Dow Elastomers for Automotive TPO Compounds

Flexible Solutions. Endless Possibilities.

Dow Elastomers

Look to Dow for Innovative TPO Material Solutions for Automotive Interiors and Exteriors

The automotive industry is constantly seeking to reduce vehicle weight in order to attain aggressive fuel efficiency targets. Different regions of the world seek to implement environmental measures in different ways.

This has led to increased efforts to reduce the overall weight of a vehicle by employing even more innovative technologies. The role of plastics in automotive design has become critical in both achieving the performance characteristics of a modern car and enabling this performance to be achieved more cost effectively. In today's transportation industry, plastics and composites have become increasingly important as a way to reduce the weight of the vehicle to achieve ever more stringent weight targets.

One of the most widely used materials in automotive today is thermoplastic polyolefins (TPOs), which generally consist of a blend of polypropylene (PP), a high performance impact modifier, and a filler, such as talc. TPOs have been widely adopted for use in both exterior and interior applications as a replacement for more traditional materials, like metal, as well as engineering thermoplastics, such as acrylonitrile butadiene styrene (ABS) and polycarbonate (PC)/ABS.

A potential route to reduce the weight of a vehicle is to further downgauge components by providing stiffer materials. This, however, presents significant technical challenges since the part has to maintain its stiffness and at the same time be produced with conventional processing technologies such as injection molding.

Automotive manufacturers continue to move toward global platforms and require suppliers to have a global footprint with the ability to serve them wherever they are. Manufacturer specifications describe a variety of requirements, which can vary from low-end impact performance up to ductile behavior at -40°C. This has led to the development of a number of different PP and elastomer products tailored to meet specific criteria. In the case of polyolefin elastomers (POEs), this has led to a range of different flow rates and densities.

Leading the Way

As the world's largest producer of POEs and a leader in ethylene propylene diene monomer (EPDM), Dow offers an innovation-rich portfolio and deep industry experience that continue to deliver solutions for applications across the specialty elastomers marketplace. Included are specialized solutions for "hard" TPOs used in automotive exterior and interior applications as well as "soft" TPOs for instrument panel (IP) skins and other interior components.

Dow materials offer the flexibility you require to meet your specific engineering needs and processing requirements. In many cases, Dow materials and technology can help you identify TPO solutions that deliver better performance and economics as replacements for PC/ABS, flexible polyvinyl chloride (f-PVC), thermoplastic vulcanizates (TPVs), leather, fiberglass, and other materials.

Our product offering continues to expand as we apply our advanced and proprietary polymer and catalyst technologies to identify TPO solutions that enable our customers to meet emerging requirements, differentiate their products, and improve their competitive positions. Likewise, Dow continues to strengthen its global manufacturing footprint to reliably supply products from North America, Europe, and Asia into a variety of applications and markets.

INSITE™ Technology

One important platform for Dow innovation is INSITE™ Technology, which combines metallocene catalysts invented by Dow with advanced material science and process technology. INSITE™ Technology is used by Dow to design new molecules and create innovative new specialty olefin products that deliver significant improvements in performance, cost, recyclability, and material usage over the polymers they replace.

Meeting Your Requirements

Advanced Dow technology, coupled with in-depth knowledge of automotive TPO compound requirements, enables Dow to offer a range of solutions based on desired compounding and processing characteristics as well as finished part performance and appearance.

Specialty elastomers from Dow are used as copolymers with polypropylene to enhance impact resistance, improve weatherability, minimize weight, and contribute to the recyclability of parts. Dow materials can also improve the processability of TPO compounds, enhancing productivity and economy in injection molding, sheet extrusion/thermoforming, and blow molding operations.

Serving You Globally

Global automotive supply chains demand global material solutions. Dow's worldwide capabilities enable us to meet your current needs and your expanded needs tomorrow. These world-class capabilities include:

- Global application and development and technical service resources
- Global customer service organization
- Global production capabilities and raw material integration

Flexible Materials from Dow

Here's an overview of the specialty elastomer materials available to you from Dow for TPO compounds:

ENGAGE™ Polyolefin Elastomers (POEs) have long been the impact modifiers of choice in hard TPO applications. Today, they are contributing to new advances in the performance and processability of both hard and soft TPOs as the use of TPO technology expands across today's vehicles and the cars of tomorrow. Recent developments include:

- ENGAGE™ HM POEs – which place increased emphasis on high melt strength and toughness.
- ENGAGE™ XLT POEs – which offer opportunities to produce lighter, thinner TPO parts with increased stiffness, comparable impact strength, improved fit and finish, and reduced cycle times versus the leading impact modifier.

