were fabricated using dual barrel co-injection molding machine (TEDERIC, model TRX-60C) at the identical temperature profile, 160°C, 165°C, 170°C, 175°C and 180°C from feed to nozzle, respectively. The sandwich specimen with volume fraction of core varied from 0.5, 0.7 and 0.9 were controlled by shot volume and finally calculated from the surface ratio between core area and total cross section area of the sample at the middle position of the sandwich specimen. Sample incubation in the oven saturated with moisture at 105°C, called post cured or sauna treatment, for at least 12 hours was performed to accelerate the completion of crosslink reaction via silane/water condensation.

2.3 Testing

Heat distortion temperature(HDT) of all specimens were tested in accordance with ASTM D648 using the Atlas HDT testing machine (model HDV 1) at the heating rate of 2ºC/min and standard load of 455 kPa. The mechanical properties by mean of tensile, flexural, and notched Izod impact testing were performed according to ASTM D638, ASTM D5943, and, ASTM D256, respectively. The tension and flexure were performed using an Instron universal testing machine (UTM, model 5565) with a load cell of 5 kN. The scanning electron microscope(SEM) was used to examine the impact fractured surface and trace of surface adhesion of the composites.

2.4 Calculation

In this work, the rule of mixture(ROM) model was employed for prediction the tensile and flexural

strengths and Young's modulus of the injected sandwich composites. The formula of ROM is given by equation (1).

$$\sigma_t = v_c\sigma_c + v_s\sigma_s \quad (1)$$

where σ_t σ_c and σ_s are strength(or modulus) for the constituents, core, and skin, of the composite, respectively. v_c and v_s are denoted as volume fraction of the core and skin. The well known Fox's equation is also gathered for prediction the HDT of the sandwich samples.

3 Results and discussions

3.1 Thermal properties

As expected, the HDT of the sandwich composite specimen as shown Table 1 and plotted in Fig. 1, were decreased with increasing the volume fraction of xHDPE for both original and post cured systems. The sauna cured process also obviously enhanced the thermal properties of the specimen. As seen, the HDT of xPP and xHDPE before sauna incubation are approx. 100°C and 75°C and they are increased to 123°C and 113°C after curing, respectively. It is probably due to the forming of network chains and also crystallinity during annealing at 105°C. By applying the Fox's equation, the calculated results are reviewed that the post cured samples are more closely relied on Fox's than the original ones. This probably indicates that enhancing in surfaces adhesion of the samples via silane/water crosslink reaction would be more homogenous in nature.

3.2 Mechanical properties

Table 1 and Fig. 1 also illustrate the impact strength of the sandwich. Yet again, it is shown that the measured values are increased with increasing the volume fraction of the core. It is also obviously seen that degree of elevating in strength is significant for the post cured specimen. This result strongly reinforces the statement that crosslinking via silane/water reaction and can enhance the surfaces bonding and then superior in toughness. Table 2 and Fig. 2 show the tensile strength and flexural strength of the sandwich structure. As expected, it is seen that the properties are graduately decreased with increasing the volume fraction of xHDPE core. However, the completed crosslink composite, sauna cured, show higher test values than the original ones. Calculation by ROM of both tensile and flexural strengths, they are again found that the post cured samples are more closely obey the rule than the original. The outcomes indicate that sauna treatment can superiorly enhance the mechanical properties by mean of impact, tensile and flexural strength of the composites when compare with the sample without treatment. The values calculated from ROM show better agreement for the sauna cured systems than the original ones. These results strengthen that crosslink reaction via peroxide and silane can improve the surface adhesion between skin and core of the sandwich composite and hence enhance the properties of sandwich structure. Tensile modulus and flexural modulus as shown in Table 3 and Fig. 3 presents the decreasing trend when volume fraction of xHDPE core is increased. However, the post cure specimens show higher value than the original one. They are indicated that ductility of the samples is improved by the tough xHDPE.

3.3 Morphological properties

The fractured surface SEM micrographs of xPP, xHDPE, 50% xHDPE core(original) and 50% xHDPE core(cured) are given in Fig. 4, respectively. There is no evidence of crosslink occurred at the fractured surface of xPP. However, there is clearly observed the crosslink webs on the interfacial surface of xPP/xHDPE. Moreover, it is obviously seen that interfacial adhesion between xPP and xHDPE is improved after silane/water crosslinking process. The SEM study confirms that surface bonding of the sandwich structure can be achieved by silane/water crosslink reaction via sauna treatment.

