

LyondellBasell Polybutene-1 Grades

Shaping what comes next in ...seal peel and reclosable packaging

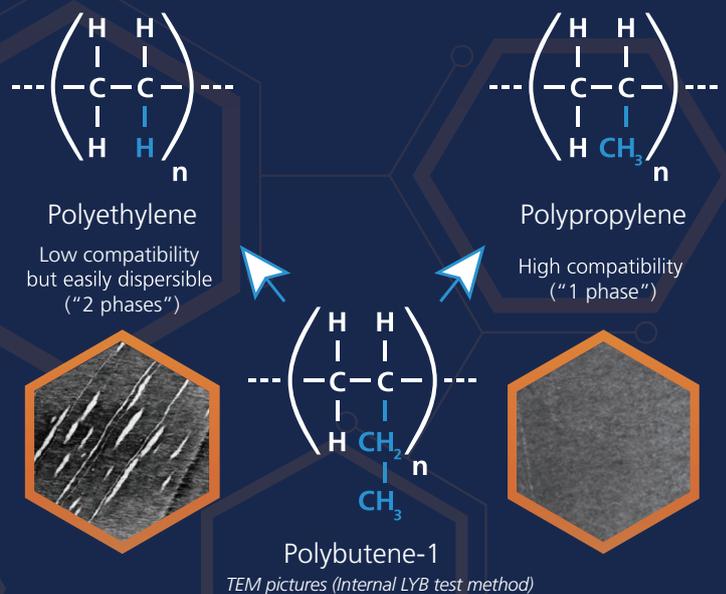


LyondellBasell is one of the world's largest plastics, chemical and refining companies. Around the globe, wherever the quality of life is improving, LyondellBasell products are likely there. These products are the structural building blocks of countless goods – numerous products which make our lives easier, safer and more enjoyable. Popular examples include computers, portable electronics, personal care items, food packaging, sports equipment, durable construction materials, piping, automotive components, biofuels, textiles and medical supplies.

The Company's Amazing Chemistry is applied at 55 manufacturing sites located across five continents. Our plant in Moerdijk, Netherlands is the biggest Polybutene-1 plant in the world. PB-1 is a polyolefin

obtained by the polymerization of Butene-1 with Ziegler – Natta or Metallocene catalyst. PB-1 is fully miscible with Polypropylene, and has a low compability but is easily dispersible in Polyethylene.

Moerdijk Plant



Amazing Chemistry...for food packaging

Consumers have a number of requirements towards food packaging. It needs to support their busy lifestyles and allow for the protection of ready-to-eat meals. It also needs to allow for re-sealing of any

packaged food item once the desired amount of food has been removed. Additionally, it also needs to be easy to open, with little force and without the need for a cutting instrument.

LyondellBasell is a recognized leader in Easy Peel Technology, and thanks to its ongoing research efforts has developed a wide range of Polybutene-1 grades that offer different solutions to customers' requirements.



- PB-1 Technology or the so called "dry blend" approach: used for PE film application
- *Toppyl* Technology or the "ready-to-use" approach: used for PE and PP film application
- *Toppyl* SP 2400 F for interlayer delamination: used for PE film application
- *Toppyl* SP 2300 F for non polyolefin substrates

All the above Easy Peel Technologies offer several advantages to the consumers and to the converters alike in a wide range of applications and machining parameters, such as safety

and convenience, a broad range of seal peel temperatures, reproducible performance, constant opening force, clean peel surface without strings and good seal integrity.

The “dry blend” approach

LyondellBasell offers four PB-1 grades for the dry blend approach. These grades have to be blended with PE in the seal peel layer and the choice of PE material used (LDPE, LLDPE, m-LLDPE, HDPE, EVA), the choice of the PB-1 material and its concentration are depending on final requirements of the application.

