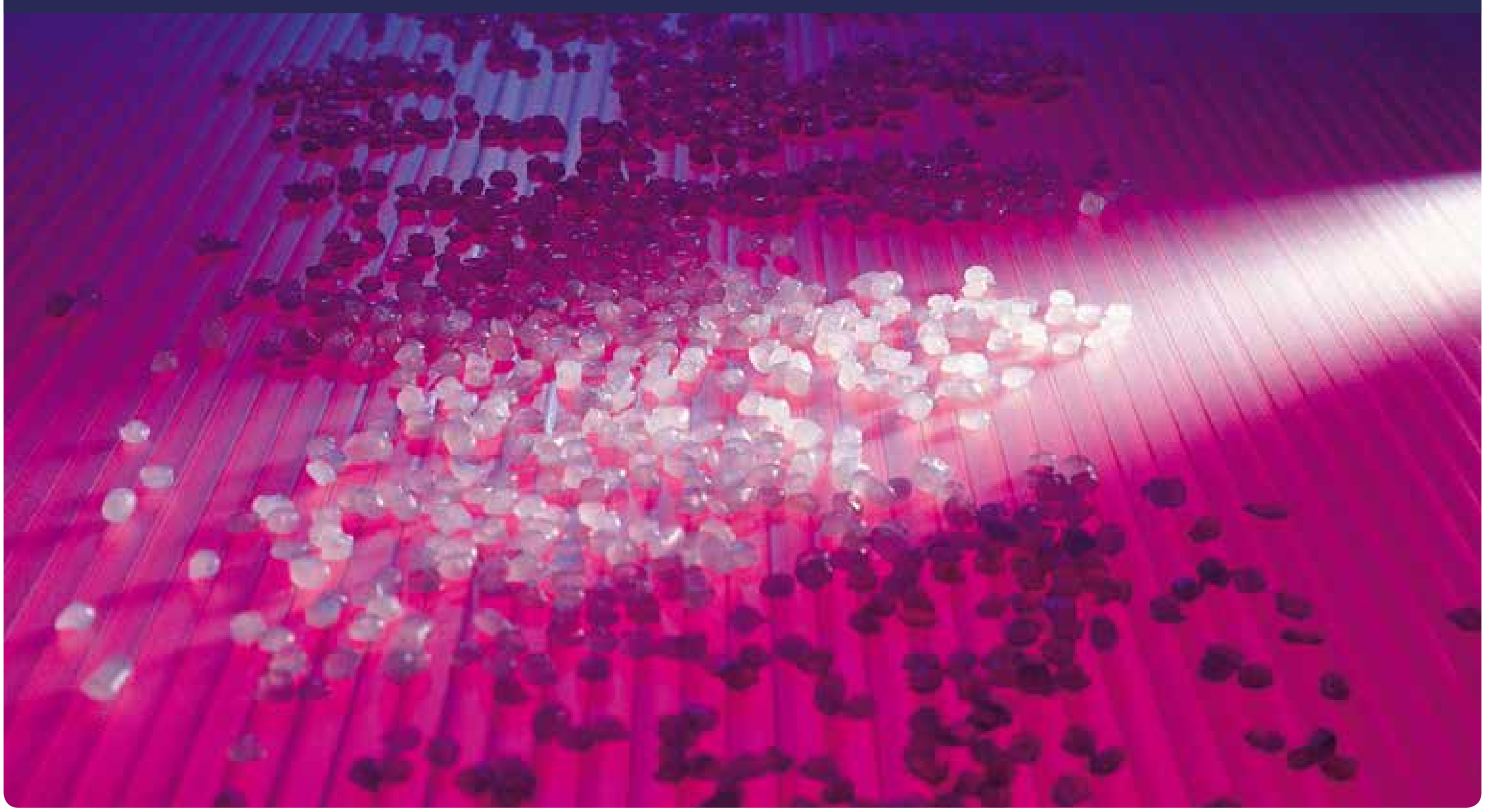
Pro-fax and *Moplen* Polypropylene Primer



lyb.com

About Us

LyondellBasell is one of the world's largest plastics, chemical and refining companies. We are the largest producer of polypropylene and polypropylene compounds; a leading producer of propylene oxide, polyethylene, ethylene and propylene; a global leader in polyolefins technology; and a producer of refined products, including biofuels.