4 Conclusions

Thermal property by mean of HDT and mechanical properties of the sandwich structure between xPP and xHDPE are the combined properties between xHDPE core and xPP skin. The crosslink process via silane/water condensation reaction can enhance the interfacial adhesion and hence the mechanical properties of the composite structure and the ROM can be closely applied for approximation.

Sample	Impact strength (kJ/m^2)		HDT (◦C)	
	Original	Post cure	Original	Post cure
xPP	1.68±1.59	1.86±0.37	100.7±2.08	123. 7±1.61
xPP/xHDPE50/xPP	1.29±0.52	2.81±1.06	90.5±0.87	124.2±0.76
xPP/xHDPE70/xPP	2.40±1.18	3.02±0.55	88.0±1.00	122.8±0.76
xPP/xHDPE90/xPP	3.69±1.38	12.14±2.03	80.3±2.52	115.0±2.00
xHDPE	6.81±1.53	18.26±1.72	75.3±1.15	113.0±1.32

Table 1. Impact strength and HDT of xPP/xHDPE/xPP sandwich composites.

Sample	Tensile Strength (MPa)		Flexural Strength (MPa)	
	Original	Post cure	Original	Post cure
xPP	30.68±1.06	32.23±1.72	45.33±0.62	51.72±0.70
xPP/xHDPE50/xPP	26.36±0.88	28.86±0.61	35.16±0.96	41.33±0.91
xPP/xHDPE70/xPP	24.04±0.87	25.97±0.48	28.24±1.53	35.45±1.85
xPP/xHDPE90/xPP	22.15±0.80	24.73±0.15	25.56±0.84	27.96±1.07
xHDPE	22.90±0.17	25.30±1.12	23.94±0.22	28.31±1.79

Table 2. Tensile strength and Flexural strength of xPP/xHDPE/xPP sandwich composites.

Sample	Tensile Modulus (MPa)		FlexuralModulus (MPa)	
	Original	Post cure	Original	Post cure
xPP	1313.8±61.97	1406.7±23.26	1321.5±23.85	1503.0±31.72
xPP/xHDPE50/xPP	1070.2±37.48	1181.8±25.19	1053.0±22.24	1201.1±98.68
xPP/xHDPE70/xPP	869.1±73.09	999.0±46.65	891.1±83.44	1019.6±95.90
xPP/xHDPE90/xPP	711.4±36.19	746.0±18.76	732.0±20.26	844.9±34.68
xHDPE	665.0±8.53	736.0±7.11	664.9±17.83	841.6±39.14

Table 3. Tensile modulus and Flexural modulus of xPP/xHDPE/xPP sandwich composites.

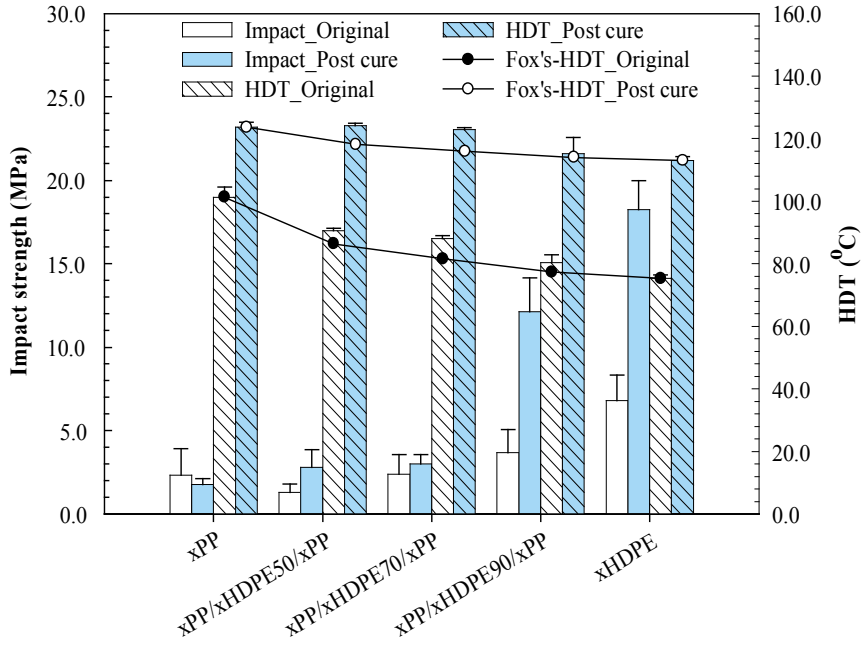

Fig.1. Impact strength and HDT of xPP/xHDPE/xPP sandwich composites.

