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LyondellBasell Polybutene-1 grades

Shaping what comes next in …seal peel and reclosable packaging

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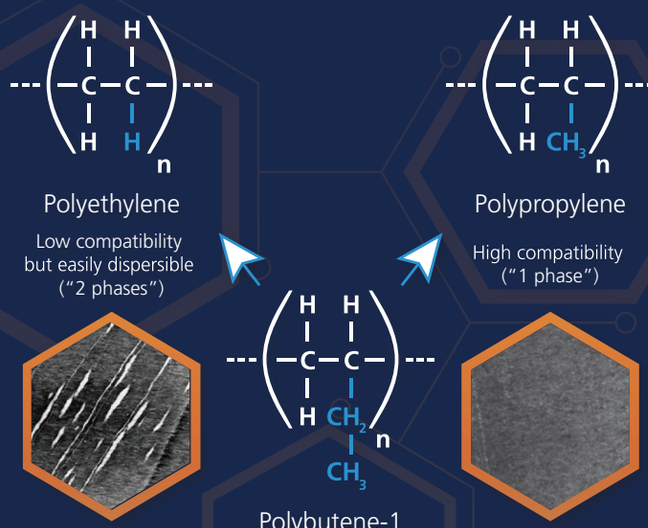
LyondellBasell is one of the world's largest plastics, chemical and refining companies. Around the globe, wherever the quality of life is improving, LyondellBasell products are likely there. These products are the structural building blocks of countless goods – numerous products which make our lives 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 dispersable in Polyethylene.

Moerdijk Plant



TEM pictures (Internal LYB test method)

Amazing Chemistry…for food packaging

Consumers have a number of requirements towards food packaging. It needs to support their busy lifestyles and allows for the protection of ready-to-eat meals, it also needs to allow for re-sealing of any packed food item once the desired amount of food have been removed. But last but not least, 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 today a wide range of Polybutene-1 grades that are each offering 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* SP2400F for interlayer delamination: used for PE film application
- *Toppyl* SP2300F for no 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.

PB-1 Technology or the so called “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
PB0110M	0.4	128	Retort up to 121°C	General use	General use	General use
PB8640M	1.0	114	General use	General use	General use	General use
PB8340M	4.0	114	Improved optics	General use	General use	General use
DP8220M	2.5	97	Improved optics	-	-	-

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

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.

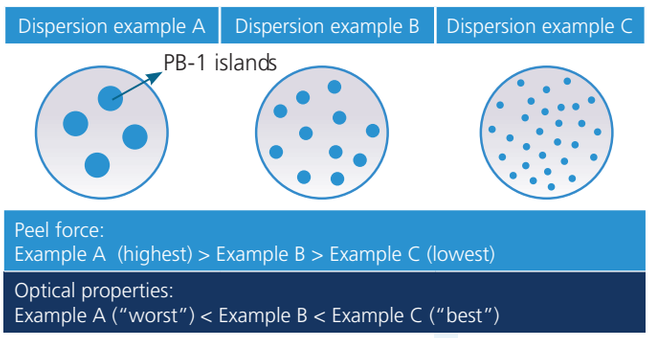
Influence of PB-1 concentration

Binary blend	**Peel-Force (*)**
Lupolen 2420H + 10% PB8640M	5.0 N/15mm
Lupolen 2420H + 15% PB8640M	3.0 N/15mm
Lupolen 2420H + 25% PB8640M	1.5 N/15mm

The higher the PB8640M concentration, the lower the peel force.

Lupolen 2420H: LDPE, MFR 1.9, density 0.924
(*) Results measured with Internal LYB test method (seal peel layer against itself)

Effect of dispersion quality



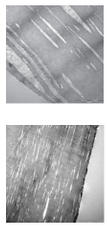
Peel force:
Example A (highest) > Example B > Example C (lowest)

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% PB0110M (MFR 0.4)	4.9 N/15mm
Lupolen 2420H + 15% PB8640M (MFR 1)	3.0 N/15mm
Lupolen 2420H + 15% PB8340M (MFR 4)	1.6 N/15mm



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

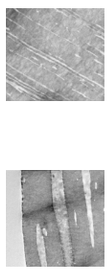
The higher the PB8640M concentration, the lower qthe peel force.

