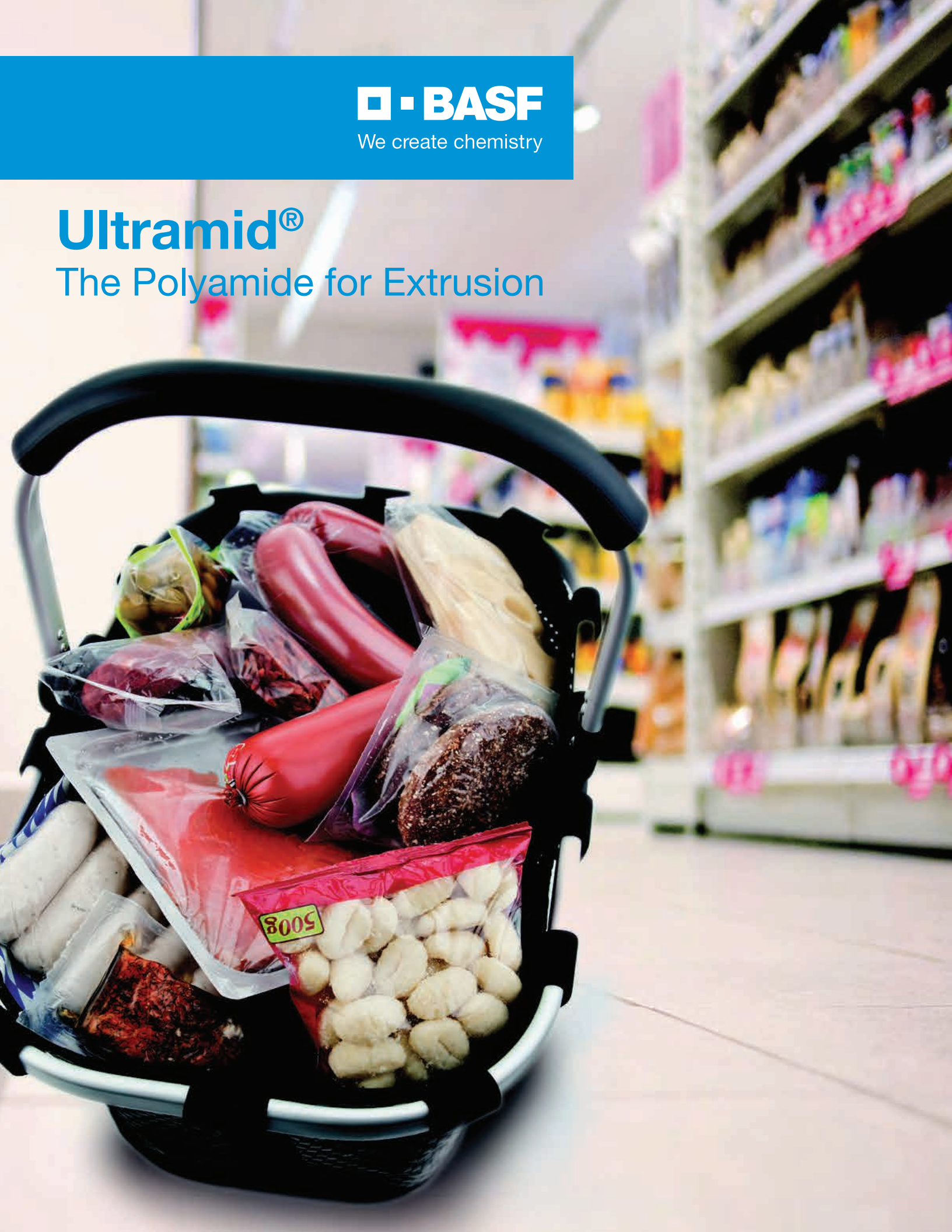
BASF
We create chemistry

Ultramid®

The Polyamide for Extrusion





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Ultramid® : The Clear Choice

Ultramid® is BASF's trade name for its line of polyamide (PA) products. BASF started manufacturing Ultramid® polyamides over 60 years ago. Today, BASF is one of the world's largest producers of polyamides. Our line of products includes Ultramid® B (PA 6) and Ultramid® C (PA 6/66 copolymer).

