Product Innovation through Catalyst Solution to Polyolefin Producers

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Regional Technical Manager-A/P
Agenda

• Introduction of Grace Business
• Grace’s Catalyst Solution
• Product Innovation to Polyolefin Producers
• Summary
$~$2B in 2017 Sales

Refining Technologies  
Specialty Catalysts  
Materials Technologies

Over $1B in Strategic Acquisitions to Strengthen Polyolefin Catalyst Portfolio

- 2010 –Synthetech for Single-Site Catalysts
- 2013 –UNIPOL® PP Licensing and Catalysts Business
- 2016 –BASF / LYNX® Polyolefin Catalysts Business
- 2018 –Albemarle Polyolefin Catalysts Business

- FCC Catalysts
- Hydroprocessing
- Hydrocracking
- Polyolefin catalysts
- Independent polypropylene process technology licensing
- Specialty silica gel

1 Sales based on FY2016; Catalysts Technologies includes unconsolidated ART joint venture. FCC = Fluid Catalytic Cracking, SC = Specialty Catalysts, ART = Advanced Refining Technologies®. FCC and ART together are referred to as Refining Technologies.
Catalysts / Refining Technologies

Competitive Advantages
- Customer-focused, solutions-oriented approach
- Broad, highly-differentiated portfolio of products
- Industry-leading technical service
- Flexible manufacturing system
- Research leadership and innovation centered on customers’ current and future needs

Key Customers
- Global public oil companies
- National (state-owned) oil companies
- Regional independent refining companies

Meeting refiners’ needs and ensuring success

FCC Catalysts
- Achieving maximum yields of most valuable refining products
- Providing optimal catalyst selection for refinery crude slates

FCC Additives
- Improving specific yields
- Enhancing product quality
- Reducing emissions

ART Hydroprocessing Catalysts
- Fixed and ebulating bed resid
- Hydrocracking
- Distillates
Delivering Value

- Customer-focused, solutions-oriented approach
- Broad, highly-differentiated portfolio of products
- Ability to develop and optimize catalyst properties to specific applications
- Flexible assets for the scale-up and production of commercial catalysts
- Wide range of analytical tools and testing for product and process improvements

Key Customers

- Global petrochemical companies
- National (state-owned) petrochemical companies
- Plastic resin producers

Polystyrene (PE) catalysts
- Hydrogenation catalysts
- Technologies for alternative and traditional feedstock
- Catalyst performance is a combination of design, characterization, and manufacturing
- UNIPOL® PP Proprietary Gas Phase Polypropylene Process Technology
- Simple to build, operate, and maintain

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Chemical Catalysts
- Catalysts and supports
- Hydrogenation catalysts
- Technologies for alternative and traditional feedstock

Process Licensing
- Polyethylene (PE) catalysts
- Polypropylene (PP) catalysts
- Catalyst supports
- Components

UNIPOL® PP Proprietary Gas Phase Polypropylene Process Technology
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UNIPOL® PP Proprietary Gas Phase Polypropylene Process Technology
- Simple to build, operate, and maintain
Grace Specialty Catalysts Solution
Grace Integrated Polyolefin Catalyst Portfolio

The only fully integrated supplier of polyolefin catalyst solutions across all processes and catalyst technologies

**Polyethylene**
- Gas Phase
- Loop
- CSTR/Solution CSTR

**Polypropylene**
- Bulk/Gas
- Gas Phase

**Chromium Catalysts**
- Ziegler Natta Catalysts
- Single Site Catalysts
- Supports and Components

**SYLOPOL® MAGNAPORE®**
- ActivCat®
- LYNX®

**Development Capabilities**

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Polymer</th>
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<tr>
<td>Lab Scale</td>
<td>Bench scale reactors</td>
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<tr>
<td>Mini-plant (1-3 kg)</td>
<td>PP Pilot plant</td>
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<tr>
<td>Pilot plant (20-100 kg)</td>
<td>Polymer characterization lab</td>
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<tr>
<td>Commercial scale (200+ kg)</td>
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Better Resin Performance by Design

- The possible combinations provide the basis for differentiation in our industry
- Controlling the inputs defines the resin architecture output
- Catalyst is ultimately the key for unlocking a plant’s resin design capabilities
Enhance Polymer Resin designing with Catalyst Platform

mPO

- Homogeneous Active Center
- Homogeneous Polymer Properties

Z/N and Cr-PO

- Various Active Center
- Various Polymer Properties

*Narrow MwD & CCD

*Broad MwD & CCD

* CCD

- Chemical Composition Distribution
What exactly is this revolution?

