Polymerization & Polymer Additivation

NUREL’s long term experience in polymerization processes and polymer modification have converged to provide a portfolio of polyamide extrusion grades with a wide viscosity range and different additive packages.

Promyde® Polyamide 6

Promyde provides excellent gas, flavour and aroma barrier properties, as well as high mechanical and excellent thermoforming functionalities.

These inner attributes of polyamide 6 plus our quality and consistency, make Promyde the material of choice for film or laminating production.

Promyde can be extruded alone or in combination with other polymers such as polyethylene, polypropylene or EVOH.

Our technology applied to product design allows NUREL to offer specific grades that may be processed either by cast or blown, in monolayer or coextruded and in non-oriented or oriented films.

NUREL’s product portfolio includes PA6 and also copolyamides for advanced applications.

 Delivering solutions for each special requirement.

Promyde® high performance polyamides and copolyamides deliver solutions that can satisfy the most challenging requirements such as mechanical properties, barrier solutions, sealing, improved transparency and low curling.
Promyde’s oxygen and gas barrier properties avoid ageing and discolouration, whilst preserving odours and flavours.

It delivers high mechanical strength, puncture resistance, heat resistance even at sterilizing temperatures and thermoformability.

When using in BOPA films, some properties are enhanced, such as puncture resistance, strength, stiffness and elongation at break.

Polyamides are used as a component of coextruded or laminated multilayer films to protect foodstuffs from oxidation (e.g., meat, sausage casings, cheese, coffee, nuts, stand-up pouches, shrink bags, etc).

Promyde is also used in medical film to safely protect medical devices, as well as in automotive applications and in decorative and protecting film.

Promyde can also be used for mulch films to increase the effect of herbicides and lessen their environmental impact.

Packaging plays an important role in extending the durability of food. Promyde® provides fundamental benefits in applications like barrier, vacuum and MAP films.
Cast film extrusion is a continuous operation of **melting one or more polymers through a flat die** to form a film that will be conveyed to successive rollers with different functions (cooling, film finishing, etc.), and finally wound onto a roll.

Typical film thickness ranges are between **20-200 μm** and **width of 400-3,000 mm**. The film thickness is controlled with the die gap and the extrusion line speed.

### Cast Extrusion Grades

| BF33, BF36, BF38, BF40, BF933, BF940, BF640 & BF740 |

*All products can be lubricated (L) and/or nucleated (N).*

### Casting Rolls’ Temperatures

In cast film the temperature of the casting roll has an important influence on the film properties.

For **films requiring good dimensional stability** and strength, such as lidding films, temperature should be set to **80-120°C**.

For good **thermoforming and high transparency**, setting to **20-40°C** is recommended.

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**Multi-layer extrusion**

Polymer...

Polymer 2

Polymer 1
Blown film extrusion is a continuous operation of **melting one or more polymers through a circular die** to form a hollow tube. The tube is expanded with air, collapsed and finally rolled up.

**Processing Recommendations**

- **Blown-up ratio**: 1.1-3.0
- In asymmetric structures, **curling may be reduced by wetting** the film in a warm water bath.
- **Cooling**:
  - **Air cooling**: copolyamides are mainly used to achieve **better optical properties and low curling** in non-symmetric structures, like PE/Tie/PA. For stiffer films, copolyamides can be combined with Promyde® PA6.
  - **Water cooling**: for better optical properties and thermoformability. Copolyamides and Promyde PA6 can be used.

**Blown Extrusion Grades**

| BF38, BF38, BF933, BF940, BF640 & BF740 |

*All products can be lubricated (L) and/or nucleated (N).
Biaxially Oriented Polyamide (BOPA) films are special structures with high **gas barrier and excellent mechanical properties** (tear and puncture resistance), also achieving thinner thicknesses. It is especially recommended for **frozen packaging, top fill for rigid trays or vacuum packaging applications.**

**Processing Recommendations**

For simultaneous BOPA lines where MD and TD stretching is performed in one step, the use of lubricant is not required. For these applications we advise the use of Promyde® BF33 or BF33L.