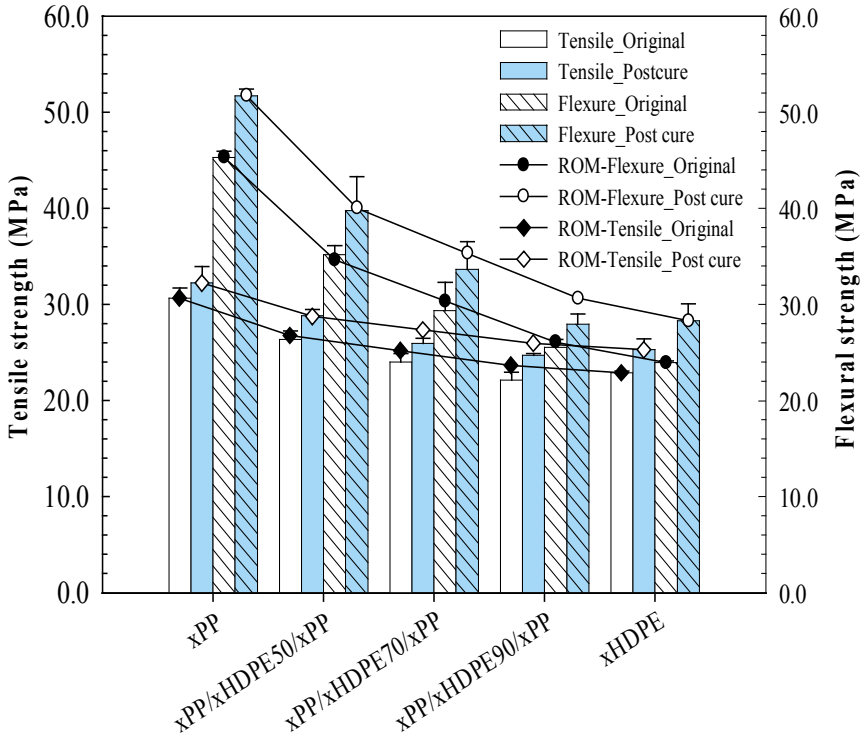

Fig.2. Tensile and flexural strength of xPP/xHDPE/xPP of sandwich composites.

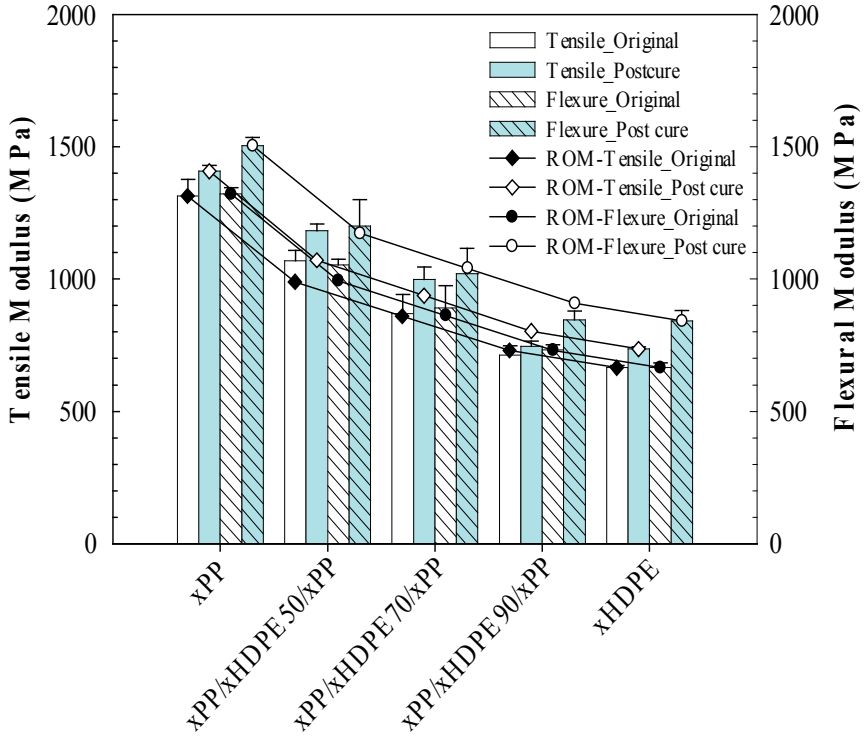

Fig.3. Tensile and flexural modulus of xPP/xHDPE/xPP of sandwich composites.