The Ultramid® extrusion grades, available in a wide variety of viscosities and additive packages, are used in nearly all fields of packaging. Due to their outstanding properties, they have become indispensable to many applications.

The strong crystalline cohesion of Ultramid® is responsible for its high melting point and high thermal stability, as well as for its hardness, abrasion resistance and high gas and aroma barrier properties. The strong intermolecular bonding in the amorphous zones provide polyamides with high impact strength and elasticity which results in polyamide films with excellent thermoforming characteristics.

The semicrystalline nature of polyamides results in an excellent combination of properties and also makes them an important raw feedstock for packaging materials. For extrusion applications, Ultramid® is the material of choice if those properties are required:

- puncture resistance
- outstanding mechanical performance (strength - stiffness - toughness - ratio)
- high transparency
- oxygen and carbon dioxide barrier
- flavor and aroma barrier
- thermoformability
- heat resistance
- chemical resistance

Table 1: Melting temperatures of Ultramid® resins

Ultramid®	Polyamide type	Melting temperatures (°C)
B	PA 6	220
C	PA 6/66	189 -195





Ultramid® is highly appreciated in multilayer films for the packaging of food.

Ultramid® polyamide – more than just a high-tech product
Ultramid® is engineered especially for your packaging application. Moreover, BASF provides its customers the wide assortment of services that you expect from a leading supplier of engineering plastics, including:

- worldwide availability of Ultramid® grades from manufacturing locations and sales offices throughout the world
- uniform product quality lot-to-lot through the consistent application of BASF's high quality standards which are identical all over the world
- certification in accordance with ISO 9001

Most importantly, we offer our customers comprehensive technical support. Experienced technical service representatives specializing in extrusion processes respond quickly to your questions about materials and processing. Our laboratories are available to perform an extensive number of tests to analyze materials and help you in your product development. In addition, our plastics processing facilities give you access to film extrusion pilot lines, supporting to optimize your manufacturing process.



Ultramid® Film: Properties and Applications

Ultramid® is especially well-suited for the packaging sector due to its high strength, outstanding thermoformability, high thermal stability, including resistance to sterilizing temperatures, and very good barrier properties towards gases, especially oxygen, flavors and aromas.

In multilayer constructions with polyolefines and EVA, high-quality flexible film may be produced for vacuum packaging of oxygen-sensitive foods such as meat, cheese, processed food, sea food and sausage.

Vacuum packaging is one of the main applications of Ultramid® today. Ultramid® films' good thermoformability guarantees particularly wellshaped vacuum packing with good contact clarity and outstanding appearance as well as good cost efficiency.

Ultramid® is well suited for the production of biaxially oriented (BOPA) film which provides high stiffness, puncture resistance, barrier and transparency.

Polyamide based sausage casing is characterized by a high oxygen barrier as well as good printing properties and constant diameter and shape.

Due to its special property profiles Ultramid® based mono- or multilayer constructions may also be used in industrial applications such as release films for sheet molding com pound (SMC), prepregs or roof underfelt sheeting.

The selection of the suitable Ultramid® grade is determined by film property requirement, the processing method to be applied and, in the case of coextruded films, on the viscosities of the other polymers involved. Ultramid® B36 LN 01 is typically combined with PE-LD or PELLD of 3.0 - 4.0 g / 10 min melt index, whereas Ultramid® B40 L or B40 LN is coextruded in combination with PE of 0.7 -1.0 g / 10 min melt index.

Typical values for the properties of film made from Ultramid® are provided in table 2.

Table 2: Standard properties of Ultramid® polyamide films (conditioned)

			Ultramid® B36 LN 01 40 µm cast film cold chillroll	Ultramid® C40 L 40 µm blown film cold air	Ultramid® B31 15 µm BOPA film
Melting temperature	DSC	°C	220	189	220
Density		g /cm^3	1.12 - 1.15	1.12 - 1.15	1.12 - 1.15
Tensile modulus	MD	MPa	700	600	3000
Tensile modulus	TD	MPa	650	600	3000
Stress at break	MD	MPa	75	70	260
Stress at break	TD	MPa	75	70	250
Elongation at break	MD	%	400	480	85
Elongation at break	TD	%	380	475	90
Oxygen Transmission Rate	23 °C / 50	% rh cm^3 /m^{2}d bar	14	14	25
CO2 Transmission Rate	23 °C / 0 % rh	cm^3 /m^{2}d bar	110		200
Water Vapor Transmission Rate	23 °C / 85 % rh	g /m^{2}d	28	25	43

Ultramid® Film: Processing Fundamentals



Barrier or three-section screws having an length of 24 to 32 D and a constant pitch of 1 D are generally considered to be suited for processing of Ultramid® (cf. table 3). The compression ratio should be between 3:1 and 3.5:1 (fig. 2). The flight depth depends on the screw diameter D and on the melt viscosity.