Product type	MFR* (g/10min)	Tm** (°C)	Extrusion Technology			
			Blown film	Cast film	Sheet	Extrusion coating
<i>Toppyl</i> PB 0110M	0.4	128	Retort up to 121°C	General use	General use	General use
<i>Toppyl</i> PB 8640M	1.0	114	General use	General use	General use	General use
<i>Toppyl</i> PB 8340M	4.0	114	Improved optics***	General use	General use	General use
<i>Toppyl</i> PB 8220M	2.5	97	Improved optics***	-	-	-

* MFR measured at 190°C/2.16 kg (ISO 1133) ** Tm measured with Internal LYB test method

*** vs. *Toppyl* PB 8640M but narrower seal peel window

This is typically a tailor-made solution by the converters, but at the same time it is very flexible and the wide range of technical parameters that can be modified lead to a broad

window of application. The peel force is typically affected by a PB-1 concentration and by the dispersion of PB-1 in PE matrix.

Influence of PB-1 concentration

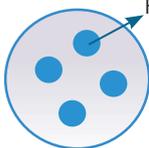
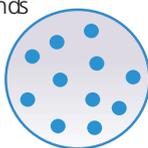
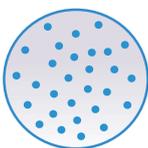
Binary blend	Peel-Force (*)
<i>Lupolen</i> 2420H + 10% <i>Toppyl</i> PB 8640M	5.0 N/15mm
<i>Lupolen</i> 2420H + 15% <i>Toppyl</i> PB 8640M	3.0 N/15mm
<i>Lupolen</i> 2420H + 25% <i>Toppyl</i> PB 8640M	1.5 N/15mm

The higher the *Toppyl* PB 8640M concentration, the lower the peel force.

Lupolen 2420H: LDPE, MFR 1.9, density 0.924

(*) Results measured with Internal LYB test method ('non-laminated blown film'), based on ASTM D882-90

Effect of dispersion quality

Dispersion example A	Dispersion example B	Dispersion example C
		
PB-1 islands		
Peel force: Example A (highest) > Example B > Example C (lowest)		
Optical properties: Example A ("worst") < Example B < Example C ("best")		

The dispersion of PB-1 in the PE matrix, in turn, is affected by the PB-1 Melt Flow Index (MFI) and by the PE MFI. The type of Polyethylene used has an impact on the peel force as well, as shown below.

Influence of Melt Flow Rate of PB-1

Binary blend	Peel-Force (*)	
Lupolen 2420H + 15% Toppyl PB 0110M (MFR 0.4)	4.9 N/15mm	
Lupolen 2420H + 15% Toppyl PB 8640M (MFR 1)	3.0 N/15mm	
Lupolen 2420H + 15% Toppyl PB 8340M (MFR 4)	1.6 N/15mm	

The higher the MFR of the PB-1, the lower the peel force.

The higher the Toppyl PB 8640M concentration, the lower the peel force when the seal-peel is to PE or to itself with a PE+PB-1 blend.

Lupolen 2420H: LDPE, MFR 1.9, density 0.924 TEM pictures Toppyl PB 0110M & Toppyl PB 8640M (internal LYB test method)

(*) Results measured with Internal LYB test method (non-laminated blown film), based on ASTM D882-90

Influence of Melt Flow Rate of LDPE (binary blend)

Binary blend	Peel-Force (*)	
Lupolen 2420F (MFR 0.75) + 15% Toppyl PB 8640M	1.6 N/15mm	
Lupolen 1806H (MFR 1.6) + 15% Toppyl PB 8640M	3.0 N/15mm	
Lupolen 2420H (MFR 1.9) + 15% Toppyl PB 8640M	3.0 N/15mm	
Lupolen 2420K (MFR 4) + 15% Toppyl PB 8640M	5.5 N/15mm	

The lower the MFR of the LDPE in the seal peel layer, the lower the peel force.