LyondellBasell products and technologies are used to make items that improve the quality of life for people around the world including packaging, electronics, automotive components, home furnishings, construction materials and biofuels.

Table of Contents

Primary Types

Homopolymer (isotactic)

Made in a single reactor with propylene and catalyst. It is the stiffest of the three types and has the highest tensile strength at yield. In the natural state (no colorant added) it is translucent and has excellent see-through or contact clarity with liquids. In comparison to the other two types it has less impact resistance, especially below 35°F.

Random Copolymer (homophasic copolymer)

Made in a single reactor with a small amount of ethylene (<5%) added which disrupts the crystallinity of the polymer allowing this type to be the clearest. It is also the most flexible with the lowest tensile strength of the three. It has better room temperature impact than homopolymer but shares the same relatively poor impact resistance at low temperatures.

Impact Copolymers (heterophasic copolymer)

Made in a two reactor system where the homopolymer matrix is made in the first reactor and then transferred to the second where ethylene and propylene are polymerized to create ethylene propylene rubber (EPR) in the form of microscopic nodules dispersed in the homopolymer matrix phase. These nodules impart impact resistance both at ambient and cold temperatures. This type has intermediate stiffness and tensile strength and is quite cloudy. In general, the more ethylene monomer added, the greater the impact resistance with correspondingly lower stiffness and tensile strength. Many times the misnomers “block” or “graft” copolymers are attributed to this type of polypropylene.

Formulation Ingredients

Flake

Polypropylene comes from the reactor as a fine, sand-like particle and is then melt compounded with additives into pellets for the intended application. Flake is not suitable for melt processing of any kind without the antioxidant additives noted below.

Spheres

A type of flake that is a larger particle (~3 mm diameter) in the form of round spheres.

Barefoot

Basic antioxidant package only.

Antioxidant package

- Antioxidant to inhibit oxidation

- Melt stabilizer to inhibit breakdown during processing

- Heat stabilizer to aid long term plastic life at elevated temperatures

- Antacid to react with the very small amount of chlorine residue from the catalyst.

Nucleator

An additive that causes crystals to form at about 260°F during the cooling cycle for homopolymers rather than at the normal 240°F (temperatures vary somewhat for other types). Parts set up faster for faster injection molding cycles. Nucleation results in slightly more shrinkage, and increases stiffness by about 10%. Nucleation may cause warpage problems where there are wide differences in part thickness. In homopolymers, there is a slight improvement in clarity. Note that certain pigments (e.g., ultramarine blue, phthalocyanine green and blue, oranges, etc.) are also nucleators.

Clarifier

An additive most often used in random copolymers, the chief purpose of which is to make clearer parts by causing more and smaller crystals to form at a slightly higher temperature during the cooling cycle than when using other nucleators. There is little effect on homopolymers and almost no effect on impact copolymers.

Antistat

Hydrophilic additive which migrates to the part surface as it cools and attracts moisture from the air to the surface, preventing or reducing electrostatic charges and associated attraction of airborne dirt.

Slip agent

These oily additives are added in very small amounts and migrate to the part surfaces after molding to lower the coefficient of friction and allow ease of molded part and extruded film handling.

Antiblock

Very finely divided inorganic material, typically of the silica family, added to improve the unwinding characteristics of thin films.

Physical Properties

Density (ASTM D 792B)

All three unfilled types have a molded density of 0.90 g/cm3 (0.033 lbs/in3) (solid).

Spheres

A type of flake that is a larger particle (~3 mm diameter) in the form of round spheres.

Melt flow rate (MFR) (ASTM D 1238)

A method of measuring melt viscosity at very low shear rates at 230°C (446°F) using a 2.16 kg weight. The measurement is inverse to viscosity and molecular weight (i.e. higher MFR means lower viscosity and molecular weight). As noted on data sheets, the MFR is meant to be considered as a target value. Production specifications for a particular resin have an allowable range (±3 sigma) which can vary from ±0.15 for a target of 0.45 MFR to ±7 for a target of 35. The range variation is due to the logarithmic relationship of MFR and intrinsic viscosity. Polyethylene is measured using the same equipment (piston weight, orifice size, etc.) but at 190°C (374°F), and the results generally referred to as Melt Index (MI or MFI).

