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# ETHYLENE- $\alpha$ -OLEFIN/PP BASED THERMOPLASTIC COMPOUNDS – EFFECT OF RHEOLOGY MODIFICATION

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The advent of metallocene-based ethylene  $\alpha$ -olefins produced via constrained geometry catalyst (CGC) polymerization, has added a new player in the thermoplastic elastomers (TPEs) scenario. Blending of these polymers is of great interest for a range of new applications. In this paper, we describe a process for rheology modification of ethylene-1-octene and ethylene-1-butene copolymers in blends with polypropylene to produce a new family of TPEs with improved processing and end use properties. The melt rheology, and physical properties are presented to discuss the morphological structure and properties of the blends.

## Introduction

Polymer blending allows engineers to develop materials with a specified balance of properties and processability. Thermoplastic Elastomers (TPEs) are a family of materials in which many of the physical properties of vulcanized rubber co-exist with the ease of processing thermoplastics<sup>1</sup>. TPEs can be cost effectively produced from a blend between an elastomeric ethylene- $\alpha$ -olefin (EAO) and a semi-crystalline polymer<sup>2</sup> (eg. polypropylene) through melt-mixing or reactive blending, a process called Rheology Modification (RM)<sup>3,4</sup>. During the past years studies on RM of metallocene-based ethylene-1-octene copolymer compounds have been reported for automotive applications, most of them focused on hard compounds<sup>4,5</sup>. However the search toward flexible compounds drives the need for soft TPEs having improved processing characteristics, melt strength, reduced hardness, while maintaining or improving physical properties. This study covers the effects of rheology modification on the melt rheology, morphology and physical properties of PP-EAO blends.

## Experimental

The ethylene- $\alpha$ -olefin copolymers were obtained from DuPont Dow Elastomers L.L.C.

*EO* – it is a 1 Melt Index (2.16 kg load at 190°C), 0.87 g/cm<sup>3</sup> density semi-crystalline ethylene-1-octene copolymer.

*EB* – it is a 0.8 Melt Index (2.16 kg load at 190°C), 0.88 g/cm<sup>3</sup> density semi-crystalline ethylene-1-butene copolymer.

The polypropylene was supplied by Dow Chemical Co. under trade name Inspire® C-105-02 – a random copolymer raco-PP with melt flow rate of 1.5 grams/10 min at 230°C, and 0.91 g/cc density. Polymers were

melt blended at 190 °C in a Haake Mixer with cam type rotors at 75 rpm. The rheology modified (RM) materials were prepared according the formulation in Table 1 (in phr).

**Table 1** – Recipe of EAO-PP blends

	<i>Blend</i>	<i>RM</i>
EAO	100	100
PP	67	67
Sunpar 2280 (Shell)	30	30
Irganox 1076 (Ciba)	1	1
tri allyl cyanurate (TAC)	0	0.3
2,5-dimethyl-2, 5-di-( <i>t</i> -butylperoxy)hexane	0	0.3

Each recipe was made using both the EO and EB materials, leading to four different compounds.

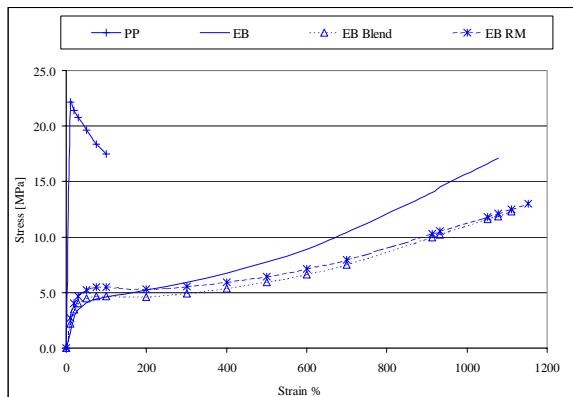
Rheological properties as a function of shear rate were examined using a Rheometric Scientific, Inc ARES (Advanced Rheometric Expansion System) dynamic mechanical spectrometer at 190 °C using dynamic frequency range from 0.1-100 rad/s parallel-plate mode with a 2 mm gap and 15% strain.