TEM pictures Lupolen 2420F & Lupolen 2420K based blends (internal LYB test method) (*) Results measured with Internal LYB test method (non-laminated blown film), based on ASTM D882-90

Influence of PE type in the seal peel layer

Binary blend	Peel-Force (*)
LDPE (MFR 1.9) + 25% Toppyl PB 8640M	1.5 N/15mm
C4-LLDPE (MFR 2.8) + 25% Toppyl PB 8640M	6.0 N/15mm
LDPE (MFR 1.9) + 15% Toppyl PB 8640M	3.0 N/15mm
HDPE (MFR 0.9) + 15% Toppyl PB 8640M	5.8 N/15mm

Two phenomena are taking place at the same time:
 - Change or modification of the dispersion (decrease in peel force)
 - Increase in adhesion strength between PB-1 and PE matrix (increase in peel force)

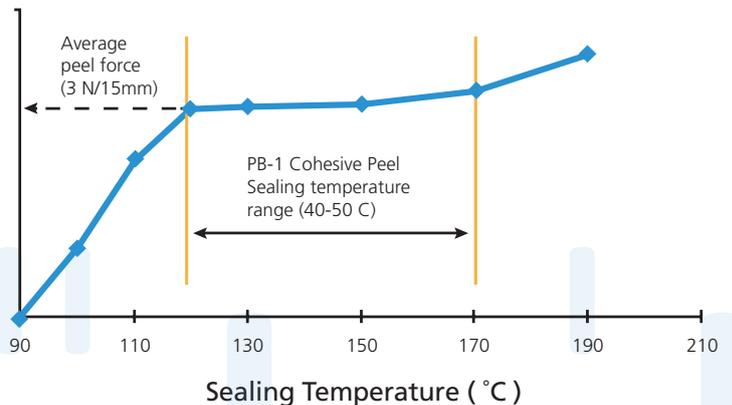
EVA (low % VA) < LDPE < HDPE < LLDPE < mLLDPE

Lowest adhesion

Highest adhesion

(*) Results measured with Internal LYB test method (non-laminated blown film), based on ASTM D882-90

Typical PB-1 seal peel trace: seal-peel temperature range



Seal peel layer: 60% LDPE + 25% C4-LLDPE + 15% Toppyl PB 8640M (real measuring points) Internal LYBI test method, based on ASTM D882-90

The peel force is not the only parameter that the converter has to tailor. There are other factors that play an important role in the performance of the final packaging solution. Usually PB-1 is used in a binary blend but in case the final application requires a broader seal peel window, very good consistency of the seal peel performance, good sealing properties and /or better hot tack properties, internal trials have shown that a ternary blend may offer the desired results.

Please consult our AD/TS team at pb1_specialties@lyb.com for more details.

Technology for the “ready-to-use” approach

LyondellBasell offers five *Toppyl* grades for the “ready-to-use” approach. Two products in the *Toppyl* B range for seal-peel to PE and itself, and three in the *Toppyl* C range for seal-peel to PP and itself. With the “ready-to-use” approach, all seal-peel layers are created with *Toppyl* products. No additional blending with PE is required, which may simplify the production process for the converters.

Product type	MFR* (g/10min)	Seal & peel to	Additivation	Heat-sterilisable	Extrusion technology			
					Blown film	Cast film	Sheet	BOPP
<i>Toppyl</i> SP 2000 B	2*	PE & itself	S, AB		X			
<i>Toppyl</i> SP 2001 B	0.8*	PE & itself	S, AB		X			
<i>Toppyl</i> SP 2101 C	8**	PP & itself	S, AB	X	X	X	X	X
<i>Toppyl</i> SP 2102 C	6.5**	PP & itself	S, AB		X	X	X	X
<i>Toppyl</i> SP 2103 C	6.5**	PP & itself		X	X	X	X	

* MFR measured at 190°C / 2.16 kg (ISO 1133)

** MFR measured at 230°C / 2.16kg (ISO 1133)

S = Slip AB = Antiblock

Toppyl B the “ready-to-use” approach for seal peel to PE and Itself

The *Toppyl* B grades are suggested for PE based film, as they work against PE substrates and against themselves.

LyondellBasell has developed two *Toppyl* B grades:

- *Toppyl* SP 2000 B

– This grade is used for “medium” peel force (± 4 N/15mm before film lamination*) (*Results measured with internal LYB test method, non-laminated blown film against non-laminated PE blown film based on ASTM D882-90) and it provides “medium” hot tack properties. *Toppyl* SP 2000 B is fully formulated with slip and antiblock agents.