A temperature of **45-60°C is recommended during MD stretching and 75-100°C during TD stretching.**

BOPA sequential lines first stretch the film in MD and then, on a second step, stretch the film in a transversal direction.

In this case, during MD stretching hydrogen bonds are generated between PA chains. For this reason we encourage the use of lubricated products to assist the TD stretching (Promyde BF33L).

**BOPA Extrusion Grades**

BF33 & BF33L
The main purpose of using three-bubble technology is to get a **good controlled shrinkage** and **improve mechanical properties** of down gauging films. The use of polyamide is mainly recommended for **sausage casings and coextruded for high barrier packaging shrink film**.

### Processing Recommendations

First bubble is collapsed and cooled down quickly in order to minimize the crystallization, then the film is warmed up in a hot water bath and then blown and oriented in a second bubble.

In this orientation step, MD: 2.0-3.3 and TD: 2.5-3.8 ratios are recommended. After the second bubble collapses, the annealing step takes place by a third bubble which is maintained at a certain temperature in order to control the % of shrinkage of the final product. **The use of all Promyde Copolyamides and PA6 is granted.**

#### Three Bubble Extrusion Grades

BF38, BF38L, BF40, BF40L, BF940 & BF940L
New Product Development

For new product development, we start from a customer request, based on the end-use of the product, its processing method and specific requirements. Then, we analyse the product definition, and propose a new formulation thanks to our polymer chemistry know-how.

We design the process from lab scale to industrial scale, and prepare a sample for the customer approval. Once we confirm that the material meets the customer’s requirements, we run an industrial scale production. Our technical capacity for the development of new products, together with versatility, innovation and quality consistency, deliver in a reduced time-to-market.

Characterization Laboratory

Our laboratory is fully equipped in order to achieve a complete mechanical and chemical characterization of every polymer for any application. This information helps us to assure the quality of our products, and it is also used to support any customer project or demand.

Working with our customer’s at every stage of the process.

Our R&D team works closely with brand owners, packaging manufacturers, packaging designers and converters to develop tailor made solutions:

- Project definition
- Product modelling
- Pilot prototyping
- Industrial scale-up
- Product approval

Polymerization Facilities

- Lab-scale polycondensation reactor: Batch reactor designed for the product definition at lab-scale
- Pilot-scale polymerization plant: Universal polymerization pilot plant, integrated by a batch reactor, distillation tower condensers, automatic valves, vacuum line, extrusion and cutting system
- Solid state postcondensation pilot plant: This equipment is optimum to dry or post condensate polymers in solid state

Plastics Processing Units

- Pilot-scale twin screw compounder: Twin screw extruder designed for the production of plastic compounds, blends and masterbatches. Its main applications are the development of new products and sample production, or small batch production of engineering plastics
- Injection moulding machine: Its main function is the production of test samples or small parts
- Cast and Blown film pilot lines: Designed for product development and sample production
Films manufactured with standard PA6 often have a hazy appearance due to the semicrystalline nature of PA6 and its rapid crystallization rate, this problem frequently occurs in films made in blown extrusion.

New low crystallization temperature copolyamides to enhance transparency.

The most effective solution to improve transparency is to substitute these materials for low crystallization temperature copolyamides.

NUREL introduces Promyde BF933 and Promyde BF940 that thanks to its lower temperature and speed of crystallization allow to obtain films with an unique transparency and gloss.

Due to its improved breaking deformation, these copolyamides are the best choice for demanding thermoforming applications such as deep thermoforming.

Due to their low crystallization temperature, Promyde BF933 and Promyde BF940 also avoid the formation of curling in non-symmetrical multilayer films.

An Alternative for Multilayer Packaging

Promyde 933 and Promyde 940 copolyamides with low crystallization speed represent an adequate alternative to PA6 and PA6/66 in multilayer packaging scope.

- Competitive cost
- Advantages compared to PA6/66
- Greater transparency
- Less curling
- Excellent thermoforming
COPOLYAMIDES WITH MODIFIED BARRIER & SEALABILITY PROPERTIES

Polyamides are used in containers that require high performance, such as special mechanical properties (puncture resistance) and pasteurization or special gas barrier properties that help to extend shelf life of food.