DOW™ Very Low Density Polyethylene (VLDPE) Resins are good impact modifiers that also contribute strength, toughness and flexibility in hard and soft TPOs.

NORDEL™ EPDM products are industry-leading ethylene propylene diene monomer materials that offer enhanced processability and impart low temperature toughness to other polymers.

Dow Innovation Continues

Dow continues to develop innovative new solutions that enhance the performance and processability of TPO compounds.

VERSIFY™ Plastomers and Elastomers are just one example. These versatile propylene-ethylene copolymers are used as performance or processing modifiers that contribute superior optics, elasticity, flexibility, softness, and other haptic properties.

INFUSE™ Olefin Block Copolymers (OBCs) feature alternating blocks of hard (highly rigid) and soft (highly elastomeric) segments. These innovative materials offer the potential for TPOs with improved flexibility/durability, soft-touch feel, increased heat resistance, faster cycle times, and many other benefits.

AMPLIFY™ GR Functional Polymers are maleic anhydride (MAH) grafted polyolefins with excellent adhesive properties, compatibility with other materials, low melting temperatures, thermal stability, and low density for improved compatibility of inorganic fillers and enhanced TPO quality.

Dow's ongoing contributions to the expanded use of hard and soft TPOs are reducing vehicle weight, improving vehicle safety, improving durability, reducing glass fogging, and improving the recyclability of materials at the end of vehicle life.

Applications for TPO Compounds Containing Dow Elastomers

Processing and Performance Characteristics

Specialty elastomers from Dow can meet the full range of processing requirements for automotive TPO compounds. Dow offers several options for compounds used in injection molding of hard TPOs. Included are ENGAGE™ POE, DOW™ VLDPE, and NORDEL™ EPDM grades offering an excellent balance of impact resistance and economy, lower density materials for greater impact strength and low temperature ductility, as well as materials offering maximum impact resistance and higher flow during processing…the answer for today's increasingly complex and demanding part designs.

For thermoforming and blow molding of hard and soft TPOs, Dow has developed several grades of ENGAGE™ POEs that exhibit high melt strength due to the introduction of long chain branching into the polymer structure. In blow molding, high melt strength provides better sag resistance than conventional polyolefin elastomers, as well as extensibility for high blow-up ratios. In thermoforming, extruded sheet material made with our high melt strength materials is compliant during processing, yet retains shape stability, minimizing sag during preheating. This results in parts with high levels of surface quality and consistency as well as color stability. When combined with high melt strength polypropylene, these elastomers contribute to higher re-crystallization temperatures, allowing parts to be removed from molds more quickly, enhancing productivity.