- *Toppyl* SP 2001 B

– This grade is used for “low” peel force (± 2 N/15mm before film lamination*) (*Results measured with internal LYB test method, non-laminated blown film against non-laminated PE blown film based on ASTM D882-90). *Toppyl* SP 2001 B is fully formulated with slip and antiblock.

Both products can be considered valid and efficient alternatives to the standard PE/PB-1 “dry-blend” approach. The advantage in using these “ready-to-use” products for the sealing layer is that the ratio and grades of PE/PB-1 are already provided, which results in a less complex and more efficient selection process when choosing the right solution for the intended application. The “ready-to-use” solution is less flexible than the dry blend approach, so the final choice of which seal peel technology to use depends on the customer's final application requirement. The LyondellBasell AD/TS team supports customers in method selection, providing suggestions about the best film structure, and processing conditions.

Toppyl C the “ready-to-use” approach for seal peel to PP and Itself:

LyondellBasell products used in seal peel technology for PP film are in the *Toppyl* C family. Customers use these products in a broad range of film extrusion technologies like cast film, blown film, sheet extrusion, and BOPP. Typically *Toppyl* C is used in multilayer PP-based or barrier film structures.

- *Toppyl* SP 2101 C

– This grade could be used by customers for heat-sterilizable applications, which require an average peel force $\pm 3 - 4$ N/15mm before film lamination [*Results measured with internal LYB test method, (non-laminated cast film against non-laminated PP cast film) based on ASTM D882-90]. *Toppyl* SP 2101 C is fully formulated with slip and antiblock agents.

- *Toppyl* SP 2102 C

– This grade could be used by customers for non-heat sterilizable applications; the average peel force of this grade is $\pm 3- 4$ N/15mm before film lamination [*Results measured with internal LYB test method, (non-laminated cast film against non-laminated PP cast film) based on ASTM D882-90]. *Toppyl* SP 2102 C is fully formulated with slip and antiblock agents.

- *Toppyl* SP 2103 C

– In case customers need a seal peel solution to PP film for heat-sterilizable applications with a higher peel force compared to *Toppyl* SP 2101 C, LyondellBasell has developed *Toppyl* SP 2103 C. The average peel force of *Toppyl* SP 2103 C is around $\pm 6 - 8$ N/15mm before film lamination [*Results measured with internal LYB test method, (non-laminated cast film against non-laminated PP cast film) based on ASTM D882-90]. *Toppyl* SP 2103 C is a barefoot material, so it doesn't contain slip and antiblock additives.

Additional solutions:

Toppyl SP 2400 F: the interlayer delamination method

For applications where the integrity of the seal layer is extremely important, LyondellBasell has recently developed a new *Toppyl* grade called SP 2400 F. This *Toppyl* grade is based on PB-1 technology that allows packaging to open easy via interlayer delamination. Customers use *Toppyl* SP 2400 F as the second layer of a multi-layered film structure, containing five or more layers, produced via blown film or cast film extrusion technology.

This grade provides an average peel force of ~ 5 – 6 N/15mm before film lamination [*Results measured with internal LYB test method, (non-laminated blown film against non-laminated PE blown film based on ASTM D882-90) in combination with superior optical performance.] The main application area is for the preparation of lidding films that have to be used in combination with PE, or with PE laminated trays.

Toppyl SP 2300 F: the solution for non-polyolefin substrates

This grade has been recently developed by LyondellBasell to satisfy those customers that need easy peel solutions suitable for non-polyolefin trays. *Toppyl* SP 2300 F offers the customers a seal-peel solution for a broad range of substrates like: APET, PS, PVC, PP and PE. *Toppyl* SP 2300 F also provides lock-seal once sealed to itself. Customers report that film produced with *Toppyl* SP 2300 F offers good optical properties and it could be used in a wide range of sealing temperatures.

Depending on the substrate used, the use of *Toppyl* SP 2300 F results in different peel forces (*Results measured with internal LYB test method, non-laminated blown film against non-laminated PE blown film based on ASTM D882-90).