Barrier screws are used especially for constant output. More gentle fusion and transport at constant speed are possible in a narrow output range.

The screw clearance (radial clearance between the screw and barrel) should be 0.1 to 0.2 mm to minimize leakage. For screws having diameters above 90 -150 mm, shear sections located at 22- 25 D are recommended.

Screen packs having a mesh count of 400 to 3,600 /cm² are usually recommended for the required backpressure and good melt homogeneity.

Processing temperature is typically in the range of 240 to 270 °C for Ultramid® B and 210 to 260 °C for Ultramid® C. Suitably powered heater bands and drives (e. g. 10 kW heater power and 60 kW drive power for an extruder having a screw diameter of 60 mm) with precise controllers for screw barrels, adapters and dies are required. Lubricants and nucleation agents have no significant effect on the resultant melt temperature.

Table 3: Guide values for screw geometry (extrusion)

Length of sections		
Total length	L	24 - 32 D
Feed section	L_E	8 - 9 D
Transition section	$L_Ü$	4 - 6 D
Metering section	L_A	8 - 15 D1)

1) with shear section, length 1-2 D

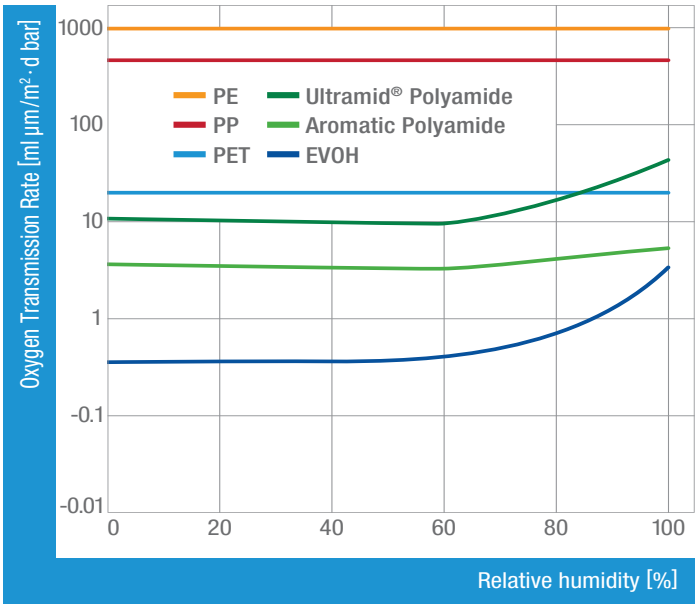


Fig. 1: Barrier properties of polyamide films

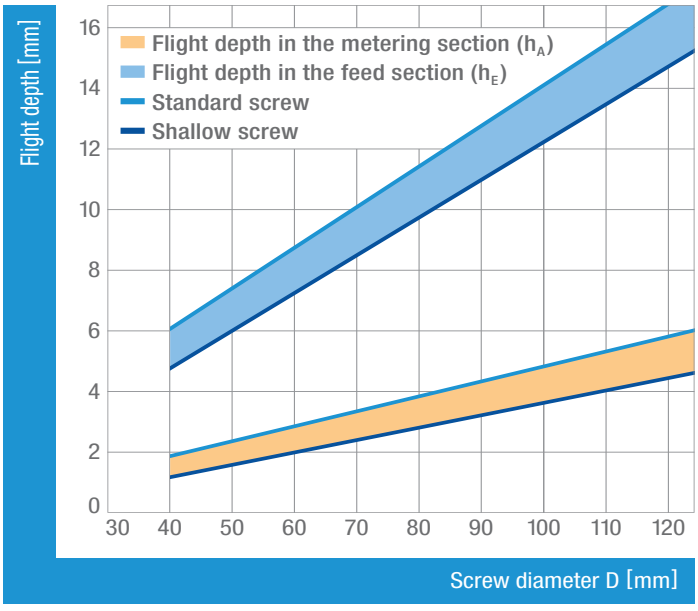


Fig. 2: Screw flight depths for three-section screws in extrusion machines

Ultramid® Film: Processing Techniques

Cast film and blown film, which are used primarily for packaging food, may be extruded from Ultramid® B (PA 6) and C (PA 6/66) grades of medium to high viscosity, usually in the form of a multilayer film containing polyethylene.