Tensile strength at yield (ASTM D 638)

The stress required to strain a test specimen to its yield (plastic) point. It is a measure of the general strength of the material. Reported as psi in English units and MegaPascals (MPa) in metric units.

1 psi = 0.0069 MPa.

Elongation at yield (ASTM D 638)

The percent strain at the point of yield.

Flexural modulus (ASTM D 790A)

A measure of the force required to bend a specimen. LyondellBasell generally reports data as the 1% secant value at a crosshead speed of 0.05 in/min. Reported as psi in English units and MegaPascals (MPa) in metric units. In the past, LyondellBasell has reported this value using ASTM D 790B which uses a crosshead speed of 0.5 in/min. Values determined by this technique would be 20-30,000 psi higher than with the presently used ASTM D 709A.the part surface as it cools and attracts moisture from the air to the surface, preventing or reducing electrostatic charges and associated attraction of airborne dirt.

Notched izod impact strength (ASTM D 256A)

A measure of the impact resistance of a sharply notched test specimen. Reported as ft-lbs/in in English units and joules per meter (J/m) in metric units. Specimens normally break in a brittle mode during testing. Consistent ductile failure or no failure at levels higher than 15 ft-lbs/in are reported as “No Break”. As with other crystalline polymers, higher MFR grades usually have lower notched Izod values. As this test depends on a high internal stress (notch), strict comparisons between dissimilar polymers are not recommended. 1.0 ft-lb/in = 53.4 J/m.

Other uniaxial (e.g. unnotched Izod, Charpy, tensile impact, etc.) and multiaxial (e.g. Gardner, Dynatup, dart, etc.) impact tests are widely used in the plastics industry but do not correlate to one another.

Drop weight impact @ -20°F (-29°C) (LyondellBasell method)

This falling weight impact test value is the multiaxial impact force necessary to fracture impact copolymers at cold temperatures. Changing to a similar grade with a higher MFR has little or no effect on this test. Due to low temperature embrittlement, data is not reported for homopolymers or random copolymers. Using the Bruceton staircase statistical method of analysis, the number reported is the average height of breakage times the weight of the tup. Reported in ft-lb of force to break in English units and joules (J) in metric units. 1 ft-lb = 1.36.

Hardness

LyondellBasell in North America no longer reports hardness values. However, the following may be used for estimation purposes: homopolymers will be in the 85-95 Rockwell R (approximately 76 Shore D) range. Impact copolymers will be in the 75-85 (approximately 72 Shore D) range with random copolymers being a bit softer. Nucleation will increase these values.

Application Information

Bulk density

For calculating the storage capacity of bins, silos, etc., the bulk density for pellets is typically 34-35 lb/ft3, for flake, it is 33-34 lb/ft3 and for spheres, it is 29-30lb/ft3. Bulk density varies slightly by pellet shape and additives; if accuracy is needed, for example when designing silos or setting feeders, the actual grade to be used should be tested.

Water absorption (ASTM D570)

Polypropylene is very hydrophobic, and as such needs no drying (unfilled). Typical absorption after 24 hours via this test method is 0.02%. Many filled polypropylenes need to be thoroughly dried prior to molding; 180-220°F for 2-4 hrs should be adequate.

Permeation

Liquids and gases will permeate through polypropylene, as with all other plastics, at a rate specific to the liquid or gas and its temperature and pressure. Polypropylene is particularly resistant to moisture with a moisture vapor transmission rate (MVTR) of 0.7 g.-ml/100 in2 -24 hr at 100°F (homopolymer) second only to HDPE among the more common plastics. It has rather poor resistance to the passage of gases such as oxygen and carbon dioxide with permeation rates (homopolymer) of 240 cc -ml/100 in2 -24 hr-atm at 25°C for oxygen and 800 cc-ml/100 in2 -24 hr-atm at 25°C for carbon dioxide. The resin grade and the forming process used may cause these values to vary considerably.

Chemical resistance

All primary types are highly resistant to chemical attack. With few exceptions inorganic and polar organic chemicals produce little or no effect at ambient temperature. Non-polar organic solvents such as gasoline, benzene, toluene, carbon tetrachloride, etc. will cause swelling and softening, particularly at elevated temperatures. Refer to the Pro-fax Polypropylene Chemical Resistance brochure for more information.