Stress-strain data were obtained using an Instron model 1123 with a 1 kN load cell and a constant crosshead speed of 127 mm/min performed according ASTM 1708 procedure at room temperature. Shore A was recorded 10s after contact with the sample.

## Results and Discussion

Figure 1 shows the stress-strain curves for the EB series and Table 2 summarizes the physical properties for all the studied compounds. The blends and RM materials showed high elasticity in accordance with the fact that in a co-continuous morphology the EAO will provide some elastic response at the experiment's time scale<sup>6</sup>. The differences observed between EO and EB can be attributed to distinct co-monomers and levels,

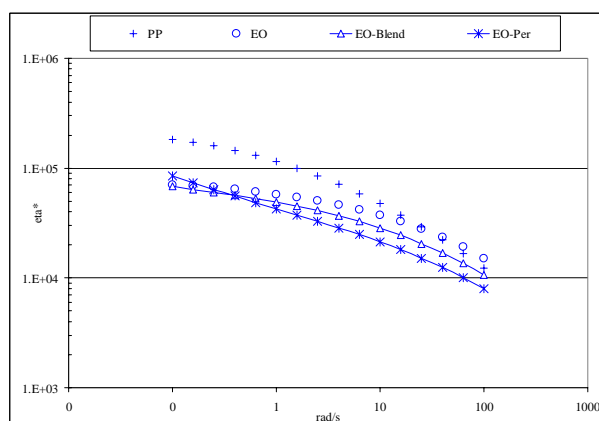
leading to differences in total crystallinity<sup>7</sup>. RM using peroxide tends to lock the melt morphology increasing entanglements between the phases and increasing service temperature, however the  $\beta$ -scission of PP caused by peroxide needs to be mitigated by the use of co-agent (TAC) or through mixing technique.



**Figure 1** – Stress-Strain curves for EB blends.

**Table 2** – Physical properties for EO and EB blends.

	EO	EO	EB	EB
	Blend	RM	Blend	RM
Hardness (Shore A)	76	77	77	81
Tensile Strength (MPa)	16.1	7.5	12.3	13.0
Elongation at Break (%)	913	725	1110	1152
Total Crystallinity (%)	21.6	17.9	20.7	20.8



**Figure 2** – Apparent viscosity versus frequency for EO at 190°C

Figure 2 shows the dependence of the logarithm of the complex viscosity versus the logarithm of the frequencies for the EO blends. As expected for such pseudoplastic systems the viscosity decreases as frequency increases. Power law flow index ( $n$ ) was calculated from the linear regression of log shear stress vs log shear rate plots and Rheology Ratio ( $RR$ ) from the  $\eta_{app}^{0.1 \text{ rad/s}}$  divided by  $\eta_{app}^{100 \text{ rad/s}}$  relationship. The results reported in Table 3 show how these blends fits the two-parameter Power-Law [ $\sigma = K\dot{\gamma}^n$ ], where  $K$  is

the consistency and  $n$  is the flow exponent. Also the principal relaxation time ( $\tau$ ) is reported in milliseconds for the pure polymers as obtained from Cole-Cole plots. The higher the  $n$  the less shear sensitive the blend is in the power law region of the spectrum. As expected the  $n$  decreases and  $RR$  increases when the samples are RM, leading to improved processability of compounded materials.

**Table 3** – Rheologic Parameters of EAO-PP blends.

	$RR$	$n$	$\tau(ms)$
PP	14.9	0.36	1580
EO	4.7	0.52	100
EB	3.8	0.52	40
EO-Blend	6.4	0.50	-
EB-Blend	5.2	0.52	-
EO-RM	10.6	0.52	-
EB-RM	9.4	0.53	-

## Conclusions

The rheological and mechanical properties were reported for the EO and EB blends and RM compounds using peroxide as modifier.

RM EAO-PP based compounds, render improved processability, with lower viscosity at high shear rates and higher melt strength at low shear, when compared to the simple blend.

EAO based compounds showed a new route to soft TPE materials with interesting properties. These RM compounds can be plasticized to adjust physical properties.

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