From castor oil to Specialty Polyamides:  
the success of the diversification  

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Global Market Development Manager,  
Specialty Polyamides
Agenda

► Introduction ARKEMA

► Rilsan® PA11 the first bio-based high performance polyamide

► Product range expansion in bio-based Specialty Polyamides

► Conclusion
Arkema - In a snapshot

- Global producer of specialty chemicals
- Sales of €6.5 bn
- Worldwide no.1 to no.3 on 90% of our sales
- 14,000 employees in 40 countries
- 85 industrial plants
- 10 research centers

Sales by region:
- Europe: 40%
- North America: 34%
- Asia and ROW: 26%

Sales by segment:
- Industrial Specialties: 33%
- High Performance Materials: 34%
- Coating Solutions: 34%
Three business segments

**High Performance Materials**

World of high value and innovative solutions

- Specialty polyamides
- Fluoropolymers
- Adorption/filtration (CECA)
- Organic peroxides

**Industrial Specialties**

Global and integrated industrial niches

- Thiochemicals
- Fluorochemicals
- PMMA (Altuglas International)
- Hydrogen peroxide

**Coating Solutions**

Solutions for decorative paints, industrial coatings and high-growth acrylic applications

- Acrylics
- Coating resins
- Photocure resins (Sartomer)
- Rheology additives (Coatex)
ARKEMA Sustainable Strategy

Ready to take up the environmental challenges, with R&D innovation to contribute to the development of:

► Bio-sourced materials
  ● Be the leader in bio-based high performance PA based on castor oil chemistry
  ● Combine renewable and ethical
    ■ No competition with food
    ■ No deforestation
    ■ Grown on poor soil in semi arid areas

► Lightweight materials and structures
  ● High temperature PA to replace metal and rubber
  ● Thermoplastic composites
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Arkema high performance polyamides

► Rilsan® PA11:

a 100% bio-sourced polymer…

![Diagram of the production process of Rilsan® PA11](image)

- **Harvesting**
  - Castor plants
  - Renewable resource

- **Grinding**
  - Castor seeds

- **Methanolysis / Cracking / Hydrolysis**
  - Castor oil

- **Monomer Synthesis**
  - Amino 11
  - Monomer

- **Polymer Synthesis**
  - Rilsan®
  - Polyamide 11

- **Amination**
  - 11-aminoundecanoic acid

- **Hydrobromuration**

- **Hydrolysis**

- **PA11**

- **Rilsan®**

- **Arkema®**
60 years of experience in Rilsan® PA11!

- **Starting of the Rilsan® PA11 manufacturing in 1950’**
  - Base resin: 100% from castor oil
  - First applications in textile markets

- **Moving to technical applications from 1960’ in Automotive, Oil & Gas,…**
  - More than 40 years of experience in most severe environments for Fuel lines, Air brake, O&G flexibles, ….
60 years of experience in Rilsan® PA11!

- Starting of the Rilsan® PA11 manufacturing in 1950’

- Moving to technical applications from 1960’ in Automotive, Oil & Gas,…

  - Intrinsic high performance of long chain PA11
    - Outstanding chemical resistance
    - Very low moisture absorption
    - High hydrolysis resistance
    - High impact strength at low T°C

Rilsan® PA11 polyamide:
The First and Unmatched 100% bio-based PA - and still the reference
Rilsan® PA11 still the long-chain PA reference

★ Flexibility
★ Processability
★ Ageing resistance
★ Chemical resistance
★ Abrasion resistance
★ Low Temperature impact

Applications
★ Oil & Gas
★ Sports
★ Automotive
★ Air brake
★ Electric
Cradle to gate LCA (base polymer)

► Climate Change /Global warming impact

from - 40 %  up to - 52 %

PA11 benefits vs PA12, PA6 or PA6.6

• Global warming reduced by 40 up to 52 %
• For 100 t polymer, up to 470 t CO₂ saved (equivalent to up to 3.5 million km by car)
• Similar NR-CED for PA11
• PA 11 is 100 % bio-sourced

► Non renewable cumulative energy demand

Data sources:
PA11, PA12: Arkema internal LCA  /  PA6, PA6.6: Plastics Europe
How to boost their applications?

- Starting of the Rilsan® PA11 manufacturing in 1950’
- Moving to technical applications from 1960’ in Automotive, Oil & Gas,…
- Expansion of product range
  - Long Chain PAx.y
    - Elastomer
    - Transparent PA
    - HT flexible PPA

Arkema Specialty polyamides:
The largest product range of bio-based PA of the world
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Arkema’s Long-Chain PAx.y Product range

- **Polyamide 11**
- **Polyamide 12**
- **Polyamide 10.12**
- **Polyamide 10.10**
- **Polyamide 6.12**
- **Polyamide 6.10**

**Polyamide** : Biobased long chain PA / **Polyamide** : Fossil based long chain PA
Polymerization of PAxy Polyamides

- PA10.12 from Decamethylene Diamine (DA10) & Dodeconioic Diacid (DC12)
- PA10.10 from Decamethylene Diamine (DA10) & Sebacic Acid (DC10)
- PA6.10 from Hexamethylene Diamine (DA6) & Sebacic Acid (DC10)

➤ with DC10 & DA10 coming from the castor oil chemistry
Specialty Polyamides: A Building Block chemistry

With the best monomer integration
Technical positioning of base resins

**Renewable Carbon**

<table>
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<tr>
<th>Resin</th>
<th>0%</th>
<th>45%</th>
<th>62%</th>
<th>100%</th>
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<td>45</td>
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**Melting point**