Stress-cracking

Polypropylene has excellent resistance to environmental stress cracking. Embrittlement that occurs with other plastics (e.g., HDPE) in the presence of oils, detergents and other agents is not observed with these materials. Generally, only very potent oxidizing agents (e.g., 98% sulfuric acid, fuming nitric acid, liquid bromine, etc.) produce stress-cracking in polypropylene.

Stress whitening (Blushing)

Parts made from darkly colored (e.g., blue, black, etc.) impact copolymers may whiten or blush when they are sharply struck. The choice of white or pastel colorants or the use of blush resistant grades will lessen this appearance issue. LyondellBasell has grades such as Pro-fax SB786 and SB823 that have been designed to minimize this blushing effect.

Hot water immersion

Long term heat aging (LTHA) additives may be required to reduce extraction of antioxidants when polypropylene is continuously immersed in hot water.

Weathering (Ultraviolet Resistance)

Polypropylene has limited resistance to weathering or exposure to UV light, a component of sunlight. The incorporation of 2.0-2.5% carbon black pigment has protected LyondellBasell polypropylene parts outdoors for up to 30 years. If black is not acceptable, then appropriate ultraviolet stabilizers should be added to achieve the desired outdoor life.

Sterilization (see also LyondellBasell's medical brochure)

The three methods most commonly used for the sterilization of single use, disposible medical devices and products are:

- **Steam**
  In general, any PP grade can be steam sterilized or autoclaved. This process typically exposes molded parts to steam in a pressure vessel at 121°C to 132°C for relatively short periods of time (5 to 45 minutes). Many thermoplastic devices, including those manufactured using PP, are routinely sterilized by steam.
- **Ethylene Oxide**
  Ethylene oxide (EtO) gas is typically used as a sterilant for medical devices or products in gas permeable packages that are not compatible with steam or radiation sterilization conditions. EtO rapidly penetrates deep pores and narrow crevices, and passes through wrappings of most plastics (including PP), without damaging the materials or parts being sterilized.
- **Radiation (gamma and e-beam)**
  Typical polypropylene resins are not recommended for applications where radiation (gamma and ebeam) sterilization is required due to both yellowing and loss of physical properties, including embrittlement. LyondellBasell offers several radiation resistant grades that are specially formulated to minimize such effects.

Decorating

Printing and adhesion are affected by oil, slip and antistat additives. All LyondellBasell resins are printable as supplied, but only after appropriate flame or corona treatment. The surface of polypropylene is quite resistant to a wide variety of chemical substances and therefore must be chemically altered to allow the adhesion of appropriately formulated paints, inks and many adhesives. Untreated polypropylene has a surface tension of 29 dynes/cm2. Surface tension must be raised to allow these materials to wet effectively. For solvent-based inks and coatings, the surface of the polypropylene must be at least 35 dynes/cm2 and for water based materials, 38 dynes/cm2. Therefore a surface tension of at least 40 dynes/ cm2 at the time of application is recommended. Surface treatment is somewhat perishable and will decay over several days or weeks. Therefore it is important that printing, painting, etc. occur shortly after treatment. The incorporation of additional oily materials (e.g., stearates, slip agents, etc.) may totally inhibit printability such that the heat from corona or flame surface treatment will only result in more ingredients coming to the surface, thus preventing adhesion.

Gluing

With the extreme chemical resistance of polypropylene, normal adhesives do not attack the resin surface and allow good mechanical bonding. Certain flexible hot melt adhesives will stick to untreated polypropylene surfaces and give adequate service where structural bonding is not required and a degree of flexibility is acceptable. Reasonably good mechanical properties (100-200 psi tensile strength) can only be attained by first treating the surface as noted above and then using special, generally two-part adhesives developed for this use.

Bonding/welding

Polypropylene may be hot-plate welded, hot bar-sealed (films), spin-welded and vibration welded using appropriate procedures. Certain grades which have a flexural modulus of 200,000 psi or greater may be ultrasonically welded. However, due to its microwave transparency, polypropylene cannot be radio frequency (RF) welded without the addition of special fillers.

Living hinges

Polypropylene has the unique characteristic of developing extremely durable "living" hinges when the appropriate design is used and molded properly. Homopolymers and random copolymers have better flex lives than impact copolymers. Low MFR resins perform better than those with higher MFR. However, all unfilled polypropylene resins will perform adequately for most intended purposes. For more information, refer to LyondellBasell's brochure Design Issues on Living Hinges.