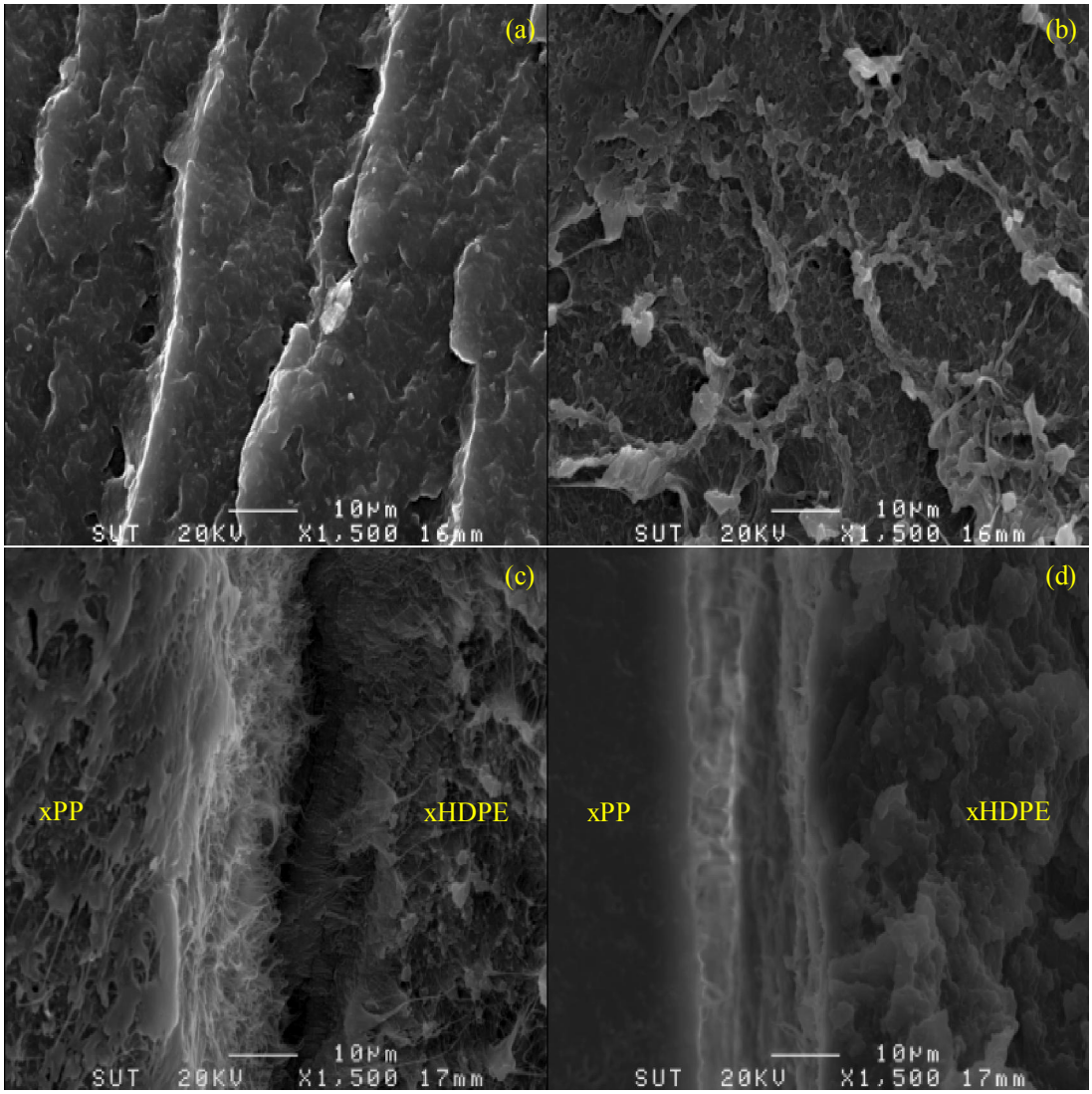

Fig.4. SEM photographs of (a) xPP, (b) xHDPE, (c) and (d) Original and Post cure xPP/xHDPE50/xPP of sandwich composites.

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