Exterior TPO Applications

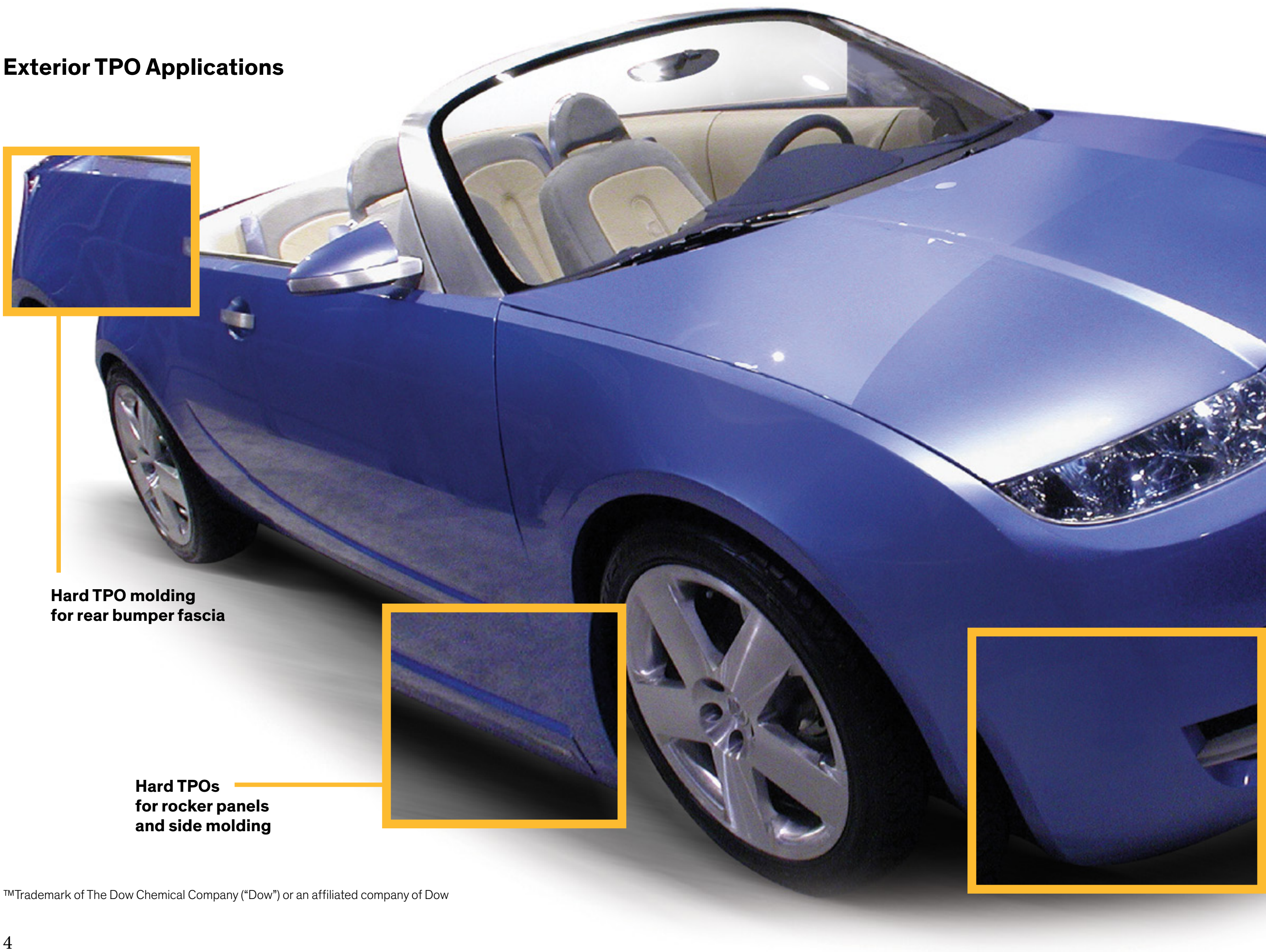

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Table 1: Elastomer Introduction for TPO Applications

Method	Positives	Deltas
PP In-Reactor		
Adding ethylene to the PP reactor to create ethylene-propylene (EP) elastomer segments for impact copolymer (ICP) or a reactor TPO (r-TPO)	• Excellent dispersion of the ethylene comonomer • Lower elastomer needs for compounding or for at-press and in-line processing	• Often lower throughput on the PP train (higher cost) • The reactor elastomer is generally not as efficient as higher performance elastomers – especially for low temperature impact strength • Still likely need to compound filler/additives for TPO use
PP Post-Reactor		
Feeding an elastomer into the PP compounding operations downstream from manufacturing	• Often higher manufacturing throughput of the base polypropylene • Increased flexibility in formulation versus in-reactor addition	• Capital may be needed for elastomer introduction • Still likely need to compound filler/additives for TPO use
Compounding		
Adding an elastomer to PP, fillers, and other additives in a compounding operation	• Greatest degree of flexibility • Multiple sources of ingredients • Ability to optimize cost and performance	• Capital requirements for compounding operations • Logistics/heat history
At-Press or In-Line		
Adding an elastomer directly to the ingredients stream in an injection molding or extrusion operation	• Bypasses compounding operation and reduces cost • Can modify elastomer levels as needed	• Generally less efficient dispersion than with compounding • Possible need for new capital and higher elastomer levels to meet impact requirements

Incorporating Elastomer into a TPO Compound

Elastomers can be introduced into a TPO at several different points in the value chain. While there is no right or wrong way to introduce the elastomer, there are inherent benefits and risks which may influence the direction of the manufacturer, compounder, or processor (see Table 1).