Blown film

Multilayer blown film from Ultramid® B or C resins, polyolefins and suitable adhesive materials may be coxetruded utilizing commercially available equipment as used for manufacturing of polyethylene blown film. Especially in the case of a non-symmetric layer structure (e. g. PE / tie / PA), copolyamides (Ultramid® C) are preferred to produce highly thermoformable and flexible multilayer film with high transparency and low curl. The curl may be further reduced by humidification of the film by a hot-water bath. Monolayer blown film may also be produced using Ultramid® B grades.

The die gap should be approx. 2.0 - 2.5 mm (multilayer film) or 0.5 -1.5 mm (monolayer film). The extruded film is cooled with air, a take-off speed of more than 30 m /min (100 ft /min) is achievable. Typical blow-up ratio (die diameter / tube diameter) lies in the range of 1: 3.0.

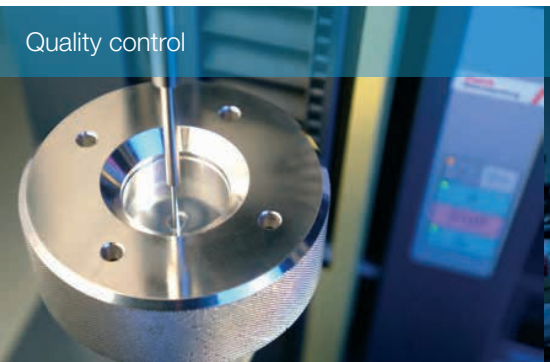
The tube should be collapsed as close as possible to the solidification zone (frost line) so that the film is laid flat while still warm and flexible.

Downward extrusion into a cold-water (6 - 20 °C) cooling bath with outside or in / outside water cooling is also possible. In this case, line speed up to 150 m / min is feasible. Table 4 contains an example of tubular film extrusion processing parameters.

Cast film

Cast film is mainly extruded from Ultramid® B grades. It is normally drawn to a thickness of 20 to 250 µm (1 to 10 mils) from T- or coathanger dies of up to 2,000 mm (6.5 ft) wide. The die gap should be approx. 1.0 - 1.2 mm (multilayer film), line speed of 120 m / min is possible. For efficient production, extruders having screws of 50 -150 mm (2.0 - 6.0 in) in diameter (28 to 32 D in length) are recommended.

Film properties and quality (i. e. tolerances, dimensional stability, machinability and transparency as well as thermoformability), are highly determined by the processing conditions. The chill-roll temperature should be set to 20 - 40 °C for thermoforming film of high transparency or 80 -120 °C for film of high dimensioned stability.


Quality control


Testing of film strength during quality control


Cast film



Oriented PA film

Biaxially oriented (BOPA) film may be manufactured from Ultramid® B resins by rapid cooling of film and subsequent simultaneous or sequential stretching in machine and transverse direction. Cast (tenter frame) or blown (double bubble) technology may be applied. Stretch ratio will usually be between 2.7 and 3.2 (both machine and transverse direction).

Artificial sausage casing may be manufactured from Ultramid® as both conventional as well as biaxially oriented shrinkable blown film.

PA 6 is highly suited for oriented, shrinkable film. Biaxially oriented casing is frequently coextruded with polyolefins in order to achieve the required water vaporbarrier film application.

For processing examples, refer to table 4.