Application examples:

Toppyl grades have been successfully used in the seal peel film market for over 30 years. During this time, customers have introduced this material into a broad variety of applications. The easy use of PB-1 in all film extrusion technologies in conjunction with the broad range of available PB-1 grades, has allowed customers to modulate and fine tune their film structures according to the final application requirements.

The main application segments today are in flexible packaging and lidding film for rigid trays where the peelable film is laminated. Customers report that the use of PB-1 based film achieves very good results for the packaging of slice cheese and meats, fresh pasta, tofu, pizza, "ready-to-eat" meals, yogurt cups, smoked salmon, pet food, sandwich packs and hygiene packaging.

Vacuum packaging is also another important segment where the use of PB-1 products has enabled customers to develop a wide range of film structures which typically are used for the safe packaging of coffee, peanuts, vacuum rice, powder milk, meat packaging (e.g. sausages) and cheese packaging.



PB-1 technology has also been successfully used by customers in the production of easy peel bags and pouches. Typical applications in this segment are: rice packaging, biscuits/cookies, cereals, coffee, coffee pads packaging, lap seal applications.

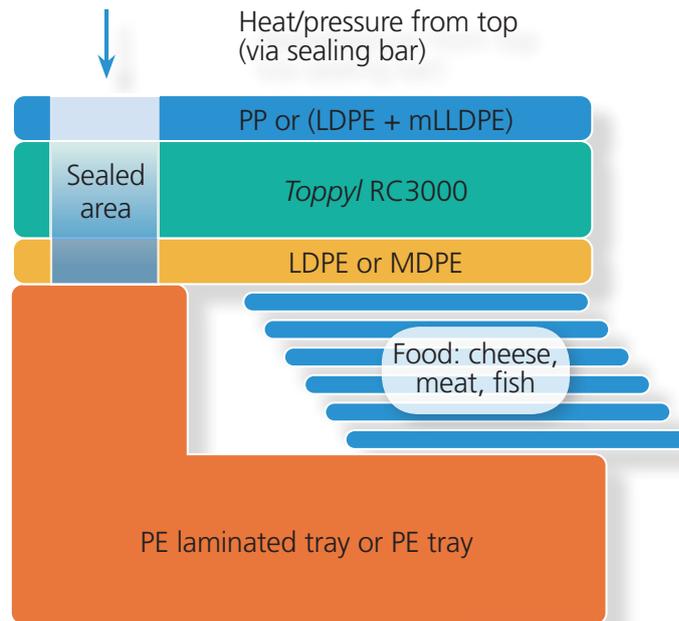
Toppyl RC3000: the LyondellBasell solution for seal peel reclosable packaging



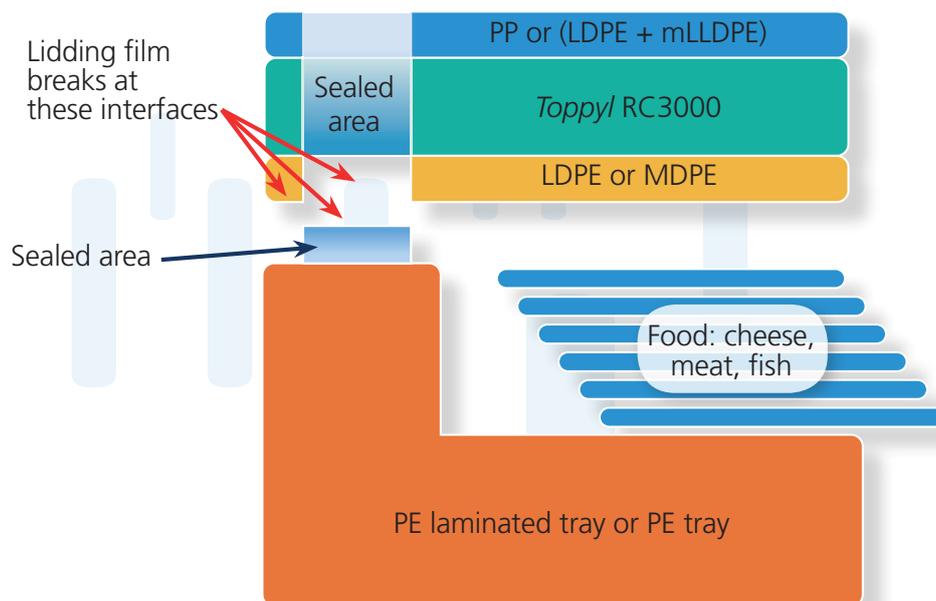
How many times have we tried opening a tray with slices of ham or cheese and we were not able to preserve all the product in the packaging? All the time we are faced with the same question: How can we keep the remaining food fresh for the next time?

