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Metallocene Technology



Univation's success story still being told

The opening chapter of our metallocene success story began with a major breakthrough that set the benchmark for others to follow. In the early 1990s, Exxon Chemical Company, now ExxonMobil Chemical Company, developed revolutionary single-site metallocene catalysts for use in a subsidiary of Dow Chemical's gas-phase UNIPOL™ PE Process. Environmentally friendly and safety oriented, this low-pressure process has provided a perfect platform for developing metallocene technology.

Building on that success, The Dow Chemical Company and ExxonMobil Chemical Company formed a joint venture, Univation Technologies, which introduced XCAT™ Metallocene Catalysts to the market.

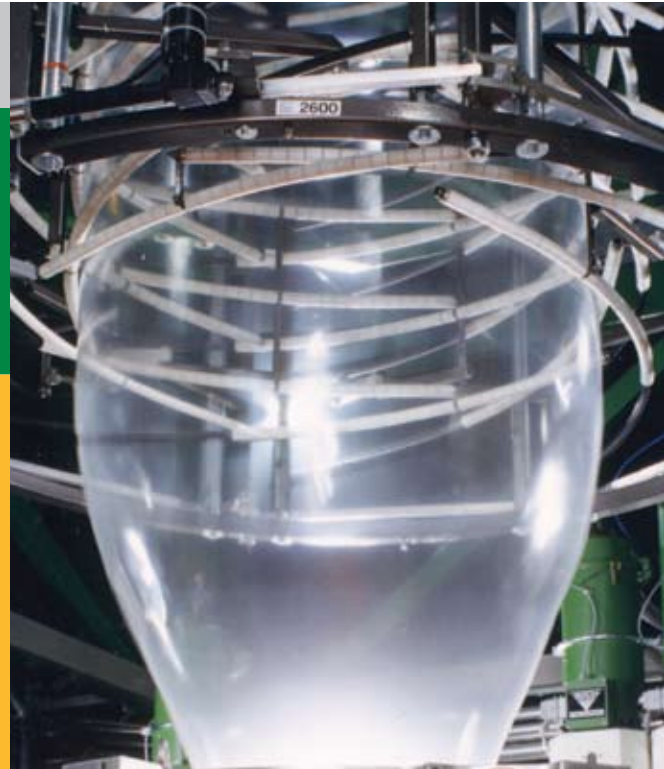
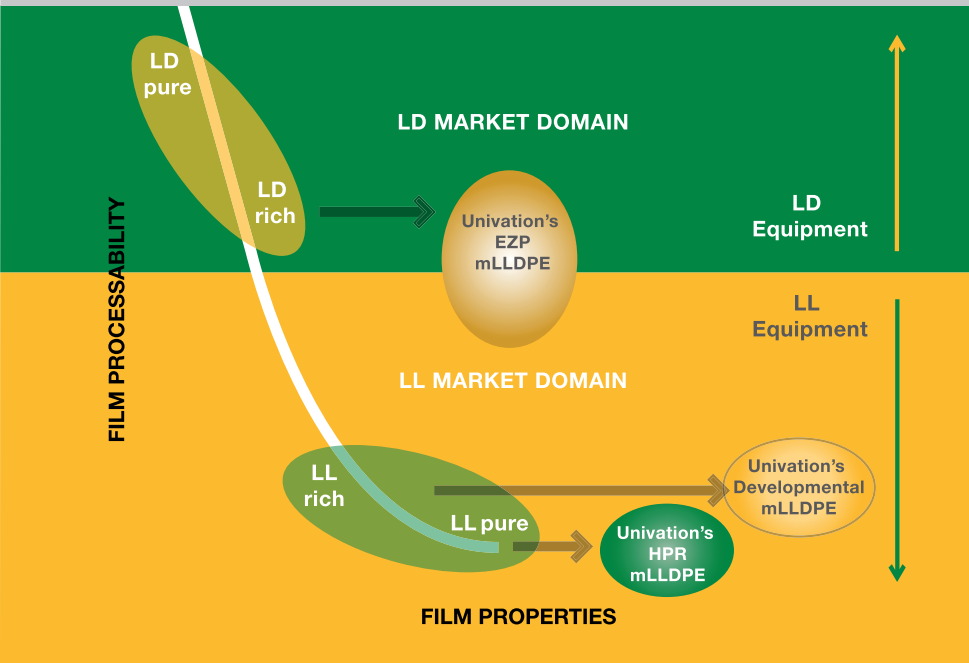
Tougher, clearer and easier to process than competing resins, the high-performing metallocene linear low-density polyethylene (mLLDPE) resins produced using XCAT catalysts provide the primary ingredient for a wide range of products. Among them: Flexible packaging, pallet stretch wrap, collation shrink-films, general-purpose and carrier bags, heavy-duty bags, and food-packaging and agricultural films.