Table 4: Examples of film extrusion processing parameters for Ultramid®

Product	Unit	Ultramid® B36 LN 01	Ultramid® C40 L	Utramid® B33 LN 01
Production process		cast film	blown film	BOPA film
Film type		multilayer film PE / PA	multilayer film PE / PA	PA / PA /PA film
Film width	mm	1800	900	4200
Film thickness (total/PA)	µm	120 /30	90/15	15
Screw diameter	mm	90	60	175
L /D		28	28	28
Screw sections	L /D	9 /5/14	9 /5 /14	9 /5/14
Flight depth lf/lm[1)]	mm	14 /14.5	8 /2.5	18 /6
Heater temperatures				
Cylinder	°C	265	250	265
Adapter	°C	260	245	260
Die	°C	260	245	260
Melt temperature	°C	265	250	265
Melt pressure	bar	120	150	150
Screw speed	RPM	50	70	65
Output (total / PA)	kg/h	500/180	250/50	750
Die		T-die	circular die	T-die
Die width[2)]	mm	w = 2000	w = 300	w = 1650
Die gap	mm	1.2	2.0	2.0
Blow-up ratio			2.2	
Cooling		chill-roll 30 °C air knive, vacuum box	air 12 °C IBC	chill-roll 12 °C electrostatic pinning
Stretching (MDO/TDO)				3.2 /3.0 sequential or simultaneous
Winding speed	m /min	70	35	150

1) Flight depth in the feeding zone (lf) and the metering zone (lm)
2) w = die width, d = die diameter



Ultramid® Monofilaments: Processing and Applications

Ultramid® can also be used for the production of stretched monofilaments such as industrial wires, fishing lines, tennis racket strings, weed trimmer lines and bristles.

Ultramid® B27 E, a PA 6 of low viscosity, is optimally suited for blending with other Ultramid® grades for the production of monofilaments of dia meters up to 0.7 mm. Applications include e. g. monofilaments for fishing nets, bristles or fine monofilaments for industrial fabrics.

Ultramid® B33 01, a PA 6 of intermediate viscosity, is the general purpose grade for the production of fine and medium gage monofilaments for the fisheries sector and industrial applications such as filters, paper screening fabric and bristles.

Ultramid® B33 SLX is a slow crystallization PA 6 of intermediate viscosity wich is well suited for fishing net and fishing line applications.

Ultramid® B40 L 01 is particularly suitable for manufacturing stretched monofilaments having medium and relatively thick diameters of up to 5 mm and for bristles.

Ultramid® B33 L 01 is used in production of weed trimmer lines, for softer lines plasticizers have to be added.

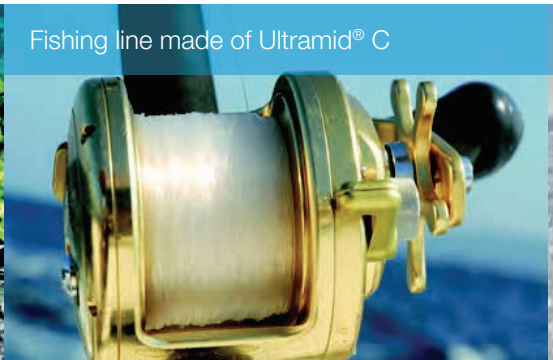
Ultramid® C40 LX is suitable for the manufacture of high-grade sports fishing lines, hook monofilaments, long lines and tennis racket strings.

Extrusion lines for monofilaments and bristles mainly consist of a single-screw extruder, spinning pump (precision gear pump), spinneret (multiple die), waterbath for cooling, roll stretching units, hot-water stretching bath and/or hot-air stretching channels. The ratio of the peripheral speeds of the roll stretching units, usually seven-roll sets, corresponds to the stretching ratio which is preferably in the range of 1: 4 to 1: 6. Depending on the type of monofilament stretching, is done in one or more steps. The subsequent shrinkage or relaxation step comprises of a further hot-air channel and a set of three rolls which run at a lower peripheral speed depending on the required percentage shrinkage (e.g. 5 to 10 %).

Special methods involving particular know-how are occasionally used for the production of monofilaments or wires having large diameters (> 3 mm).

Table 5 provides examples of mono-filament extrusion.


Artificial gras made of Ultramid® B


Fishing line made of Ultramid® C


Velcro-fastener made of PA 6



Fishing nets are often made of Ultramid® B because they have to be soft and strong at the same time.