Part of the answer to this question is *Toppyl* RC3000, the latest addition to the *Toppyl* family. This new LyondellBasell grade allows the production of lidding film for PE trays that could open easily and reclose tightly, without re-sealing.

Toppyl RC3000 offers a polyolefin based reclosable solution. Customers use this product in blown film technologies with standard PE processing conditions. In multilayer co-ex blown film, *Toppyl* RC3000 is used in the layer of the structure that is right next to the sealing layer.



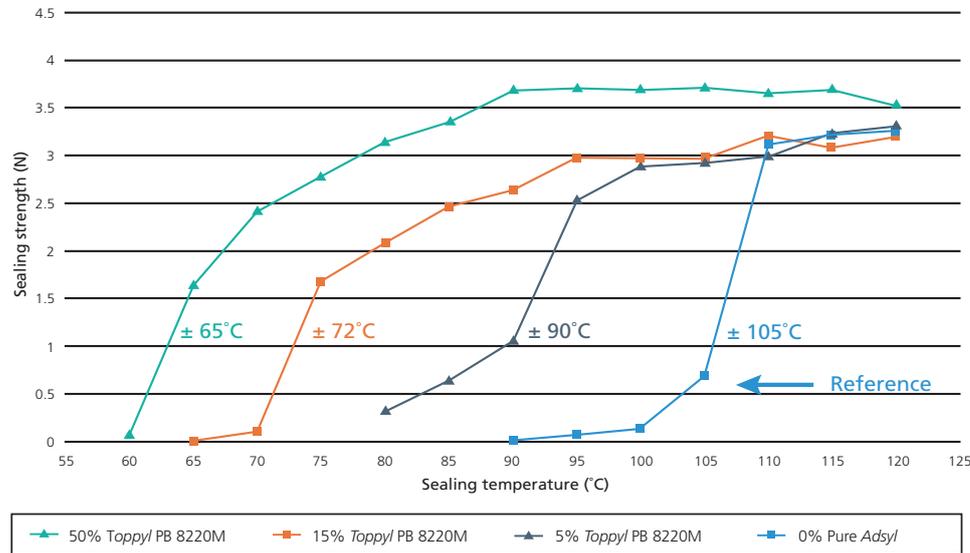
It works for interlayer delamination peeling.



Customers report that the film produced with *Toppyl* RC3000 is very transparent, which allows the consumer to identify the product inside the packaging, providing a perception of freshness and safety of the food.

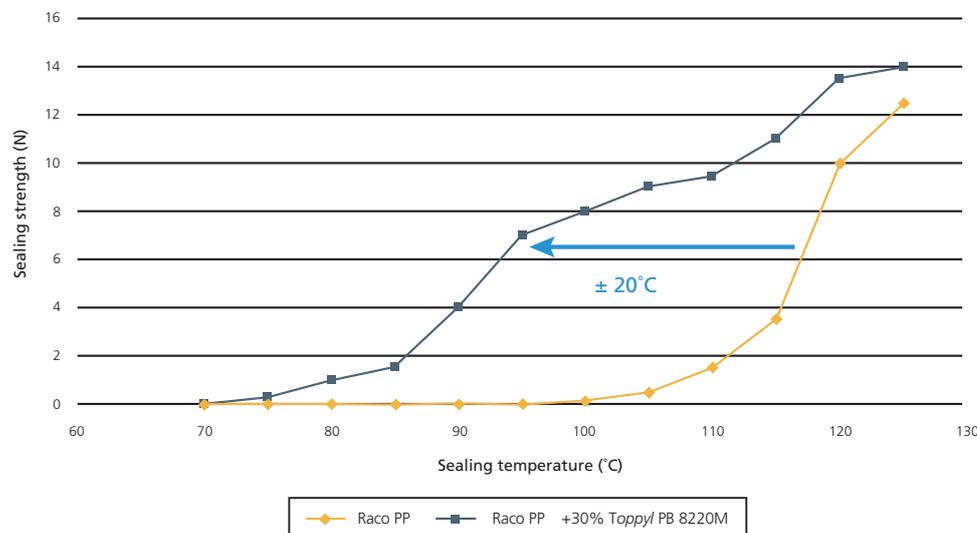
Use of PB-1 as a modifier of Seal Initiation Temperature for BOPP and Cast PP Films