Post-melt crystallization

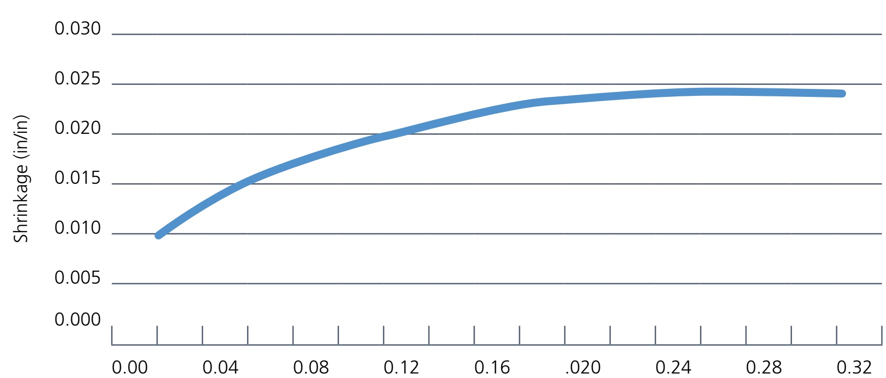
Polypropylene crystallizes rather slowly, and this crystallization, which results in shrinkage, continues even at room temperature for a considerable time. Therefore it is important that critical property measurements not be made until at least 24-48 hours after molding when approximately 90% of the ultimate values have been reached. This includes not only important physical dimensions but also stiffness, tensile strength, impact strength, etc.

Shrinkage

The longer it takes for polypropylene to cool, the higher the level of crystallinity and the more shrinkage that will occur. The factors that result in greater shrinkage are:

- Thicker parts
- Higher melt temperature
- Hotter tool surface (coolant temperature)
- Lower packing pressure
- Hotter part ejection

Nucleated resins and those nucleated by colorants (e.g. green, blue, orange, etc.) will shrink more. Otherwise all three primary types (homopolymers, random copolymers and impact copolymers) shrink approximately the same. The chart is applicable for all these materials, regardless of MFR. Values shown are the maximum to be expected at least 48 hours after molding under most conditions. Although the data are useful in determining mold cavity allowances, lower values can be obtained when molding conditions are adjusted as noted above.



Pro-fax Polypropylene Shrinkage Variation with Thickness

Scientific Information

Coefficient of friction (COF)

This depends on many factors including the surface finish on molded parts, additives that may be included in colorants, applied pressure, etc. However, for estimation purposes, the COF between polypropylene and polished steel may be considered to be 0.5-0.6. With the addition of slip and antiblock to film grades, this may be reduced to 0.2-0.3. Note that no reliable data are available for wear estimation. However, polypropylene is generally not considered to have good abrasion resistance.

Thermal conductivity - Solid

- Homopolymer	2.8 x 10-4 cal.-cm/cm^2-°C-sec
- Impact copolymer	3.5-4.0 x 10^{-4} cal.-cm/cm^2-°C-sec
- Specific Heat	0.45-0.50 cal/g-°C at 23°C
- Melt Density	46.1 lb/ft^3 (0.74 g/cm^3)

Coefficient of linear thermal expansion (CLTE)

Note that the following values are for homopolymer types and are from laboratory produced molded plaques. Data from production parts may vary considerably depending on molding and cooling conditions.

- 3.9 x 10^{-5}in/in/°F, from -20 to 32°F
- 5.4 x 10^{-5}in/in/°F, from 32 to 85°F
- 6.1 x 10^{-5}in/in/°F, from 85 to 140°F

Electrical properties

All primary types of natural polypropylene have approximately the same electrical properties, which are noted below. Fillers or other additives (e.g. colorants) may change these properties significantly.

- Dielectric constant	2.25 @ 100 KHz and I MHz
- Dissipation factor	0.0003 @ 100 KHz and 1 MHz
- Dielectric strength	600 volts/mil (1/8” thick) in air 800 volts/mil (1/8” thick) in the absence of air Filled polypropylene will yield lower values
- DC resistivity	>1 x 10^{15} ohm-cm

lyondellbasell

Responsible Care®
OUR COMMITMENT TO SUSTAINABILITY

08/2015