Table 5: Examples of monofilament extrusion processing parameters for Ultramid®

Ultramid®	Unit	Ultramid® B33 SLX	Ultramid® C40 LX
Product		Monofilaments for fishing nets	Monofilaments for fishing lines
Production technique		Extrusion, water quenched, stretched between rolls	Extrusion, water quenched, stretched between rolls
Dimensions[2)]	mm	d = 0.30	0.30
Screw diameter D	mm	45	45
L /D		25	25
Flight depth h_E/h_A	mm	8.0 /2.5	8.0 /2.5
Screw sections[1)]		06.07.12	06.07.12
Heater temperatures			
Cylinder	°C	260/290/285/275	270/280/275/270
Adapter	°C	275	265
Die	°C	275	265
Melt temperature	°C	275	265
Melt pressure	bar	120	32
Screw speed	min-1	55	32
Type of die Dimensions	mm	Die · 30 1.40 2.0 d	Die · 20 T-die 3.0 d
Additional cooling		Waterbath 10 - 20 °C	Waterbath 35 - 40 °C
Stretch ratio		1: 4.6	1: 5.5 -1:6.0
Stretch temperature		120 °C (steam) / 220 °C (hot air)	120 °C (steam) / 230 °C (hot air)
Take-off speed	m /min	25.0	20.0
Weight per unit length	g /m	0.0806 (stretched)	0.0806 (stretched)
Output	kg /h	16.8	10.3

1) Length of feed /compression /metering sections as multiple of screw diameter D.
2) s = thickness, d = diameter, b = width; for dimensions of roads and tubes see DIN 16980, 16983, 16982

Other Extrusion Applications



Polyamid can reduce PVC in wire and cable jacketing. It reduces costs and enhances abrasion resistance.

Ultramid® provides high resistance to lubricants, engine fluids, hydraulic and radiator oils, aliphatic and aromatic hydrocarbons and many other solvents – even at elevated temperatures. Therefore tubes for central lubrication systems, fuel and oil pipes, pneumatic and hydraulic control lines and Bowden cables are produced utilizing high viscosity grades like Ultramid® B40 L 01. Corrugated tubes for the automotive industry are also made of Ultramid® B40 L 01.

As the global leader in polyamide for building wire jacketing, BASF knows what it takes to succeed in this industry. By replacing a large portion of the PVC insulation with a thin layer of durable, abuseresistant Ultramid®, performance increases while costs decrease. Our special grade Ultramid® B27 HM 01 not only provides a higher level of abrasion resistance, end-use temperature rating, and hydrocarbon resistance, but also reduces PVC consumption, overall cost and weight.

Post-treatment of Ultramid®

Surface coating

Due to its outstanding resistance to most solvents, Ultramid® may be coated in one or several layers of various paints which adhere well and have no adverse effects on mechanical properties. One- or two-component paints with binders matched to the substrate are suitable.

Metallizing and lamination

Articles made from the various Ultramid® grades may be metallized in high vacuum following priming or by electroplating after suitable preliminary treatment. Excellent surface quality can be achieved.

Printing

Due to its printability performance films made from Ultramid® grades are widely used for printed packaging. Films made from Ultramid® grades are suitable for both processes, flexoprint and gravure printing. Gravure printing is often used to get high quality prints on oriented PA 6 films (OPA and BOPA), which are normally used as reverse printed substrates in laminates. Nucleated Ultramid® B grades are the material of choice for PA 6 monolayer films with optimized stiffness, suitable for cost efficient flexoprint process.

