Imagine working with a company that has no boundaries on exploring solutions.

Major Markets & Applications for Beta Nucleated Polypropylene
Outline

1. Attributes of beta crystallinity and differences from alpha crystallinity

2. Major Markets
   I. Geogrids
   II. Packaging:
      a) welding & heat sealing
      b) Thermoforming
   III. Pressure Pipe
   IV. Oriented film
   V. Impact Improvement

3. Mayzo’s Strengths & New Technology
Differences Between Alpha and Beta Crystal Phases in PP

**Alpha Phase**
- Melts at ~ 164°C
- Most common phase
- Many nucleants known: Some nucleants are also clarifiers
- Alpha nucleants increase modulus and reduce cycle time

**Beta Phase**
- Melts at ~ 150°C
- More ductile: Increases impact strength and break elongation with small losses in tensile strength and flexural modulus
- Very few beta nucleants are known
- Generally cannot be produced in alpha nucleated PP
DSC Melting Curves for Alpha and Beta PP

Alpha PP

Beta PP
Geogrids
Geogrid Production Process

- Extruded PP Sheet
- Biaxially stretched Geogrid
- Holes Punched in Sheet
- Transverse Stretching of Sheet
- Perforated Sheet after MD Orientation
Geogrid Made With and Without The Beta Nucleation

**Non-nucleated**

Node thickness of 3.4 mm

**Beta Nucleated**

Node thickness of 2.3 mm
Ultimate Tensile Strength of PP Geogrids With and Without Beta Nucleation

- **No Beta, 4.5 mm**: 313 g/m²
- **Beta, 4.5 mm**: 309 g/m²
- **Beta, 4.15 mm**: 268 g/m²
- **Beta, 3.84 mm**: 254 g/m²

Sample ID, Nucleation, Sheet Thickness (mm)
Advantages of Beta Nucleation in the Production of Geogrids

• Higher tensile strength allowing for up to 20% down-weighting
  • less material, lower costs
• Can be run at higher production speeds
  • Increased throughput and productivity
Packaging
Welding & Heat Sealing

• Good weld and heat sealing are important aspects for many packaging segments such as food and personal care
  • increases throughput and productivity
  • reduces product reject rates
  • provides broader package design capability
• Beta nucleation leads to much higher weld strengths in polypropylene
Vibration Weld Strength of Beta vs Alpha Crystalline Polypropylene

Weld Strength (kJ/m²)

- α-α
- β-β
- α-β

PP Type and Melt Flow Rate

- PP-H 0.8 MFR
- PP-R 11MFR
- ICP 12MFR
Schematic of In-Line Thermoforming

Extrusion    Heating    Forming    Trimming
Thermoformed 16 oz Cups Made with Non-nucleated and \(\beta\)-Nucleated PP

Note: No TiO2 used in Beta nucleated HPP
Sidewall Thickness Distribution in Melt-Phase Formed Cups

- Non-nuc.
- 1% MPM 1101
Optimum Crush Strength of ACCPRO ET® vs Control Resins with the 6219 Package

- Crush strength (lbs)

- Homopolymer
- High stiffness Homopolymer
- Impact Copolymer

ACCPRO ET®
6219 Control
High Temperature Dimensional Stability of Beta vs Alpha Nucleated PP

Containers filled with tomato sauce and heated at high setting for 5 minutes

Beta Nucleated

Alpha Nucleated
Advantages of Mayzo Beta Nucleation Technology in the Thermoforming of PP

• Broader processing window
• Less sag with no change in melt rheology
• Lower sidewall density (lighter weight)
• White appearance without pigments
• Better material distribution and better crush strength
• Potential to down-weight up to 20%, equals cost savings
• Faster cycle times (up to 25% higher productivity)
• Improved High Temperature Dimensional Stability
Oriented Microporous Film
Beta Nucleation in Oriented PP Film

- Higher Tenacity
- Higher yield (more m² per kg)
- De-lustered without fillers
Tenacity of Carpet Backing Tapes

- No beta: 4.0 grams per denier
- 1% MPM 1113: 5.0 grams per denier
- 1% MPM 1113 & 1.5% CaCO3: 6.0 grams per denier
Beta Nucleated BOPP Film for Li-Ion Batteries and Supercapacitors

Film Thickness: 22 microns   Film Density: 0.28 g/cm³
Advantages of Beta Nucleation in the Production of Microporous Films

• Production of white, low density microporous films without the use of fillers or pigments
• Improved printability
• Extremely low density films with high breathability can be produced in the BOPP process.
  • Used in protective clothing, construction applications, and as separator membranes in Li-ion batteries and supercapacitors
• Produces high tenacity, de-lustered carpet backing fibers (patent pending)
Impact Improvement
Using Beta Nucleation to Improve the Impact Strength of PP

![Graph showing the notched Izod impact strength at 23°C for different resins. The X-axis represents the resin type (HPP, ICP, ICP, RCP) and the Y-axis represents the notched Izod impact strength in J/m. The graph compares normal and beta nucleated resins.]
Effect of Test Temperature on the Impact Strength of Beta Nucleated PP
Notched Izod Impact of Random Copolymer PP With Beta Nucleation
Flexural Modulus of Random Copolymer PP Beta Nucleation
## Properties of Non-Nucleated & β-Nucleated PP Homopolymer with 0.3% MPM 2000

<table>
<thead>
<tr>
<th>Property</th>
<th>β-Nucleated</th>
<th>Non-Nucleated</th>
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</thead>
<tbody>
<tr>
<td>MFR (g/10 min)</td>
<td>3.2</td>
<td>3.3</td>
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<tr>
<td>Yield Strength (psi)</td>
<td>4350</td>
<td>4976</td>
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<tr>
<td>Yield Elong. (%)</td>
<td>11.0</td>
<td>8.9</td>
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<tr>
<td>Flex. Modulus (psi)</td>
<td>213,520</td>
<td>212,170</td>
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<tr>
<td>Notched Izod @23 °C</td>
<td>3.23</td>
<td>0.78</td>
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<tr>
<td>(ft-lbs/in)</td>
<td></td>
<td></td>
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</tbody>
</table>
Impact Enhancement in Rotomolded PP

**ARM Impact (23°C)**

- PP + Mayzo MB
- Std. PP
- LMDPE

**No. of repeated impacts**

- PP + Mayzo MB
- Std. PP
- LMDPE
Impact Strength Improvements Using Beta Nucleation

• Beta nucleation leads to dramatically higher impact strength improvements with only small losses in flexural modulus
• Beta nucleation allows PP to be used in rotomolding applications without the extreme brittleness normally seen in this application
• Mayzo’s latest beta masterbatch, MPM 2000, can be used at very low addition levels to achieve these benefits
Product Offerings

• **MPM 1110**: black pellets, used for geogrids. Typically 0.75%-1% addition level.

• **MPM 1113**: brown pellets, used for thermoforming, film, injection molding, when higher loading of nucleant is needed to overcome interfering additives. Typically 0.5% - 1.5% addition level.

• **MPM 2000**: latest generation MB, white pellets. Highest beta nucleation activity and Tc value. Works in many alpha nucleated PP resins including talc reinforced PP. Typically 0.75% - 1.0% addition level.