Furthermore, the selection of the elastomer may be influenced by the capabilities of the manufacturer (PP producer, compounder, or molder/extruder), the other TPO compound ingredients, and desired end-use performance. In many instances, the best cost/performance balance comes from compounding a lower-performing PP with a high-performance elastomer versus use of a polypropylene impact copolymer or reactor TPO (r-TPO).

Interior TPO Applications

Elastomer Design and Selection

The elastomer manufacturer has a variety of catalysts, processes, and monomers to create elastomers that are useful for TPOs.

Dow's use of INSITE™ Technology in the early 1990s enabled the creation of ENGAGE™ POEs that offered improved control of molecular architecture using metallocene catalysis and processing capabilities. These novel elastomers combined several benefits which led to improved TPO compound performance and their rapid success as replacements for other ethylene copolymers like EPDM:

- Low glass transition temperature – increasing alpha-olefin chain length from propylene (C3) up to butene (C4) and octene (C8) gives enhanced low temperature impact performance (see Figure 1) [1]
- Narrow molecular weight distribution and low branching levels – contribute to improved dispersion of the elastomer in the polypropylene (see Figure 2)
- Pellet form – allows continuous compounding and bulk handling of the elastomer

Figure 1: Low Temperature Ductility of Various Ethylene/Alpha-Olefin Elastomers[1]

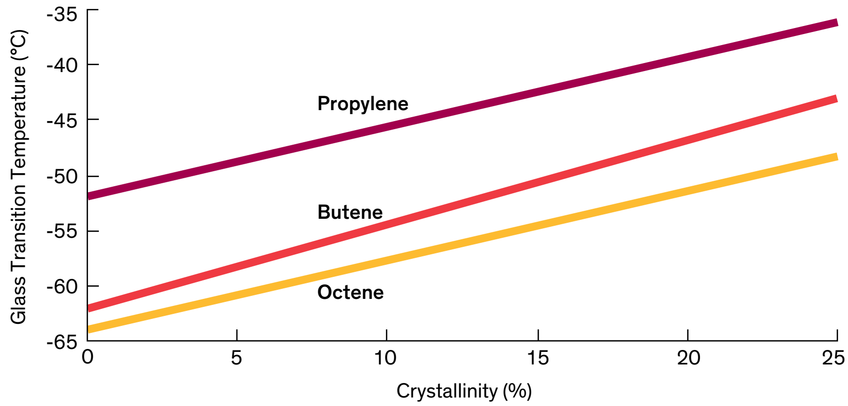
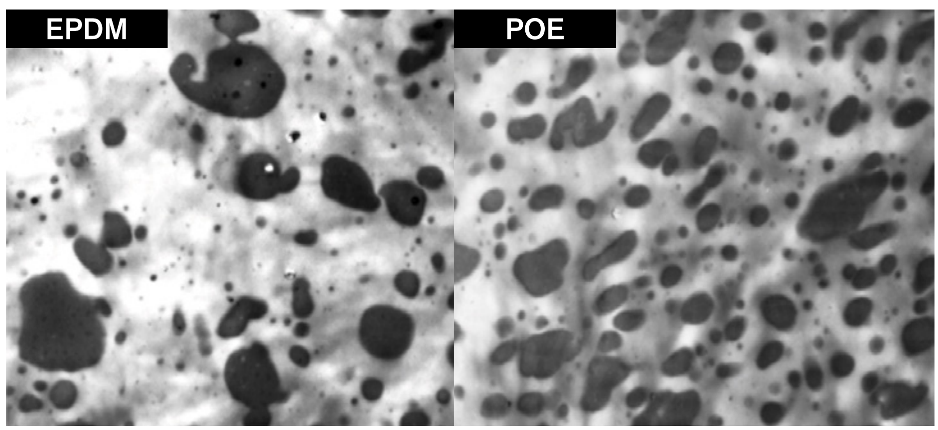


Figure 2: Elastomer Dispersion in TPO[1]



(4.5 mm = 1 micron)

Table 2: Summary of Elastomer Design Effects on TPO Performance [2]

