ABSTRACT

The Dow Chemical Company recently developed VERSIFY® Plastomers and Elastomers, a new family of propylene-ethylene copolymers produced with a newly developed catalyst family in combination with proprietary INSITE® Technology. These olefinic polymers feature narrow molecular weight distribution and broad crystallinity distribution. VERSIFY Plastomers and Elastomers have a unique molecular architecture manifested in a Tapered Isotactic Segment Distribution (TISD). This TISD relates to an excellent balance of product performance properties. The unique chain microstructure of the new polymers provides films, fibers, and molded parts with excellent optics, sealing and hot tack performance, elasticity, flexibility, softness and adhesion to polyolefins.
INTRODUCTION

Polyethylene and polypropylene constitute the two highest consumed thermoplastics in the world [Ref. 1]. Significantly increased growth of the application opportunities for these resins is driven by fundamental enhancements in their microstructure. These enhancements are driven by unique catalysts and flexible production processes, which create new materials with novel and enhanced properties as well as significant performance benefits.

The Dow Chemical Company developed a new family of catalysts, which allow copolymerization of propylene with various alpha-olefin comonomers over a broad range of compositions in an isotactic fashion with high molecular weight. Application of these catalysts in combination with INSITE Technology, has delivered a new technology platform of which the first generation products are the range of VERSIFY Plastomers and Elastomers.

These novel specialty propylene-ethylene copolymers are unique in their performance balance due to their new chain microstructure. They feature narrow molecular weight distribution and broad crystallinity distribution. The unique chain microstructure of these new polymers provides films, fibers, and molded parts with excellent optics, sealing and hot tack performance, elasticity, flexibility, softness and adhesion to polyolefins.

MICROSTRUCTURE FUNDAMENTALS

The unique chain microstructure of the new polymers is characterized by the concept of a Tapered Isotactic Segment Distribution, TISD. This TISD differentiates the microstructure of these new polymers from typical Ziegler-Natta catalyst-based and metallocene catalyst-based copolymers of propylene. This TISD is measured, for example, in Temperature Rising Elution Fractionation (TREF) by a skewing toward higher elution temperatures relative to the peak elution temperature as compared to Ziegler-Natta and metallocene products (above -1.20). The TISD is also characterized in Differential Scanning Calorimetry (DSC) by a melting behavior that is broad and remains essentially unchanged in shape as the overall crystallinity of the polymer decreases.
Figure 1 shows a TREF comparison between a developmental plastomer and a propylene copolymer made via Ziegler-Natta catalyst (Z/N-PP) or metallocene catalyst (mPP). The persistence of the crystalline fractions as the temperature increases can be used as one measure of TISD. Skewness has been quantified using Equation (1) and is depicted graphically in Figure 2. The developmental plastomers have a skewness index above −1.20 whereas the Z/N-PPs and mPPs have a skewness index below −1.20. The skewness in TREF is defined in equation (1) below as in which TMax is defined as the temperature of the largest weight fraction eluting between 50 and 90°C in the TREF curve, Ti and wi are the elution temperature and weight fraction respectively of an arbitrary ith fraction in the TREF distribution. The distributions were normalized (the sum of wi equals 100%) with respect to the total area under the curve eluting above 30°C. The skewness reflects the shape of the TREF curve of the crystallized polymer and is an example of a quantitative measurement of TISD. A higher skewness indicates a more gradual change in TREF distribution on both the low temperature and on the high temperature side.

Another characteristic of the TISD of the new VERSIFY Plastomers and Elastomers is that, in DSC, Tme remains relatively high as the overall crystallinity of the polymer decreases, as shown in Table 1. Tme is defined as the temperature at which melting ends. The developmental plastomers and elastomers exhibit broad melting behavior due to their broad crystallinity distribution. In particular, a high melting shoulder is maintained even at relatively low crystallinity, and this shoulder is absent for an mPP, as shown in Table 1. For example, at ~ 30% overall crystallinity, the developmental plastomer shows melting up to 145°C. In contrast, an mPP only shows melting up to 119°C.

The new VERSIFY Plastomers and Elastomers also show new micromolecular configurations created by the unique catalysts. For example, these polymers exhibit regio-errors that have not been present in commercial resins before, namely in the range of 14-16 ppm by 13C NMR.

\[ S_{\text{sk}} = \frac{\sum w_i \cdot (T_i - T_{\text{Max}})^3}{\left( \sum w_i \cdot (T_i - T_{\text{Max}})^2 \right)^{3/2}} \]

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The unique micromolecular configuration and the unique TISD are directly related to the observed value-added features of the developmental plastomers and elastomers. For example, the micromolecular configuration and TISD create a unique morphology [Ref. 1, 2] which manifests itself in the excellent gloss and low haze of these polymers. The melting characteristics of this unique morphology offer excellent heat sealing performance on the low crystallinity shoulder and maintained modulus on the high temperature shoulder.
The unique chain microstructure of VERSIFY Plastomers and Elastomers, which induces a unique morphology, provides a differentiating performance balance for films, fibers and molded parts with excellent optics, sealing and hot tack performance, elasticity, flexibility, softness and adhesion to polyolefins.

Figures 3-6 show the key product features and customer benefits of VERSIFY Plastomers and Elastomers in four selected market segments: Food & Specialty Packaging and Industrial & Consumer Packaging; Rigid Packaging and Durables; Thermoplastic Elastomers/Thermoplastic Olefins and Miscellaneous Compounds; and Consumer Products. Specific applications, in which the polymers have shown differentiated performance and are creating new value opportunities, are listed as well.