Currently, multilayer structures that cannot be recycled are used to accomplish this type of packaging requirements. Today, following environmental trends to achieve lighter or recyclable structures has become a priority for all of us who are part of the packaging value chain.

Extending the Shelf Life of Food

Current food containers are multilayer structures in which polyamides PA6, PA6/66 or PA6/12 oxygen properties are used in combination with PE or PP for its saleable advantages, as traditional polyamides do not seal.

NUREL is now introducing two new breakthrough solutions to modify the barrier properties of polyamides with added sealability properties for mono and multilayer films.

BF740: Low Oxygen Permeability

Promyde BF740 has been specifically designed for packaging solutions that require oxygen barrier to preserve food.

By using BF740 the polyamide layer thickness will be reduced maintaining oxygen permeability, in some applications EVOH use can be avoided, resulting in lighter and more cost efficient packagings.

Unlike traditional polyamides, BF740 preserves its oxygen barrier even under high environmental humidity conditions, being a highly valued solution for containers that undergo pasteurization processes or that are destined to high humidity geographical areas.

Promyde BF740 represents the following advantages compared to PA6:
- One third of $O_2$ permeability
- Deeper thermoforming
- More transparent and higher brightness
- Lower curling
- Sealing at 110-115°C
- Suitable for thermic treatments up to 100°C

BF640: Performance and Cost Advantages

Promyde BF640 is the material of choice for premium mature cheese packaging that support product’s ripening process.

Thanks to its modified $CO_2$ permeability, films made of our copolyamide BF640 allows the release of maturing cheese gasses.

PA6/12 is currently used for this purposes, but Promyde BF640 represents the following advantages:

Compared to PA6:
- Three times $CO_2$ permeability
- Less stiffness and greater break resistance
- Three times tear resistance (suitable for food with bones)
- Sealing at 110-115°C
- Deeper thermoforming
- Lower curling
- Suitable for thermic treatments up to 100°C

Compared to PA6/12:
- Competitive in cost
- Superior % strain at break and tear strength
- Lower thermoforming temperatures
### MECHANICAL PROPERTIES

#### COPOLYAMIDES COMPARATIVE

<table>
<thead>
<tr>
<th>MECHANICAL PROPERTIES</th>
<th>UNITS</th>
<th>BF38 (PA6)</th>
<th>PA 6/66</th>
<th>BF940</th>
<th>BF740</th>
<th>PA 6/12</th>
<th>BF640</th>
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</table>

**Graphical Representation**

- **BF740**
- **BF640**
- **PA**
- **PE**

- Process Temperature
- Oxygen Barrier
- Water Vapour Barrier
- Softness
- Tensile Strength
- Tensile Elongation
- Thermoformability
- Puncture Resistance
- Trouser Tear Resistance
- Sealing
This innovation, developed entirely by NUREL, extends the shelf life of packed food. Our Active Packaging technology consists of incorporating encapsulated active principles to the polymer matrix in order to provide antioxidant, antimicrobial or antifungal properties. Our capsules can also help to remove, from packed food, undesired substances such as liquids, odours and gases.

Microencapsulatation Technology

(1) Active principles are released outside the capsules by air controlled diffusion method (pressure difference inside and outside the capsule). Higher diffusion towards the food side layer occurs due to the food contact and the moisture.

(2) Gas-phase radicals permeate through film layer containing capsules being stabilized.

Antioxidant

Based on an encapsulated natural antioxidant extract. It is active at vapour phase, vapour radicals from oxidation are neutralized by the active principles.

Test In-Vivo Visual Colour (CIELAB Colour Space Model)

- **Food:** raw chicken breast, pork steaks and pork ground patties
- **Shelf life:** 4 days
- **Packaging:** Vacuum, 50 microns films (control and antioxidant)
- **Storage:** 7°C during 6 days
- **Quality controls:** “a” Colour (red colour)
Envisioning a Sustainable Packaging Industry

Around 25.8 million tonnes of plastic waste are generated in Europe every year. Less than 30% of such waste is collected for recycling. The European Commission is taking actions to improve this situation. The EU Action Plan for a circular economy propose that by 2025 at least 55% of all plastic packaging in the EU should be recycled. The objective will be to ensure that, by 2030, all plastic packaging placed on the EU market is reusable or easily recycled.

