Selecting the proper polyamide for multilayer food packaging films: intrinsic factors leading to performance considerations

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Polyamides are so useful for numerous reasons

- High Mechanical Strength
  - *Fishing line, Rope, Bristles*

- Easily co-extruded
  - *Multilayer structures with dissimilar polymers possible*

- Heat & Chemical Resistance
  - *Roasting bags, Intake manifolds*

- Thermoformable
  - *High residual corner thickness*

- Barrier
  - *Barrier mulch film*

- Abrasion Resistance
  - *Weed trimmer, wire jacketing*
Intrinsic factors can dramatically alter the final properties of the film

Intrinsic

Mechanical Properties

Structural
Key polyamide intrinsic factors

Intrinsic

Mechanical Properties

Structural
What about crystallinity?

amorph PC, PMMA

Figure 1 These crystallites have order in which the zigzag polymer chains are held together in a regular pattern by intermolecular forces.
Flexible packaging’s polyamide crystallinity spectrum

- Decreasing crystallinity / higher transparency / less haze
- Increased softness / higher flexibility / better thermoforming
- Higher blow up ratio
- Lower melting point / lower processing temperature / higher frost line
- Fewer wrinkles during blown film collapse process
- Increased shrinkage from orientation process
- Increasing puncture resistance @ constant force
- Higher tear strength / Lower tensile strength
Intrinsic crystallinity comparison

DSC melting endotherm of a **semicrystalline polymer**

\[ T_m = T_m(l) \]

- **(Polyamide 6/66)**
  - Tm: 180 to 200°C
  - Tc: 110 to 145°C
  - Delta H: 34 to 40 J/g

- **(Polyamide 6)**
  - Tm: 220°C
  - Tc: 170°C
  - Delta H: 50 J/g

- **(Polyamide 66)**
  - Tm: 260°C
  - Tc: 218°C
  - Delta H: 70 J/g
Intrinsic crystallinity comparison

<table>
<thead>
<tr>
<th>Sample: UM C40L extruded film</th>
<th>% Crystallinity</th>
<th>Entalphy (J/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UM C40L extruded film</td>
<td>29.2%</td>
<td>31.3</td>
</tr>
<tr>
<td>UM C37LC extruded film</td>
<td>25.6%</td>
<td>27.6</td>
</tr>
<tr>
<td>UM B40L extruded film</td>
<td>46.6%</td>
<td>50</td>
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Key polyamide process factors

Intrinsic

Mechanical Properties

Structural
PA crystallinity differences show in various ways including film haziness.

- PA 6/66 (haze 3.0)
- Very low crystallinity PA6/66 (Ultramid® C37LC) (haze 0.45)

Blown Film 150µm / BUR 1:2 / ASTM D-1003
Crystallinity affects polymer strength and elongation

![Graph showing yield strength for different Ultramid grades.](image-url)
Homopolyamides display a higher degree of crystallinity rendering it a stiffer material.
A high degree of crystallinity also corresponds to better barrier properties.
On the other hand, homopolyamides are more susceptible to tear propagation

Elmendorf Tear Ultramid® Nylon

<table>
<thead>
<tr>
<th>Sample</th>
<th>MD gf</th>
<th>CD gf</th>
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<tr>
<td>B-33 L 01</td>
<td>38</td>
<td>174</td>
</tr>
<tr>
<td>B-40 L 01</td>
<td>38</td>
<td>699</td>
</tr>
<tr>
<td>C-37 LC</td>
<td>70</td>
<td>1111</td>
</tr>
<tr>
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<td>367</td>
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Elmendorf MD gf  Elmendorf CD gf
High crystallinity polyamides don’t stretch as well
Higher orientation is possible with low crystallinity copolyamides

Tape stretch ratio at max. machine force

- **PA6/66**: 1:4
- **Low crystallinity PA6/66 (Ultramid C37LC)**: 1:4
- **Low crystallinity PA6/66 (Ultramid C37LC)**: 1:5
- **Low crystallinity PA6/66 (Ultramid C37LC)**: 1:6
Key polyamide structural factors

**Intrinsic**

```
H   O   H   O   H
N---C---N---C---N
O   H   O   H   O
H   O   H   O   H
N---C---N---C---N
```

**Mechanical Properties**

**Structural**

Image of mechanical properties and structural factors.
Most food packaging applications are multilayer structures

- **Sealant Layer**
- **PA commonly 25-40% of overall structure**
- **Common PA/EVOH/PA combination for barrier**
- **Moisture barrier**
- **Abrasions/Heat resistant**
- **Printability**
Blown film curl as a function of asymmetry

1. Directly after die
   - >220° C
   - all components molten

2. PA frostline
   - 180-140° C
   - PA solidifies+shrinks
   - PE soft → shrinks

3. PE frostline
   - 120-80° C
   - PE solidifies+shrinks
   - PA rigid → can not shrink/PE
   - curl to PE side
Lower melting point and crystallinity improves processing

- Higher bubble stability
- Higher frost line towards PE/PP
- Reduced curl

Very low crystallinity

PA6/66
(Ultramid C37LC)

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<td>A.</td>
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<td>B.</td>
<td>Tie</td>
<td>18µm</td>
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<tr>
<td>C.</td>
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C37LC
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