We’re not just selling tire elastomers, we’re providing solutions to the tire industry

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Tire and Specialty Rubbers (TSR)
Clemson University Global Tire Industry Conference
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Introduction of LANXESS TSR

End group functionalized NdBRs

Tire survey snapshot
New TSR business unit represents the merger of the PBR and BTR business units was launched Jan. 1, 2015

Our elastomers provide air retention, grip, fuel economy & treadwear
### Facts
- Market position: LANXESS No. 1-3 in synthetic rubber
- Customers: > 250
- Production capacity: > 1,200,000 t/a (all rubber grades)

### Products & Brands
- Product groups:
  - Regular Butyl Rubber (IIR)
  - Halobutyl Rubber (BIIR, CIIR)
  - Polyisobutylene (PIB)
  - Solution styrene-butadiene rubbers (SSBR)
  - Polybutadiene rubbers (PBR)
  - Emulsion styrene-butadiene rubbers (ESBR)

### Applications
- Various images of products and applications, including tires, hoses, and other rubber-related items.
Broad and innovative portfolio, excellent reputation and a truly global footprint

- Global footprint with state of the art plants and first class technical support in Europe, Asia and the Americas
- Comprehensive portfolio of (H)IIR, BR and SBR products
- Extensive and proven rubber know-how for tire production and non-tire applications like adhesives, golf balls, and medical stoppers among others

Growing with our customers

- Butyl sites
- PBR / S-SBR sites
- E-SBR sites
- Sales center
- R&D / technical center
NAFTA Technical Center focused on customer and plant support located in London, Ontario

<table>
<thead>
<tr>
<th>Field</th>
<th>Testing Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analytical Testing</strong></td>
<td>• NMR&lt;br&gt;• Xray&lt;br&gt;• GPC&lt;br&gt;• Volatiles&lt;br&gt;• FTIR&lt;br&gt;• TGA&lt;br&gt;• DSC&lt;br&gt;• GC/MS</td>
</tr>
<tr>
<td><strong>Mixing</strong></td>
<td>• Intermeshing (1.5 L)&lt;br&gt;• Tangential (1.5 L)&lt;br&gt;• Brabender (85 &amp; 375 mL)&lt;br&gt;• DSM Microcompounder (15 mL)</td>
</tr>
<tr>
<td><strong>Compound Testing</strong></td>
<td>• Mooney&lt;br&gt;• MDR&lt;br&gt;• DeMattia Flex&lt;br&gt;• Tensile&lt;br&gt;• RPA&lt;br&gt;• Rebound&lt;br&gt;• Garvey Die Extrusion&lt;br&gt;• Tear&lt;br&gt;• Ageing&lt;br&gt;• Permeability&lt;br&gt;• Adhesion&lt;br&gt;• Permanent Set&lt;br&gt;• Brabender (85 &amp; 375 mL)&lt;br&gt;• Permeability&lt;br&gt;• Abrasion&lt;br&gt;• Rebound&lt;br&gt;• Garvey Die Extrusion&lt;br&gt;• Tear&lt;br&gt;• Ageing&lt;br&gt;• Permeability&lt;br&gt;• Abrasion</td>
</tr>
<tr>
<td><strong>Advanced Rubber Testing</strong></td>
<td>• Dynamic Mechanical Analysis&lt;br&gt;• Creep&lt;br&gt;• Payne Effect&lt;br&gt;• Heat Build Up</td>
</tr>
<tr>
<td><strong>Surface Characterization</strong></td>
<td>• SEM/EDX&lt;br&gt;• XPS&lt;br&gt;• AFM&lt;br&gt;• Optical Microscopy&lt;br&gt;• ToF-SIMS</td>
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</tbody>
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* Via Surface Science Western located in same facility
Agenda

1. Introduction of LANXESS TSR
2. End group functionalized NdBRs
3. Tire survey snapshot
End group functionalized NdBRs - Part A.

