EPDM Materials by Design

Dr. Olaf Henschke

Colin Li Pi Shan, Varun Thakur, Jaap Den Doelder
Dow Elastomers R&D

December 7, 2016
Innovations in Rubber Design, London, UK
EPDM by Design

1. Dow’s commitment and sustainability to the rubber industry
2. New Materials Research and Development
3. Focus on Automotive Sealing Systems
Dow’s Sustainability Journey

Our Aspiration:
To advance the well-being of humanity by helping lead the transition to a sustainable society and planet.

2005 EH&S Goals
Journey to EH&S Excellence

Footprint and EH&S Culture

2015 Sustainability Goals
Product Solutions to World Challenges

2025 Sustainability Goals
Thought Leadership and Actions

Blueprint

Handprint

1995 2006 2016 2025
Delivering Sustainable Impact

Dow is a thought leader in delivering sustainable impact for global challenges

- Leading the Blueprint
- Delivering Breakthrough Innovations
- Advancing a Circular Economy
- Valuing Nature
- Increasing Confidence in Chemical Technology
- Engaging Employees for Impact
- World-leading Operations Performance

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Du Pont Begins to Sell Nordel Rubber, Synthetic With Special Properties

By a WALL STREET JOURNAL Staff Reporter

NEW YORK--Du Pont Co. announced it has begun to sell Nordel rubber, a new synthetic rubber the company says has properties natural rubber and some other synthetics lack.

Du Pont said the rubber would find "a number of commercial uses very promptly, in January or February," probably first in the appliance, electrical and automotive industries. The synthetic, which was announced early in 1961, has been field-tested for two years.
Old Assets Dominate EPDM Industry Capacity

Industry Asset Capacity vs. Age by Technology

Almost 50% of current assets are 25 years old

Source: Estimates based on public information
Delivering Industry-leading Efficiency

Production Energy Sources

Low & High Pressure Steam + Electricity (Direct & Refrigeration) + Fuel Gas = Total MJ/kg EPDM

Source: Nexant and IHS

Data per tests conducted by Dow. Additional information available upon request. Properties shown are typical, not to be construed as specifications. Users should confirm results by their own tests.

Dow Technology
8.25 MJ/kg

vs.

Industry Ziegler-Natta
19.11 MJ/kg
Maintaining Our Commitment to Industry Growth

U.S. Gulf Coast Shale Gas Investments:
2015-2017 Startups:
- Propane Dehydrogenation Unit
- Next-generation NORDEL™ EPDM
- High Melt Index Elastomers
Moving Beyond Traditional Catalyst Technology

Ziegler-Natta
1960 – present

Metallocene
1997 – present

Advanced Molecular Catalyst
2015 and beyond

• Low efficiency
• De-ashing needed
• Low reactor temperature

• Ultra-high efficiency
• Broad molecular weight
• Increased filler acceptance
• Faster curing
• Expanded portfolio and capabilities

• High efficiency
• No de-ashing required
• High-temperature stability
• Less gels

• High efficiency
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• High-temperature stability
• Less gels
Catalyst and Process Advancements

- High efficiency, high temperature operation
- Expanded molecular design
- Oil extension
- New tailored products

More Long Branching

Higher Molecular Weight

More Diene

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More Long Branching

- Low hLCB
- High hLCB

Higher Molecular Weight

- 90 Mu
- 50 Mu
- +150 Mu

More Diene

- Fast Curing

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Designing a New Product*

**Product Hypothesis**
Understand and develop EPDM molecular target based on future application and customer needs.

**High-throughput Catalyst Screening**
Identify and select molecular catalyst to produce target molecular architecture.

**Modeling and simulation**
Simulate and predict effects of molecular structure on melt rheology.

**Molecular Screening**
Produce small-scale samples for hypothesis testing.

**Application Prototyping**
Develop prototype for application development.

Design Challenge

Understanding what the industry does with our materials...