Elastomer Effects on TPO Performance[1]	Low Temperature Impact	Flexural Modulus	Heat Distortion Temperature	TPO Injection Molding Flow	TPO Shrinkage	Melt Strength	Gloss
Decreasing Comonomer Chain Length	↓	↔	↔	↔	↔	↔	↔
Decreasing Elastomer Crystallinity (lower density)	↑	↔	↔	↔	↓	↔	↓
Decreasing Melt Index (increasing Molecular Weight [MW])	↑	↔	↔	↓	↑	↑	↑
Decreasing Elastomer Content	↓	↑	↑	↑	↑	↔	↑
Decreasing Molecular Weight Distribution (MWD)	↑	↔	↔	↓	↔	↓	↑
Decreasing Branching	↑	↔	↔	↓	↔	↓	↑

[1] Data per tests conducted by Dow. Test protocols and additional information available upon request. Properties shown are typical, not to be construed as specifications. Users should confirm results by their own tests.

Further development of INSITE™ Technology has resulted in the ability to modify branching and molecular weight characteristics to produce high melt strength grades of ENGAGE™ HM POEs. These elastomers demonstrate benefits in extrusion, thermoforming, and blow molding applications, as well as improving aesthetics (reductions in gloss and flow lines) in injection molded parts [3].

Table 3 demonstrates Dow's breadth of specialty elastomers that can be used for TPO modification to achieve a desired balance of properties and processing.

Beyond these products, there are other innovative materials that are beginning to enter the marketplace, including propylene-ethylene elastomers [4] and olefin block copolymers [5, 6].

The Dow specialty elastomers are further divided into TPO performance levels and processing subsets as shown in Table 4 (page 9).

Using this selection guide, Dow recommends starting TPO injection molding formulations with the desired PP and filler/additives and adding progressively higher levels of the "Better" elastomers

Table 3: Typical Properties of Dow Specialty Elastomers for TPO Compounds(1)

Grade	Comonomer with Ethylene	Density, g/cm^3 (ASTM D 792)	Melt Index, g/10 min (2.16 kg @ 190°C) (ASTM D 1238)	Tg, °C (Dow DSC Method)
ENGAGE™ 7270/7277(2)	Butene	0.880	0.8	-44
ENR 7380/ENGAGE™ HM 7387(2,3)	Butene	0.870	<0.5	-52
ENGAGE™ 7447(2)	Butene	0.865	5	-53
ENGAGE™ 7467(2)	Butene	0.862	1.2	-56
ENGAGE™ 8003	Octene	0.885	1	-46
ENGAGE™ 8100/8107(2)	Octene	0.870	1	-52
ENGAGE™ 8130/8137(2)	Octene	0.864	13	-57
ENGAGE™ 8150/8157(2)	Octene	0.868	0.5	-52
ENGAGE™ 8180/ENR 8187(2,3)	Octene	0.863	0.5	-55
ENGAGE™ XLT 8677(2)	Octene	0.870	0.5	-65
ENGAGE™ 8200/8207(2)	Octene	0.870	5	-52
ENGAGE™ 8400/8407(2,4)	Octene	0.870	30	-54
ENGAGE™ 8842(2)	Octene	0.857	1	-58
ENGAGE™ HM 7487(2)	Butene	0.860	<0.5	-57
DOW™ VLDPE 1085(5)	Butene	0.884	0.75	-52
ENGAGE™ HM 7280	Butene	0.884	0.1	-49
DOW™ VLDPE 1095(5)	Butene	0.886	1.3	-52
ENGAGE™ HM 7289	Butene	0.886	0.45	-49
NORDEL™ IP 3720P(6)	Propylene	0.870	1	-44
NORDEL™ IP 3745	Propylene	0.870	<0.5	-44
AMPLIFY™ GR 216(7)	Grafted	0.875	1.3	-54