Polybutene-1 is fully compatible with Polypropylene and, to obtain a homogenous and monophasic compound, could be blended in a variety of ways.



Due to this product feature, *Toppyl* PB 8220M is used by customers to modify the sealing properties of PP based films. A typical customer example is the reduction of the seal initiation temperature (SIT) of BOPP sealing layers without compromising on the transparency of the film. Shown left is the effect of adding *Toppyl* PB 8220M to *Adsyl* 5C39F in the sealing layer of a film structure to further tailor the SIT.

Results measured according to Internal LYB test method



Customers have also added *Toppyl* PB 8220M to Cast Polypropylene (CPP) film structures, where it can be added as a building block to the sealing layer of the film structure to lower the SIT, as shown to the left, where a Polypropylene Random is modified with 30% of *Toppyl* PB 8220M.

Laboratory comparison measured on 30 micron CPP film - Sealing conditions: 1.5 kg/cm², 0.5 seconds Raco PP: high C2 modified material

Several BOPP and PP applications have been developed by LyondellBasell customers where *Toppyl* PB 8220M is successfully used to lower the SIT:

- Bread packaging
- Snack Food packaging
- Pasta & rice packaging
- Ice cream packaging



Koattro resins – a new high performance plastomer family

In recent years, LyondellBasell has developed and industrialized a new family of high performance plastomers based on Butene-1, called *Koattro*.

Being based on Polybutene-1, *Koattro* plastomers are available in pellet form and are fully compatible with PP. LyondellBasell offers two main *Koattro* grades:

Koattro KT AR 05: this grade is produced using the traditional Ziegler-Natta catalyst technology

Koattro KT MR 05: this grade is produced using Metallocene catalyst technology

Koattro KT AR family

Key Features:

- "High" Melting Point (114°C)
- Compression set (45-50%)
- Softness and / or Flexibility

Koattro KT AR 05

MFR (190°C, 2.16kg)	0.5 g/10 min
Density	0.89g/cm ³
Flexural Modulus	25 MPa
Tensile elongation at break	> 400%
Izod, notched (23°C)	NB
Izod, notched (-20°C)	5.1 kJ/m ²
Shore A	77

Koattro KT AR 05 in combination with C4 LLDPE provides equal or better impact properties when compared with C8 LLDPE

Koattro KT MR family

Additional Key Features:

- Improved cold impact properties
- Improved flexibility
- Improved optical properties

Koattro KT MR 05

MFR (190°C, 2.16kg)	1.3 g/10 min
Density	0.87g/cm ³
Flexural Modulus	< 10 MPa
Tensile elongation at break	> 700%
Izod, notched (23°C)	NB
Izod, notched (-20°C)	NB
Shore A	60

Customers report that the use of *Koattro* in PP film provides an improvement in terms of flexibility, elasticity, optical properties, impact resistance, less stress whitening, breathability, and toughness. Furthermore, the following sealing properties are improved: hot tack properties, seal integrity, and seal strength.

The above key features open a wide range of potential applications in the film and extrusion segments. Some application examples are: protective film, polyolefin based cling film, elastic film, breathable BOPP and interlayer blocking film.





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