In Food & Specialty Packaging (F&SP) and Industrial & Consumer Packaging (I&CP), VERSIFY Plastomers and Elastomers provide flexible films with excellent clarity and sparkle for increased customer appeal, through an advantaged performance balance of low modulus, with good heat resistance and excellent optics. In addition, the specialty polymers, through their broad crystallinity distribution, show excellent adhesion to ethylene and propylene polymers and, therefore, can be formed or combined (multi-layers or blends) with inexpensive PE or PP resins to build cost-effective and feature-rich parts. The broad crystallinity distribution and broad melting range of VERSIFY Plastomers and Elastomers also impart a broad heat seal temperature window. This provides heat seal over a wide temperature range and adaptability to machines with limited heating control. Another distinguishing feature of the polymers is their soft-touch feel which is dry and non-rubbery and results in a pleasurable “grip” or “touch” for increased consumer appeal.

Examples of attractive applications for VERSIFY Plastomers and Elastomers are in low-temperature shrink films, BOPP sealants, lamination films, sealants for PP films, calendered and extruded soft films and sheets.

**FEATURES AND BENEFITS**

The new VERSIFY Plastomers and Elastomers are characterized by the property ranges as shown in Table 2.

### TABLE 2: Property Ranges of VERSIFY Plastomers and Elastomers

- Narrow Molecular Weight Distribution (MWD): 2 to 3
- Melt Flow Rate (MFR): 2 to 25 g/10min
- Density: 0.858 to 0.888 g/cc
- Comonomer Content: 5 to 15 wt%
- Glass Transition Temperature: -15 to -35°C
- Melting Range: 50 to 135°C
- Shore A Hardness: 50 to 75
- Flexural Modulus: 1,000 to 40,000 psi (10 to 280 MPa)

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Examples of attractive applications for VERSIFY Plastomers and Elastomers are in low-temperature shrink films, BOPP sealants, lamination films, sealants for PP films, calendered and extruded soft films and sheets.

**Figure 3: Features and Benefits of VERSIFY Plastomers and Elastomers in Food & Specialty Packaging Films and in Industrial & Consumer Packaging**

**KEY PRODUCT FEATURES**

- Low modulus, good heat resistance, excellent optics
- Excellent adhesion to ethylene and propylene polymers
- Broad bonding/heat seal temp window
- Desired haptics: dry and non-rubbery, but soft-touch feel

**CUSTOMER BENEFITS**

- Flexible film or molded part with excellent clarity and sparkle for consumer appeal
- Ability to mold, form or combine with inexpensive PE or PP resins to build cost-effective and feature-rich parts
- Heat seal/bond security over a wide temp range; adaptability to machines with limited heating control
- Impart a pleasurable “grip” or “touch” for increased consumer appeal
In Rigid Packaging and Consumer Durables, the new VERSIFY Plastomers and Elastomers extend the flexibility range in combination with good heat resistance and excellent optics, delivering, for example, flexible lids with excellent clarity. In addition, the soft-touch feel, which is dry and non-rubbery, significantly increases consumer appeal, for example, in soft-touch surfaces for bottles. The high flexibility and excellent optics are complemented by a broad sealing window with low heat seal initiation temperature. The combined features of the polymers offer a flexible, transparent and heat sealable lidding material with attractive aesthetics and good package security. Other examples of applications where the new polymers offer this advantaged performance balance are in sealants for thermoformed lidstock.

In Thermoplastic Elastomers (TPE), Thermoplastic Olefins (TPO) and Miscellaneous Compounds, VERSIFY Plastomers and Elastomers offer excellent adhesion to ethylene and propylene polymers and, therefore, offer the flexibility to mold/form/combine inexpensive PE or PP resins with the polymers to achieve cost-effective and feature-rich parts. The new polymers provide pleasurable aesthetics via soft-touch grip and feel. Another distinguishing feature of these new products is that they allow exceptionally high filler loadings yet maintain good processability. This provides the potential for reduced material cost in highly filled compounds in, for example, Wire & Cable and for increased sound-deadening capability in Noise Vibration Harshness compounds. The elastomers, in particular, have excellent elastic recovery which results in increased comfort fit, reduced handling damage and extended lifetime/durability, for example, in coated fabrics. Other examples of promising applications in this market segment include calendared films and gaskets.
In the Consumer Products market segment, the VERSIFY Plastomers and Elastomers feature a broad bonding window with good processability on high-speed spunbond fiber spinning lines. This allows for production of soft fibers in spunbond non-wovens with improved softness and reduced noise, and for good bond security over a wide temperature range. The polymers offer an attractive performance balance in, for example, soft-touch/low-noise films. The elastomers in particular also show excellent elastic recovery in films and fibers offering comfort fit.

**SUMMARY**

The new VERSIFY Plastomers and Elastomers from Dow have a unique chain microstructure consisting of a Tapered Isotactic Segment Distribution and a differentiated micromolecular configuration. This unique chain microstructure provides a differentiating performance balance through a broad crystallinity distribution and a unique morphology. VERSIFY Plastomers and Elastomers are versatile materials offering new combinations of clarity and high gloss, softness and elasticity with desirable touch and feel, low heat seal initiation temperatures and broad heat seal window, as well as elasticity and clarity. In addition, they have a high degree of toughness and sealability, good processability in a wide range of fabrication methods, as well as excellent adhesion to polyolefins.

**References**


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