From the laboratory to the road

Buna® Nd EZ

Ω-fx-NdBR

Silica Treads
Coupling vs end group

Ω-fx-NdBR
from Plant Cement
**Buna EZ grades**

**The EZ-grades:** modified polymer structure with
- specific polymer branching &
- chemical modification of polymer structure
- for low & high ML NdBR grades.

![Graph showing rolling resistance and stiffness indicators for different grades of Buna](image)

30 BR 70 SBR 90 Silica, 100° C
Overview of different LANXESS NdBR generations
11

from the laboratory  
70/20/10 SSBR/BR/NR Silica Tread

- Buna Nd 24 EZ
- Buna CB 24

Properties:
- G*(15%)
- MTS
- Shore A 23°C
- Rebound 60°C
- Tan δ 0°C
- Tan δ 60°C
- Eplexor
- DIN Abrasion!!!

Legend:
- Red: Buna Nd 24 EZ
- Black: Buna CB 24

MTS Rebound 60°C
from the laboratory to the road: Retreaded summer tire

<table>
<thead>
<tr>
<th>Tire re-treading</th>
<th>Tire test</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Tire re-treading Image" /></td>
<td><img src="image2" alt="Tire test Diagram" /></td>
</tr>
</tbody>
</table>

**Tire re-treading**
- Treadwear
  - Front Axle
  - Back Axle

**Tire test**
- RRc
- Buna Nd 24 EZ
- Buna CB 24
- Wet braking 80-20 kmh\(^{-1}\) [m]
- Dry braking 100-0 kmh\(^{-1}\) [m]
- Rolling Noise [dB]

- Treadwear
  - Back Axle
  - Front Axle
Buna Nd22EZ and Buna Nd24EZ

Pressure during extrusion of LANXESS Buna® -compounds are significantly lower than with competitor's high Mooney NdBRs. LANXESS Buna ® Nd22 EZ shows lowest pressure among standard grades.
End functionalized Neodymium Polybutadiene
End group functionalized NdBRs - Part B.

From the laboratory to the road

Buna® Nd EZ

$\Omega$-fx-NdBR
Silica Treads
Coupling vs end group

$\Omega$-fx-NdBR from Plant Cement
End-functionalization vs Coupling

Each functionalized/coupled NdBR is compared to its non-fx / non-coupled Mooney equivalent !!!

End-fx (ML47)  End-fx/ coupled (ML 54)  Coupled (ML 70)

Ref 1 (ML47)  Ref 2 (ML54)  Ref 3 (ML 71)
Polymer vs. Compound Mooney
70/30 SSBR/BR Silica Tread

**End-fx #1**: Higher compound ML as indication for increased Rubber-Filler-Interaction
Better performance due to end group

Ref 1 (ML 47)
Ref 2 (ML 54)
Ref 3 (ML 71)

End-fx (ML 47)
End-fx/ coupled (ML 54)
Coupled (ML 70)

With only 30 phr BR improved RRI of End-fx#1 vs. standard NdBR by 11%
End group functionalized NdBRs - Part C.

From the laboratory to the road

$\Omega$-fx-NdBR
Silica Treads
Coupling vs end group

$\Omega$-fx-NdBR
from Plant Cement

Buna® Nd EZ
Novel, end functionalized Neodymium Polybutadienes (70/30 BR/NR carbon black)

<table>
<thead>
<tr>
<th>ML(1+4)100°C [ME]</th>
<th>CB22 Low ML</th>
<th>CB22-fx Low ML-fx</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML Compound</td>
<td>64 33</td>
<td>67 38</td>
</tr>
<tr>
<td></td>
<td>71 51</td>
<td>75 55</td>
</tr>
</tbody>
</table>

Amplitude Sweep @ 60°C (MTS)

Rebound @ 60°C
For all Standard NdBRs grades: RRI increases with higher Molecular Weight of polymer at same PDI and microstructure.

Evaluation of functionalization is only valid for similar Polymer Mooney Viscosities

Linear regression (LR) allows for theoretical RRI values at the same Polymer Mooney
Novel, end functionalized Neodymium Polybutadienes

LXS presents new, end functionalized Neodymium Polybutadienes for Silica and Carbon Black Compounds which result in improved Rolling Resistance.

