# NOTES

## Study on the Textile Material of PP/EVA/PS Blends. I. The Polarity of PP/EVA/PS Blends

### INTRODUCTION

Polypropylene (PP) is a versatile plastic. It is an extensively used material for technical application due to its low specific weight, excellent solved resistance, good spannability, and availability at low cost. However, PP has nonpolarity; the poor wettability gives rise to problems that it is difficult to be painted and adhered. In order to overcome these problems, some techniques have been suggested.[1-3] Among these techniques, blend with other polar polymer is one of the techniques to raise the polarity of PP.

PP can blend with ethylene-vinyl acetate (EVA) copolymer and polystyrene (PS) for improving not only its properties of painting and adhere, but also its mechanical properties. In this work, an attempt has been made to study the polarity of PP/EVA/PS blends. Our work involves three parts. The first part is to determine its contact angle and calculate its surface free energy. The second part is to discuss the effect of the EVA content on the polarity of PP/EVA/PS blends. The third part is to discuss the effect of the VA content on its polarity.

### EXPERIMENT

#### Materials

PP was supplied by Himont Co., USA, with a melt flow and rate (MFR) of 45. EVA and was obtained from Sanjin Co., Japan, with VA content of 5, 14, and 28%, and MFR of 5, 15, and 30. PS, from Sea Co., China, with MFR of 10 was used in this study.

#### Melt Blending and Specimens Preparation

Melt blending was prepared by a 30 mm diameter twin-screw extruder with an $L/d$ ratio of 29. The standard specimens were prepared using injection-molding machine.

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#### Characterizations

The contact angle was determined using contact-angle Meter, Model CA-A, Kyowa Scientific Co. Ltd., Japan. The reference liquids are water, glycerine, methyamide, glycol, and tribenzoic alcohol phosphonate ester.

### RESULT AND DISCUSSIONS

#### Determing of Contact Angle and Calculating of Surface Free Energy of Blends

The contact angle and surface free energy can characterize the polarity of polymer. The contact angle is large, so the surface free energy is small. It is a well-known relationship between contact angle and surface free energy and can be described using Young's formula (Fig. 1).

$$\gamma_{LV}\cos\theta = \gamma_S - \gamma_{SL} \quad (1)$$

The $\gamma_{LV}$ is the interface tensile between liquid and gas. The $\gamma_S$ is surface free energy of solid. The $\gamma_{SL}$ is interface tensile between solid and liquid; $\theta$ is contact angle of solid. Interface tensile involves two parts, the one ($\gamma^d$) is produced by chromatic dispersion, the another ($\gamma^p$) is produced by couple pole. So,

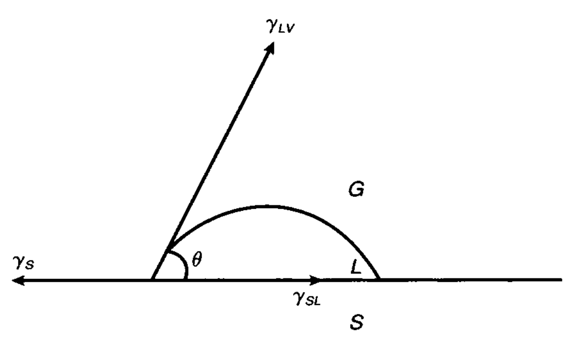


**Figure 1** Balance state of liquid in solid surface.

**Table I Contact Angle of PP/EVA/PS Blends[a]**

| Reference Liquid. | $\theta$ | $(\gamma_L^p)^{1/2}/(\gamma_L^d)^{1/2}$ | $\gamma_{LV}(1 + \cos\theta)/2(\gamma_L^d)^{1/2}$ |
|---|---|---|---|
| Water | 82.3 | 1.43 | 8.43 |
| Glycerine | 69.9 | 0.88 | 7.20 |
| Methylamide | 64.9 | 0.81 | 7.02 |
| Glycol | 54.2 | 0.74 | 6.85 |
| Tribenzoic alcohol | | | |
| Phosphonate ester | 48.2 | 0.2 | 5.55 |

[a] Component ratio: PP/EVA/PS = 87/10/3. According to formula (6), and plotted in Figure 2.

$$\gamma_{LV} = \gamma_L^d + \gamma_L^p \tag{2}$$

$$\gamma_S = \gamma_S^d + \gamma_S^p \tag{3}$$

According to Oweas–Kaelble's formula,[4,5]

$$\gamma_{12} = \gamma_1 + \gamma_2 - 2(\gamma_1^d\gamma_2^d)^{1/2} - 2(\gamma_1^p\gamma_2^p)^{1/2} \tag{4}$$

We can derive formula (4), obtaining formula (5),

$$\gamma_{SL} = \gamma_S + \gamma_{LV} - 2(\gamma_S^d\,\gamma_L^d)^{1/2} - 2(\gamma_S^p\,\gamma_L^p)^{1/2} \tag{5}$$

Formula (5) is backed into formula (1), so formula (6) can be obtained:

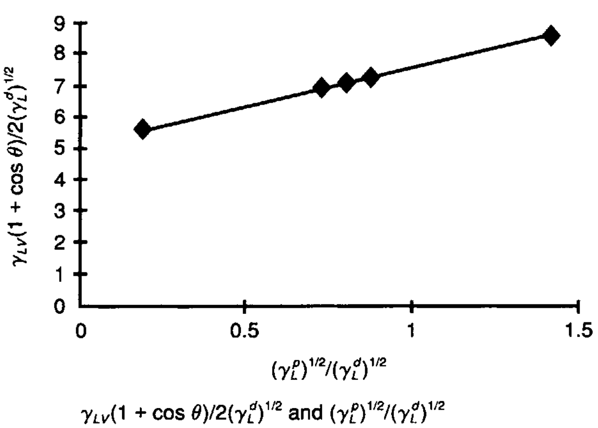


**Figure 2** Relationship between $\gamma_{LV}(1 + \cos\theta)/2(\gamma_L^d)^{1/2}$ and $(\gamma_L^p)^{1/2}/(\gamma_L^d)^{1/2}$ Component ratio: PP/EVA/PS = 87/10/3, VA content (wt %) is 5%.