(1) Data per tests conducted by Dow. Test protocols and additional information available upon request. Properties shown are typical, not to be construed as specifications. Users should confirm results by their own tests.
(2) ENGAGE™ POE/ENR products with numbers ending in 7 (e.g., 7277, 8407) and ENGAGE™ 8842 have talc partitioning for improved product handling; properties may be measured before the addition of talc.
(3) ENR designates a developmental grade. When using developmental products, customers are reminded that: (1) product specifications may not be fully determined; (2) analysis of hazards and caution in handling and use are required; (3) there is greater potential for Dow to change specifications and/or discontinue production; and (4) although Dow may from time to time provide samples of such products, Dow is not obligated to supply or otherwise commercialize such products for any use or application whatsoever.
(4) ENGAGE™ 8400 POE is available in the European region. ENGAGE™ 8407 POE is available globally. (5) Very Low Density Polyethylene (6) EPDM with diene content of less than 0.5% (7) Maleic Anhydride grafted copolymer

until the desired ductility is achieved. Further optimization of the TPO compound can then be made to achieve the desired balance of performance. Likewise, TPOs for extrusion, thermoforming, or blow molding can be formulated with high melt strength elastomers (usually an elastomer having <0.5 melt index) and coupled with branched or conventional PPs as needed for TPO compound processing stability and performance.

Moving Forward

Elastomer technologies continue to evolve to meet the cost/performance needs for TPO applications. The elastomers evolution will need to continue to coincide with advances in materials (polypropylene, fillers, and additives), and process technologies. Many of the trends for performance are well established for existing applications and processes, and further development is being focused on emerging technologies.

Table 4: TPO Elastomer Selection[1]

Injection Molding			
Better	Best		
Balance of Properties	Superior Impact	High Flow	Low Gloss
ENGAGE™ 8100/8107	ENGAGE™ XLT 8677	ENGAGE™ 8130/8137	ENR 7380/ ENGAGE™ HM 7387[2]
ENGAGE™ 8150/8157	ENGAGE™ 7467	ENGAGE™ 8400/8407[3]	ENGAGE™ HM 7487
ENGAGE™ 8200/8207	ENGAGE™ 8180/ ENR 8187[2]		
	ENGAGE™ 8842		
	ENGAGE™ HM 7487		

Extrusion/Thermoforming & Blow Molding	Other Considerations
High Melt Strength Elastomers	Compatibilizer/Other
ENR 7380/ENGAGE™ HM 7387[2]	AMPLIFY™ GR 216
ENGAGE™ HM 7487	VERSIFY™ Product Series
ENGAGE™ HM 7280	INFUSE™ Product Series
ENGAGE™ HM 7289	

[1] Data per tests conducted by Dow. Test protocols and additional information available upon request. Properties shown are typical, not to be construed as specifications. Users should confirm results by their own tests.
[2] ENR designates a developmental grade. When using developmental products, customers are reminded that: (1) product specifications may not be fully determined; (2) analysis of hazards and caution in handling and use are required; (3) there is greater potential for Dow to change specifications and/or discontinue production; and (4) although Dow may from time to time provide samples of such products, Dow is not obligated to supply or otherwise commercialize such products for any use or application whatsoever.
[3] ENGAGE™ 8400 POE is available in the European region. ENGAGE™ 8407 POE is available globally.

We're Ready to Meet Your Needs

Dow's broad portfolio of flexible polyolefin solutions offers virtually endless possibilities for the development of automotive TPOs that deliver components combining lighter weight with excellent performance, processing, system cost efficiency, and sustainability. We welcome the chance to discuss your material requirements and help you identify the optimum solution for your needs.

For more information about how the Dow products and technologies featured in this brochure can help improve your hard and soft TPO applications, contact your Dow Elastomers representative or the nearest location listed on the back cover. You can also learn more by visiting www.dowelastomers.com.

References

[1] Laughner, et. al., "Modification of Polypropylene by Ethylene/Alpha-Olefin Elastomers Produced by Single-Site Constrained Geometry Catalyst," *Proceedings of the SPE-Automotive TPO Global Conference* (1999).

[2] J.J. Hemphill, et al., "Expanding the Elastomer Portfolio for TPO Applications," *Proceedings of the SPE-Automotive TPO Global Conference* (2006).

[3] J.J. Hemphill, et al, "Continued TPO Elastomer Development," *Proceedings of the SPE-Automotive TPO Global Conference* (2007).

[4] VERSIFY™ Plastomers and Elastomers, along with ENGAGE™ analogs that provide superior melt strength for thermoforming and blow molding applications.

[5] INFUSE™ Olefin Block Copolymers

[6] L.B. Weaver, et al., "A New Class of Higher Melting Polyolefin Elastomers for Automotive Applications," *Proceedings of the SPE-Automotive TPO Global Conference* (2006).

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