Multilayer Material Replacement

It is a matter of fact that without fundamental redesign and innovation, about 30% of plastic packaging will never be reused or recycled. One of the main reasons is that usually packaging is made of several materials stuck together to enhance its functionality.

Traditionally multilayer film structures have been used in food packaging for barrier and sealing requirements and it is estimated to represent a 13% of the plastic packaging total volume. These items are, by their very design, destined for landfill, incineration, or energy recovery and are often likely to leak into the environment after a short single use.

As many of these packaging features have important functional benefits preserving food, fundamental redesign and innovation are required to maintain these properties but with a sustainable approach, for this purpose NUREL is ready for action.

Recyclable Monomaterial Solutions

NUREL has recently brought to the market two copolymides, Promyde BF740 & Promyde BF640 for replacing and improving laminated structures such us PA / Adhesive / PE. Traditional film structures are not recyclable, but by using our copolymides new mono-material containers will be 100% recyclable and will considerably reduce landfill waste.

Reduce Waste to Landfill

Our new copolymides, when used on multimaterial structures, allow to create thinner structures whilst maintaining benefits thus reducing considerably the waste from non-renewable sources, thanks to their excellent barrier properties.

(1) Source: Plastics Europe  (2) Source: Eurostat  (3) The New Plastics Economy - Catalysing Action by Ellen Macarthur Foundation
EXTRUSION
PROCESSING CONDITIONS

The film extrusion industry demands the highest quality polyamide. Promyde® delivers the continuous reliability it requires.

Promyde polyamide can be processed either by CAST or BLOWN extrusion for industrial manufacture of monolayer and multilayer film, including both non-oriented and biaxially oriented (BOPA) film.

Promyde is the material of choice for film production that delivers excellent mechanical and barrier properties.

Processing Temperatures (°C)

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>Cast Extrusion</th>
<th>Blown Extrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BFXX</td>
<td>BF9XX</td>
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<tr>
<td>Feed section</td>
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<td>210-225</td>
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<tr>
<td>Compression Section</td>
<td>240-260</td>
<td>225-235</td>
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<tr>
<td>Metering Section</td>
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</tr>
<tr>
<td>Melting Temperature</td>
<td>255-265</td>
<td>235-240</td>
</tr>
</tbody>
</table>

Screw Recommendations

- Standard single-flight, three-section screws.
- Better results can be obtained by using high performance screws equipped with shearing and mixing sections.
- The screw length should be at least 24D, and preferably 28-33D to guarantee optimum plasticizing and conveying with the high through-put rates of film extrusion (D: screw diameter).
- A three-section screw should have a compression ratio (ratio of flight depth in the feed section to flight depth in the metering section) of 3:1 to 4:1.
- Screw length sections (L: overall length of screw):
  - Feed section: 0.25 to 0.30 x L
  - Compression section: 0.15 to 0.25 x L
  - Metering section: 0.40 to 0.55 x L
Conditioning

Before converting, cutting or laminating a PA film, it should be conditioned.

Polyamide is a hygroscopic polymer that absorbs humidity after being processed. A polyamide film reaches its equilibrium by storing it in a controlled moisture and temperature environment. Active conditioning techniques such as in-line humidification or water quenching can also be used.

When conditioned, film will improve its elastic and thermoformability properties, and achieves its final dimensions and properties.

Printing and Metallizing

PA films can be also printed or metallized without any special treatment. For better results corona treatment is recommended.

Handling and Storage

Material is supplied pre-dried and ready to process. Bags and containers should be stored in a dry place at room temperature not exceeding twelve months. Material from open or damaged containers should be dried at 75 to 80ºC.

Food Legislation

Promyde® fully complies with EU and FDA regulations related to plastic materials intended to come into contact with foodstuffs.

- **FDA Regulations**: Compliance with all specifications and limitations stated in USA FDA 21 CFR (B) §177.1500, (a) 6 and (b) 6.1 and 6.2 “Nylon Resins”.

For further information, please contact NUREL’s team.