Formulating → Compound Mixing → Profile Extrusion → Foaming & curing → Coating & Assembling

High Quality
Sustainable Supply

Fast and efficient

High Productivity
Defect Free

Class A
Reliable
Weatherseals - *Keeping the noise out of the car...*

- Hood Seal
- Primary Door/Body Seal
- Sunroof
- Other:
  - Roof Line
  - Windshield
  - Rear Window
- Glass Run Channel
- Trunk Seal
- Encapsulated
- Quarter-window
- Belt Line Seal
- Secondary Door Seal
- Other:
  - Roof Line
  - Windshield
  - Rear Window
Tailoring a Branched EPDM

New capability and predictive design tools enabled polymers with tailored branching rheology and high melt elasticity*

Homogeneous Long Chain Branching (hLCB)

T-Type

- Uniformly distributed long chain branches
- Gel free
- Metallocene/post-metallocene chemistry

Melt elasticity is a key requirement for foaming

New EPDM offering for Sponge Weatherstrip

<table>
<thead>
<tr>
<th>Product Grade</th>
<th>Mooney Viscosity (ML1+4 @ 125°C)</th>
<th>C2 (Mass %)</th>
<th>ENB (Mass %)</th>
<th>MWD</th>
<th>Crystallinity (Mass %)</th>
<th>Extender (Oil %)</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORDEL 6555 OE</td>
<td>55</td>
<td>53</td>
<td>8.5</td>
<td>Medium</td>
<td>&lt; 1.5</td>
<td>19</td>
<td>Bales</td>
</tr>
</tbody>
</table>

**Features & Benefits:**

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
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<tbody>
<tr>
<td>High diene</td>
<td>Fast cure/property build</td>
</tr>
<tr>
<td>High polymer viscosity</td>
<td>Excellent physical properties</td>
</tr>
<tr>
<td>High branching</td>
<td>Excellent shape retention</td>
</tr>
<tr>
<td>Oil modified (19%)</td>
<td>Fast mixing/1-pass</td>
</tr>
<tr>
<td>Low gel levels</td>
<td>Excellent surface quality</td>
</tr>
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Designed Performance

Design challenge to produce molecular structures with a combined rheological and mechanical performance.

Multi-dimensional approach allows more accurate modelling with the use of polymerization kinetic models of Dow’s Advanced Molecular Catalysts.*
## Improved Performance for Dense and Microdense WS

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<th>Form</th>
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<tbody>
<tr>
<td>NORDEL™ IP 5565</td>
<td>65</td>
<td>50</td>
<td>7.5</td>
<td>Medium</td>
<td>&lt; 1</td>
<td>Bales</td>
</tr>
<tr>
<td>NORDEL 6565 XFC</td>
<td>65</td>
<td>55</td>
<td>8.5</td>
<td>Broad</td>
<td>&lt; 1.5</td>
<td>Bales</td>
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### Features & Benefits:

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<tr>
<td>High branching</td>
<td>Excellent shape retention</td>
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<tr>
<td>Molecular wt. distribution</td>
<td>High filler acceptance</td>
</tr>
<tr>
<td>Low gel levels</td>
<td>Excellent surface quality</td>
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</tbody>
</table>

**Faster cure, faster property build**

- 10% higher line speeds

**180°C Cure Time:**

- 10 Minutes
- 2.5 Minutes

**NORDEL 6565 Prototype**

Formulation: 347 phr total, N550, CaCO3, Sunpar 2280, sulphur cure

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One-Stop Shop - First All Dow Weatherstrip

Incumbent EPDMs

European OEM Quality, Class A Sponge and Dense Profiles

NORDEL™ 6555 OE (sponge)

NORDEL™ 6565 XFC (dense, microdense)

NORDEL™ 6535 XFC

Corner Molds
Leading the Way

• Dow continues to deliver sustainable impact for EPDM, the elastomers industry, and the plastics industry at large

• World-leading operations performance

• Breakthrough innovations
  – Advanced Molecular Catalyst offers even greater efficiency and improved performance across a broader range of applications
  – New offerings for sponge and dense EPDM options for automotive sealing
Thank You
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