Our metallocene technology redefined the performance limits of polyethylene, enabling producers to create precisely tailored resins that open the door to new and differentiated global markets.

Catalyst Evolution Timeline

Initiators	Phillips Catalyst	Ziegler-Natta Catalysts	Metallocene Catalysts			
<ul style="list-style-type: none"> • Low-density polyethylene 	<ul style="list-style-type: none"> • Linear PEs • Primarily high-density 	<ul style="list-style-type: none"> • Linear PEs • High-and-low-density 	<ul style="list-style-type: none"> • First generation • Controlled-architecture PEs: linear to bimodal • Tailored performance: improved properties and/or processing • Principally low- and very low-density 	<ul style="list-style-type: none"> • Second generation • Improved film processability • Higher strength replacements for high-pressure LDPE blends 	<ul style="list-style-type: none"> • Next generation • Extend density range • Improve product performance • Extended applications 	
				Bimodal Catalyst <ul style="list-style-type: none"> • Competitive product performance in single-reactor platform 	Bimodal Catalyst <ul style="list-style-type: none"> • Broaden application areas 	
1930s	1950s	1970s	1990s	2000s	2010s	

Polyethylene - Processability vs. Properties Map



Our Portfolio Distinguishes Us as the Industry Leader

Today, we offer a broad portfolio of metallocene technologies that distinguish us as a leader in our industry:

- mLLDPE films and very low-density films (mVLDPE) that provide excellent dart impact and puncture resistance, tensile strength and heat-sealing performance.
- Second generation easy-processing mLLDPE, the first mLLDPE to compete effectively with high-pressure, low-density polyethylene for shrink-film applications. These resins produced via XCAT catalyst offer a unique balance of easy processing, excellent shrink properties and outstanding optical characteristics.
- Engineered catalyst technology to produce PE resins with bimodal molecular-weight distribution in a single UNIPOL PE reactor – a milestone achievement that eliminates more costly two-reactor configurations.

Univation technology has many advantages to offer. Improved operating economics. Tougher, clearer, better-performing polyethyl-

ene resins. The industry's broadest range of product capabilities. Extreme versatility, enabling resin producers to change their grade slate with the changing markets. That powerful combination has resulted in a record number of licenses being issued recently and increasing commercialization of our technology by third parties.

A History of Innovation for Metallocene Catalyst Production

Univation Technologies has developed and fully commercialized metallocene catalysts for producing polyethylene resins that offer significant value over resins produced with conventional catalysts. Our XCAT Metallocene Catalysts result in exceptionally uniform metallocene polymers with narrow molecular-weight and composition distributions. They produce resins with tailored molecular designs, reliable production and impressive performance and processing properties that non-metallocene catalysts or conventional Ziegler-Natta catalyzed materials cannot provide.



Our XCAT Metallocene Catalysts give our customers' products a clear-cut competitive advantage:

- Outstanding toughness with improved tensile strength, impact resistance and puncture performance
- Excellent optics with better clarity and higher gloss for more appealing packaging
- Less odor and off-taste
- Higher recycle and reclaim incorporation rates for less waste
- Lower heat-seal initiation temperatures and higher hot-tack strength for faster line speeds and excellent seal integrity

Univation has created a variety of solutions to meet our customers' diverse requirements. Our first generation solution involves our XCAT HP Catalyst. This catalyst system produces polymer molecules with a more uniform molecular-weight distribution compared to conventional Ziegler-Natta catalyzed LLDPE. This leads to higher performance capability but reduces processability, which can be improved by blending XCAT mLLDPE with high-pressure polyethylene.

Our second generation XCAT Metallocene Catalyst is designed for making easy-processing (EZP) mLLDPE. This catalyst system produces a polyethylene that is extremely tough and provides an improved-strength replacement for LDPE/LLDPE blends and pure high-pressure LDPE products while matching the processing ease of LDPE in high-volume blown film applications. The XCAT EZ 100 catalyst was designed to replace LDPE/LLDPE blends, so high pressure is eliminated.

For converters, these resins offer easier, more efficient extrusion and conversion with less blocking, less waste and less downtime compared to conventional resins. Plus, there's no need to retool existing conversion equipment.

Overall Operability is Critical

We have developed reactor continuity additives to enhance our XCAT Metallocene reactor operability. These additives keep the plant running longer without fouling the system or producing agglomerates, which can lead to plant shutdown.