It has shown that RRI strongly depends on Polymer Mooney Viscosity. To evaluate the “real” effect of functional groups the reference has to have the same Polymer Mooney Viscosity.
Agenda

- Introduction of LANXESS TSR
- End group functionalized NdBRs
- Tire survey snapshot
LANXESS has developed capability to study tire components: Tire Inner Liner Survey

Obtain & Record
PCR: 43 Tires
- global top 25
- 205/55R16 91V
- purchased in EMEA, APAC, NAFTA

TBR: 65 Tires
- global top 10
- steer, drive, trailer
- tire purchased by Smithers Rapra, segment purchased by LANXESS

- Inner liner Dimensions

Prepare sections
• Cut sections
• Cut specimens

Measure & Calculate
- Optical Microscope & Gauge analysis (SSW)
- Average inner liner thickness

Analyze
- a. TGA
- b. Pyrolysis FTIR
- c. XRF
- d. SEM EDX (SSW)
- e. Compound density

Inner liner compound composition
- % Halobutyl
Performance of Bromo Butyl is preferred in TBR

**PCR : globally both BIIR & CIIR**

- CIIR requires NR for adequate adhesion to the carcass which is detrimental to impermeability
- Major NAFTA producers use BIIR

**TBR : globally > 95% BIIR**

- Performance of BIIR is preferred
- Major NAFTA producers use BIIR
Passenger car radial tires producers employ different strategies regarding inner liner composition and thickness

- Results in a very broad landscape for 205/55R16 tires
- Gauges range between 0.35 and 1.15 mm; concentrations between 20 and 55 wt% halobutyl
- Highest halobutyl concentration when using BIIR since CIIR requires adhesion assistance from NR
Differences in inner liner thickness in different positions bead to bead

The inner liner can be forced towards the nylon or polyester carcass cords

Multiple segments and multiple measurements required to establish an average inner liner thickness for a particular PCR tire
Truck & Bus tires: robust construction to retain high pressure

- Requires the performance of BIIR in pressure retention and carcass adhesion
- Quite consistent inner liner thickness bead to bead
- A protective cushion layer of similar thickness prevents the inner liner from being forced into the steel carcass cords
• 65 truck tires surveyed, 8 were produced in NAFTA and were Smartway® certified
• 1 of the 8 Smartway® certified tires contained silica
• We will continue to monitor truck tread compounds to help customers understand what is being done to achieve Smartway®
LANXESS’s Tire and Specialty Rubbers (TSR) business unit continues to innovate in the area of elastomer research, in order to improve tire performance.

We offer a NAFTA focused technical center in London Ontario, capable of compounding, physical and dynamic testing, surface science and tire deconstruction, as a service to our tire customers.

Expect more in the months and years to come from LANXESS TSR as we take advantage of the creative and technical synergies of the newly formed Tire and Specialty Rubbers business unit.
The manner in which you use and the purpose to which you put and utilize our products, technical assistance and information (whether verbal, written or by way of production evaluations), including any suggested formulations and recommendations are beyond our control. Therefore, it is imperative that you test our products, technical assistance and information to determine to your own satisfaction whether they are suitable for your intended uses and applications. This application-specific analysis must at least include testing to determine suitability from a technical as well as health, safety, and environmental standpoint. Such testing has not necessarily been done by us. Unless we otherwise agree in writing, all products are sold strictly pursuant to the terms of our standard conditions of sale. All information and technical assistance is given without warranty or guarantee and is subject to change without notice. It is expressly understood and agreed that you assume and hereby expressly release us from all liability, in tort, contract or otherwise, incurred in connection with the use of our products, technical assistance, and information. Any statement or recommendation not contained herein is unauthorized and shall not bind us. Nothing herein shall be construed as a recommendation to use any product in conflict with patents covering any material or its use. No license is implied or in fact granted under the claims of any patent.

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Note: The information contained in this publication is current as of April, 2015. Please contact LANXESS Corporation to determine if this publication has been revised.