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<tr>
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<td>100</td>
<td>80</td>
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<td>40</td>
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**Moisture Absorption**

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<tr>
<td>PA612</td>
<td>1.2</td>
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<tr>
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Technical Positioning of base resin

- Biobased long chain Polyamides
  - a continuum of performance opening a large opportunity to match the customer needs
  - Plasticized & Reinforced grades have been developed for specific applications

Biobased long chain Polyamides
- similar characteristics than petroleum derivated PA
**Hiprolon®** A wide range of long-chain combinations

**Hiprolon® PA6.10**
- Rigidity
- Thermal resistance
- Chemical resistance
- Processability

**Applications**
- Monofilaments
- Sports
- Automotive

**Hiprolon® PA10.10**
- Thermal resistance
- Mechanical resistance
- Chemical resistance
- Processability

**Applications**
- Automotive
- Electronics
- Automotive

**Hiprolon® PA10.12**
- Flexibility
- Mechanical resistance
- Chemical resistance
- Processability

**Applications**
- Automotive
- Hydraulic & Pneumatic
- Cable
Elastomer Pebax® Rnew

- Thermoplastic Elastomer – TPE
  Poly Ether Block Amide (eXtreme)

- Two phases structure
  - Polyamide – Rigid Block
  - Polyether – Soft Chain

- Most of properties controlled by:
  - Nature of PA and polyether
  - PE / PA ratio ➞ Flexibility

Pebax® Rnew - Biobased
Polyamide 11 as rigid segment
Pebax® Rnew range

Wide range of hardness

Renewable Carbon content

19%

PolyEther Block Esters (COPE)

Thermoplastic Polyurethane (TPU)

Polyamides

Caoutchouc / Rubber

Shore D 72D 70D 63D 55D 40D 35D 25D

Shore A 90A 85A 75A 50A

Renewable Carbon content

75%
Pebax® Rnew

Energy Return

Pebax® Rnew

has a high energy absorption
But also a lower energy loss factor than TPU

⇒ and so a BEST Energy Return*

Pebax® Rnew

(80 shore A)

⇒ Energy Loss factor = 0.1~0.2

* Capacity of a material to retain a maximum of energy during extension phase and to deliver back a maximum of it (“return”) during relaxation phase.
Pebax® Rnew

First engineering thermoplastic Elastomer range made from Renewable resources used in sport

Running shoes

Ski boots

20 to 95% renewable resources
Rilsan® Clear:
a cycloaliphatic based PA with high transparency

Transparency
More transparent than glass

Lightness
20% lighter than PC & PMMA

Chemical resistance
Much better than PC & PMMA

Weather resistance
Long lifetime under UV exposition.

Toughness
Still ductile at –30 °C.
Rilsan® Clear Rnew based on castor oil chemistry

► **Rilsan® Clear G830 Rnew & G850 Rnew**
  - Glossy finish, Flexibility
  - Easy processing, lightness, high Tg
  - Chemical & Mechanical resistance

► **Rilsan® Clear G120 Rnew**
  - Lightness / Transparency
  - Good dimensional stability (Low moisture absorption)
  - Excellent chemical resistance
  - Excellent mechanical properties (impact, scratch)
Rilsan® HT: a Breakthrough in Metal Replacement

This new PPA family creates opportunities to replace metal in tubing applications that were previously unthinkable.

Cooling:
- PA11
- HPPA MLT solution
- PA12 Special Grade
- Air Intake
  - TEEE, PA6, PA6-Alloy, Rubber

Rilsan® HT New class of flexible PPA
Rilsan® HT - The First Flexible PPA

Unprecedented Flexibility

Optimum properties of long-chain PA11 and classic PPA
Thermal ageing rating of long chain PA extrusion grades

Service & Peak temperatures *

- RILSAN® PA11
- HIPROLON® PA10.12
- RILSAN® T PA10.10
- RILSAMID® PA12
- RILSAN® HT more flexible
- RILSAN® HT flexible

* Life time based on mechanical test (cold impact) on 8*1 mm tubes, after continuous dry air heat ageing
Rilsan® HT Powertrain Applications

Air / Vacuum Mngt.
Brake Booster

Air / Pressure Mngt.
Air Intake

Air / Vacuum Mngt.
Exhaust Gas Recirculation
EGR

Aggressive Media Mngt.
Blow-By

Oil Mngt./Transport
Transmission Oil Cooling, TOC

Oil Mngt./Brake System

Rilsan® HT Flexible Tubing

The genuine alternative
to metal tubing assemblies

Air management (pressure
& vacuum management)

Oil management (hydraulic
fluids, lubricants)

Aqueous Media
Management (Cooling, SCR)

Aggressive Media
Management (Blow By, PCV)

Aqueous Media Mngt.
Cooling & SCR / AdBlue®
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Product range expansion in biobased PA

**Type** PEBA
**Bio-content** 20 to 95%
**Specificity** High performance thermoplastic elastomer

**Type** PA11
**Bio-content** Up to 100%
**Specificity** Long history of high performance applications. Best in class for low temperature impact properties (-40°C).

**Type** Amorphous PA
**Bio-content** >50%
**Specificity** Higher transparency than glass

**Type** Bio-based PPA
**Bio-content** Up to 70%
**Specificity** Resistant to high temperature environment. Metal Replacement

**Type** PA6.10, PA10.10, PA10.12
**Bio-content** 60 to 100%
**Specificity** New range of high performance bio-based PA.
Thank you for your attention