**Table II Surface Free Energy of PP/EVA/PS Blends[a]**

| No. | EVA Content (wt %) | Surface Free Energy (mN/m) |
|---|---|---|
| 1 | 10 | 32.52 |
| 2 | 15 | 33.24 |
| 3 | 20 | 33.98 |

[a] VA content (wt %) is 5%, PS content (wt %) is 3%.

$$\gamma_{LV}(1 + \cos\theta)/2(\gamma_L^d) = (\gamma_S^d)^{1/2} + (\gamma_S^p)^{1/2}(\gamma_L^{p\,1/2}/(\gamma_L^d)^{1/2} \tag{6}$$

The liquid parameter of $\gamma_{LV}$, $\gamma_L^d$, and $\gamma_L^p$ have been known by the literature.[6] Determining the $\theta$, $\gamma_{LV}(1 + \cos\theta)/2(\gamma_L^d)^{1/2}$ can be calculated. We can plot the relationship between $\gamma_{LV}(1 + \cos\theta)/2(\gamma_L^d)^{1/2}$ and $(\gamma_L^p)^{1/2}/(\gamma_L^d)^{1/2}$, obtaining a straight line. The intercept is $(\gamma_S^d)^{1/2}$, the slope is $(\gamma_S^p)^{1/2}$. However, the $\gamma_S$ can be calculated ($\gamma_S = \gamma_S^d + \gamma_S^p$).

The contact angle of PP/EVA/PS blends in the difference reference liquid are listed in Table I (see also Fig. 2).

The straight line intercept $(\gamma_S^d)^{1/2} = 5.20$, and the slope $(\gamma_S^p)^{1/2} = 2.34$. So $\gamma_S^d = 27.04$, $\gamma_S^p = 5.48$, $\gamma_S = \gamma_S^d + \gamma_S^p = 32.52$. The surface free energy of PP/EVA/PS blends (PP/EVA/PS = 87/10/3, VA content is 5%) is 32.52 mN/m.

## Effect of the EVA Content on the Polarity of PP/EVA/PS Blends

Under constanting the VA and PS content, the polarity of PP/EVA/PS blends will change with changing the EVA content in the blends. When the EVA content is increased, the polarity of the blends will be raised. The tests have verified this, seeing Table II and Figure 3.

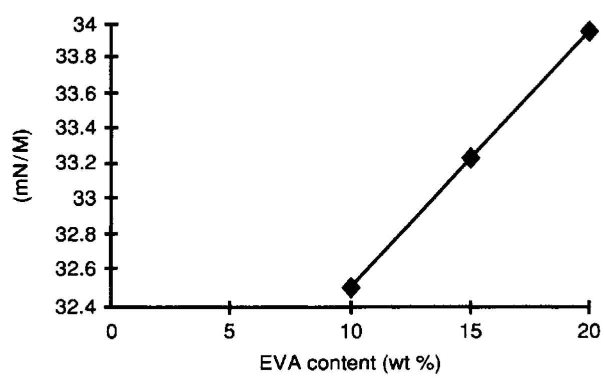


**Figure 3** Plot of surface free energy vs. EVA content. VA content (wt %) is 5% PS content (wt %) is 3%.

**Table III Surface Free Energy of PP/EVA/PS Blend**[a]

| No. | VA Content (wt %) | Surface Free Energy (mN/m) |
|---|---|---|
| 1 | 5 | 32.52 |
| 2 | 14 | 34.26 |
| 3 | 28 | 36.75 |

[a] Component ratio: PP/EVA/PS = 87/10/3.

Table II and Figure 3 show that the increasing scope of the polarity is small with increasing the EVA content.

### Effect of the VA Content on the Polarity of PP/EVA/PS Blends

The relationship between the polarity of PP/EVA/PS blends and the VA content is shown in Table III and Figure 4.

The surface free energy of PP/EVA/PS blends are raised with increased VA content. However, the increasing scope is great.

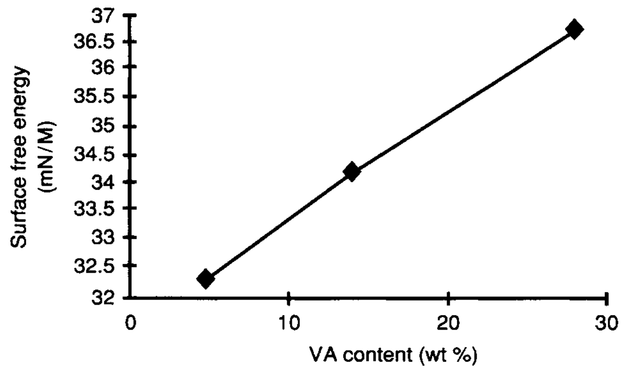


**Figure 4** Plot of surface free energy vs. VA content. Component ratio: PP/EVA/PS = 87/10/3.

## CONCLUSIONS

Based on the above discussions, the following conclusions can be obtained:

1. Polarity of PP can be raised by blending with EVA and PS.
2. Polarity of PP/EVA/PS blends raise as increasing EVA content, but the increasing scope is small.
3. Polarity of PP/EVA/PS blends raise as increasing VA content in EVA, however the increasing scope is great.

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