In addition, Univation has successfully developed several process-related technologies that result in smooth operation of metallocene-based catalysts and production of superior products for many applications. Some of the process-related technologies that were developed and successfully implemented include:

- Use of advanced detection and monitoring techniques for early detection of discontinuity events
- Advanced control strategies and algorithms
- Catalyst delivery for optimized particle morphology
- Defined procedures and reaction models for smooth operation during critical stages and steady state

These new metallocene operability enhancements facilitate UNIPOL PE's well established ability to operate at higher throughput. These advantages have allowed Univation licensees to produce large volumes of high value products.

A New Generation of Metallocene Technology

In recent years, Univation has expanded its operating experience and strengthened its understanding of the subtleties of running a PE plant. As a result, we built on the market success of our first-generation high-performance resins (HPRs) by introducing second-generation EZP technology that helped open up new markets and applications, such as shrink wrap.

These two technologies provide a perfect complement to each other in the PE field, where there are often trade-offs between a plastic's performance and its processability. Narrow molecular-weight distribution makes the product harder to process. With broader weight distribution, processability improves, but product performance drops.

Our latest technology, PRODIGY™ Bimodal Catalyst, comprises two active species with a metallocene catalyst making up the low molecular-weight fraction. This new technology gives resin producers the swing capability to produce both LLDPE and HDPE and, more importantly, to compete with bimodal HDPE products in the global market without investing capital in a two-reactor system.



More Technology Breakthroughs on the Horizon

Univation continues to be committed to major research and development programs in metallocene catalyst systems. Unquestionably, our customers' needs drive our focus. We are investing in discovery research wherever we see promise for our licensees. Our developmental XCAT VP-100 (Versatile Performance) next generation catalyst, which is being developed to broaden the scope of metallocene applications, provides a stellar example of our dedication to meeting customers' needs. It is useful not only in film applications, but in injection and rotational molding applications and other medium-density applications. The versatility is achieved by adjusting reaction conditions to make this range of products with a single-catalyst system.

While the earlier generation of metallocene products (XCAT HP-100 and EZ-100) continue to prove successful in the high-strength commercial market, the XCAT VP 100 technology promises to cover all high-performance mLLDPE film applications.

The potential of VP technology is limited only by the imagination, and we believe it will become the single catalyst that goes far beyond the film markets to fit a very broad range of applications. Our success story will continue to unfold with more exciting chapters that reveal our continued ability to accommodate the polyethylene market of the future.

Our Metallocene Technology Potential is Unlimited

Over the past 15 years, millions of tons of MCN polyethylene resins have been produced using our UNIPOL PE Process and XCAT technology. Univation has become the leading global supplier of proven metallocene PE technology, which continues to have robust double-digit annual growth worldwide. Our XCAT technology has been commercialized globally. Clearly, we have a success story worth telling.

Proven to deliver. Designed to adapt. That is the Univation promise that has made us an industry leader.



XCAT Catalysts Make for Easy Plant Retrofit

Customized for the UNIPOL PE gas-phase process, XCAT Metallocene Catalysts can be added easily to existing UNIPOL PE plants. Univation brings strong technical know-how, unsurpassed licensing experience with gas-phase PE process technology and successful production and market experience with metallocene-based resins to each metallocene-catalyst plant retrofit.

A retrofit solution with XCAT Metallocene or PRODIGY Bimodal Catalysts usually requires minimal modification and little disruption to licensee's current production schedules. Customers also find that a conversion to XCAT Metallocene Catalyst, coupled with Univation expertise, allows you to further increase output (via higher condensing) while producing a higher value product.

Clients who are constructing a new facility will assess whether they intend to produce these resins initially or at a later time. If included in the initial design, there will be minimal impact on the overall constructability of the plant as footprint and equipment requirements can be taken care of in an optimal manner.

"I consider the metallocene retrofit to be a very successful project. Univation personnel, with longtime metallocene experience, supported us through technology transfer, operational training and plant modifications for our metallocene operation. The modifications were very minor. The entire preparation process took about three months. And within three commercial scale campaigns, we were off producing products successfully on our own without Univation's assistance. We now have nearly five years of commercial run experience with metallocene technology from Univation."

Eduardo Carnaúba, Lead Engineer, Braskem
Camaçari Project

"The process of readying the UNIPOL PE process plant for producing metallocene LLDPE resins went very smoothly, thanks to the advice of Univation's Engineering and Manufacturing specialists. They provided us with excellent technical support from start to finish."

Mr. Claudio Abreu, Production Plant Manager,
Quattor (formerly Rio Polimeros), Duque de Caxias, Brazil



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