- With single site catalysts it is possible to “design” the architecture of the polymer by modifying the structure of the metallocene.
  - Control of comonomer incorporation across the range of MWD
  - Control of MWD
  - Control of branching

- Exponential growth in variations of highly complex molecules*

Polyolefin Catalyst Trends

1980s
- Early generation catalyst innovations and incremental process developments
- Focus on catalysts coupled to process technologies to differentiate

1990s
- Focus on higher throughput and high operating rates of plants
- Less focus on new process technologies
- Metallocene beachhead begins

2000s
- Wave of PO expansions based on advantaged feedstock costs
- Large new plants with smaller product wheels to maximize utilization
- Strong driver for differentiation via new catalyst technologies

Grace has invested to support our customers throughout these changes

Process and Catalyst Patents

- UNIPOL® PP plants can be >650 kton as a single train

Max unit size has increased by 67% for PP and 44% for PE since 2000

Source: IHS Markit 2017

Avg. PO Plant Capacity, kta

Source: Cap Gemini, EspaceNet, EBB analysis

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Polyolefins Developments

Single Reactor

- Early developments with smaller range of resin options
- Resin improved through catalyst development and process improvements
- Enhanced resins with dual catalysts but difficult to mix types and harder to control

Dual Reactor, Multi-Stage

- Enabled value added solutions
- Bimodal PE resins
- High rubber ICP / PP resins
- Catalyst developments and process control critical to success
- Kinetics, comonomer incorporation
- Broader reactivity range catalysts

Degree of Difficulty to Operate

PE and PP catalyst developments aligned with increasing resin design control needs

<table>
<thead>
<tr>
<th>Annual Segment Growth Rate</th>
<th>Time</th>
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<tr>
<td>Cr</td>
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<td>ZN</td>
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<td>Metallocene</td>
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<th>Product and Performance Breadth</th>
<th>PP</th>
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<td>Hyammp®</td>
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<td>LYNX® 3rd</td>
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<tr>
<th>Non-phthalate Narrow Operating Window</th>
<th>Non-phthalate Broad Operating Window</th>
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<td>CONSISTA®</td>
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**Key takeaways:**

- It is critical to carefully match catalyst to process to optimize product performance
- Catalyst innovations by Grace will continue to drive product and performance enhancements across all process platforms
Product Innovation with Catalyst Solution
Future Developments

Market Drivers

• A focus on carbon efficiency will promote resin light weighting, supply efficiency and material substitution
• Recycling regulations will drive advancement in resins to meet more demanding application needs
• Growing middle class will drive plastics demand but with a focus on sustainability
• Responsible care on life cycle of resins being passed onto resin producers
• Shale Gas momentum and North America back in competitive mode, Anticipating erosion of margin for commodity PO resin

Catalyst Opportunities

• New resin needs will be met through new catalyst developments and/or process developments with multi-catalyst inputs
• Advanced processes require advanced catalysts to meet increased requirements of operation
• Leverage catalyst capabilities to optimize resins for improved recyclability and sustainability
• Broad catalyst technology platform for polymer producers to maximize their asset and margin

Grace has strategically invested and is positioned to enable resin producers to meet these market and catalyst needs
Grace Technology Enables Better Products by Design

Customer Challenge
The range of products a production plant can make is a function of the catalyst and the range of conditions under which it smoothly operates.

Example 1: Catalyst Design
By designing a catalyst with superior Flexural Modulus capability, tougher or stiffer products can be produced in a given reactor.

Delivered Solution
- Leading UNIPOL® PP process economics
- Phthalate free products
- 10% light weighting of finished articles
- Reduced energy & carbon usage

Example 2: Donor design
By designing PP donors with superior Hydrogen response, higher melt flow products can be produced in a given reactor.

Delivered Solution
- Leading UNIPOL® PP process economics
- Phthalate free products
- Minimize/eliminate peroxide usage
- Cleaner environmentally friendlier product
Higher Activity = Lower Cost-in-Use

- Resin properties equivalent to standard MAO/silica catalysts
- Proven in a variety of process technologies
- Reduces the cost-in-use gap between conventional Z/N and metallocene catalyst.

Without Sacrificing Resin Properties
Value creation to Polyolefin Producers

Properties of LPG Cylinders

- Lightweight, up to 50% less than steel cylinders
- Composite cylinders are corrosion free
- More safety, burst pressure > 120 bar
- Easy to handle and stackable
- The valve is very well protected against impact
- It is easy to clean
- Typ IV cylinders are translucent
- The material is UV resistant to effects from sun, rain, temperature variations and handling
- Less maintenance
- Flexible & attractive design
- Very good behavior in fire, no explosion!
LPG and CNG gas tank

- Resin made with Grace Cr has been tested and passed the gas tank composite with our collaboration with Kautex, Germany.
Summary

- Grace is a **fully integrated** supplier of polyolefin catalysts across all process and catalyst technologies.

- Wide and broad catalyst technology platform allow Polyolefin Producers to benefit the solution to face the dynamic and competitive business environment.

- Grace focuses on **high-performance** products and services to enable our customers.

- Enable to maximize the product and asset.

- Grace has been **continuously investing** in capacity expansion, technology and quality improvement to better serve our customers.

Thank you for trusting us with your catalyst needs. Together, we look forward to increasing the value of your polyolefin business.
THANK YOU

Questions?