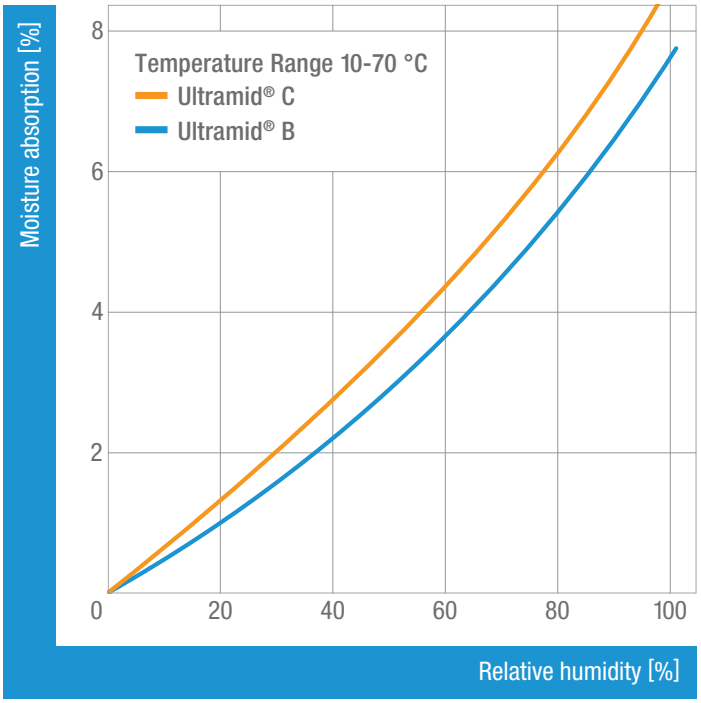


Fig. 3: Equilibrium moisture content of Ultramid® as a function of relative humidity in the temperature range 10 - 70 °C

Conditioning

Articles manufactured of Ultramid® resins will achieve their optimum toughness and final dimensions only after moisture absorption. Conditioning by exposing products to warm, humid air or steam, or passing through hot water, will ensure rapid humidity absorption to a level of 2.5 - 4 % the equilibrium content in contact with air at average relative humidity (cf. fig. 3)



Ultramid® B coated with aluminium can be used for the packaging of coffee.

Safety and Storage

Safety precautions during processing

Ultramid® resins will decompose, as all thermoplastic polymers, when exposed to excessive heat, e. g. when setting too high processing temperatures or when cleaning equipment by burning off. Besides Caprolactam smoke (in case of Ultramid® B and C), gaseous decomposition products, mainly ammonia and carbon monoxide may be formed, especially when the resin is heated to above 310 °C. At temperatures above 350 °C, small quantities of pungent smelling vapors of aldehydes, amines and other nitrogenous decomposition products may also formed.

Generally, measures should be taken to ensure ventilation and venting of the work area, preferably by means of an extraction hood over extruder cylinder and die.

Food legislation

Agency compliance status of Ultramid® extrusion grades can be obtained by contacting your sales rep or contacting us at nylon.basf.us.

Supply form and storage

Ultramid® is supplied predried and ready for processing in a variety of moisture proof containers, such as boxes, big bags (Asia) and bulk containers.

To ensure that the perfectly dry material delivered cannot absorb moisture from the air, the containers must be stored in dry rooms and always carefully sealed again after portions of material have been withdrawn. Ultramid® can be kept indefinitely in the undamaged bags. Containers stored in cold rooms should be allowed to equilibrate to normal temperature so that no condensation on the pellets may occur.



Ultramid® grades complies with food contact regulations.

Nomenclature

The Ultramid® range consists of PA 6 grades and copolyamides, such as PA 6 / 66. Ultramid® extrusion grades are designated by letters and digits which indicate chemical composition, viscosity and additives.

The letter (B, C) placed after the Ultramid® product name identifies the type of polyamide:

PA 6 grades	Ultramid® B
PA 6 / 66 grades	Ultramid® C.

Viscosity class
The following numbers specify the viscosity class by Relative Viscosity in 96 % / 23 °C sulphuric acid (i. e. 33 for RV 3.3)

27 = easy flowing, low melt viscosity
32 = intermediate viscosity
33 = intermediate viscosity
36 = intermediate to high viscosity
40 = high viscosity

The melt index (MI), measured according to ISO 1133, decreases as the molecular weight rises and is a common measurement method for polyolefins. However, as polyamides are susceptible to melt-viscosity altering moisture absorbtion, this method is not commonly used.

Additives

HM	= heat stabilized, high monomer content
L	= lubricated
LN	= lubricated and nucleated
LX	= high lubricant content
LXM	= high lubricant content, high monomer content
S	= slow crystallization

Suffix
Indicates pellets shape and production site
01 for cylindrical pellet shape
09 for round shape produced in China
no number = round shape produced in Germany

Example:
B 40 LN 01 (PA 6, high viscosity, RV = 4.0, lubricated, nucleated with cylindrical shape, produced in US)

We create chemistry

BASF – a partner you can rely on

With over 80 years of experience in polyamides, BASF is truly a partner you can rely on. We work closely with our customers to identify their needs, and we constantly strive to strengthen their competitive advantage.

We combine our know-how, products and services in one highly effective global network. We never stop asking what we can do to involve our partners in the best possible way. That is how we help our customers to be more successful.

Visit us at www.nylon.basf.us

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