Lupolen 2420H: LDPE, MFR 1.9, density 0.924 TEM pictures PB0110M & PB8640M (internal LYB test method)

(*) Results measured with Internal LYB test method (seal peel layer against itself), based on ASTM D882-90

Influence of Melt Flow Rate of LDPE (binary blend)

Binary blend	Peel-Force (*)
Lupolen 2420F (MFR 0.75) + 15% PB8640M	1.6 N/15mm
Lupolen 1806H (MFR 1.6) + 15% PB8640M	3.0 N/15mm
Lupolen 2420H (MFR 1.9) + 15% PB8640M	3.0 N/15mm
Lupolen 2420K (MFR 4) + 15% PB8640M	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 (seal peel layer against itself), based on ASTM D882-90

Influence of PE type in the seal peel layer

Binary blend	Peel-Force (*)
LDPE (MFR 1.9) + 25% PB8640M	1.5 N/15mm
C4-LLDPE (MFR 2.8) + 25% PB8640M	6.0 N/15mm
LDPE (MFR 1.9) + 15% PB8640M	3.0 N/15mm
HDPE (MFR 0.9) + 15% PB8640M	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 (seal peel layer against itself), based on ASTM D882-90

However 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 using two components, 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 ternary blend with three components may offer the desired results. Please consults our AD/TS team at pb1_specialties@lyondellbasell.com for more details)

Toppyl Technology or the "ready-to-use" approach

LyondellBasell offers five *Toppyl* grades: two products in the *Toppyl* B range of products 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 the entire 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
SP 2000 B	2*	PE & itself	S, AB		X			
SP 2001 B	0.8*	PE & itself	S, AB		X			
SP 2101 C	8**	PP & itself	S, AB	X	X	X	X	X
SP 2102 C	6.5**	PP & itself	S, AB		X	X	X	X
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, they work against PE substrate and against themselves. Customers use *Toppyl* B grades for blown film conversion processes to create multilayer PE-based or barrier film structures.

LyondellBasell has developed two *Toppyl* B grades:

- *Toppyl* SP2000B:

– This grade is used for "medium" peel force (± 4 N/15mm before film lamination*) (*Results obtained with internal test method, based on ASTM D882-90) and it provides "medium" hot tack properties. *Toppyl* SP2000B is fully formulated with slip and antiblock agents.

- *Toppyl* SP2001B:

– This grade is used for "low" peel force (± 2 N/15mm before film lamination*) (*Results obtained with internal test method, based on ASTM D882-90). *Toppyl* SP2001B is fully formulated with slip and antiblock.

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

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

LyondellBasell grouped products used in seal peel technology for PP film in the *Toppyl* C range. 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* SP2101C

– This grade could be used by customers for heat-sterilizable applications, which require an average peel force ± 3 – 4 N/15mm before film lamination (*Results obtained with internal test method, based on ASTM D882-90). *Toppyl* SP2101C is fully formulated with slip and antiblock agents.

- *Toppyl* SP2102C

– This grade could be used by customers for non-heat sterilizable applications; the average peel force of this grade is ± 3- 4 N/15mm before film lamination (*Results obtained with internal test method, based on ASTM D882-90). *Toppyl* SP2101C is fully formulated with slip and antiblock agents.

- *Toppyl* SP2103C

– In case customers need a seal peel solution to PP film for heat-sterilizable applications with a higher peel force compared with *Toppyl* SP2101C, LyondellBasell has developed *Toppyl* SP2103C. The average peel force of *Toppyl* SP2103C is around ± 6 – 8 N/15mm before film lamination (*Results obtained with internal test method, based on ASTM D882-90). *Toppyl* SP2103C is a barefoot material, so it doesn't contain slip and antiblock additives.

Additional solutions:

Toppyl SP2400F: the interlayer delamination way

For application where the integrity of the seal layer is extremely important, LyondellBasell has recently developed a new *Toppyl* grade called SP2400F. This *Toppyl* grade is based on PB-1 technology that allows packaging to open easy via interlayer delamination. Customers use *Toppyl* SP2400F 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 obtained with internal test method, based on ASTM D882-90) in combination with superior optical performance. The main application area is for the preparation of lidding film that have to be used in combination with PE or PE laminated trays.

Toppyl SP2300F the solution for non-polyolefin substrates

This grade has been recently developed by LyondellBasell to satisfy those customers that need easy peel solution suitable for non-polyolefin trays. *Toppyl* SP2300F offers the customers a seal peel solution for a broad range of substrates like: APET, PS, PVC, itself, PP and PE. Customers report that film produced with *Toppyl* SP2300F offering good optical properties and it could be used in a wide range of sealing temperature

Depending on the substrate used, the use of *Toppyl* SP2300F results in different peel forces (*Results obtained with internal test method, based on ASTM D882-90 before film lamination):

- APET: peel force ~ 5 – 6 N/15mm
- PS: peel force ~ 7 – 8 N/15mm
- PVC: peel force ~ 3 – 4 N/15mm

Application examples:

PB-1 grades are successfully used in seal peel film segment for over 30 years. During this long time frame, customers have introduced this material into broad variety of applications. The easy use of PB-1 in all the film extrusion technologies, the broad range of PB-1 grades and the excellent technical support of LyondellBasell AD/TS team 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 (seal-peel to themselves) lid film for rigid trays where the peel-able 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.

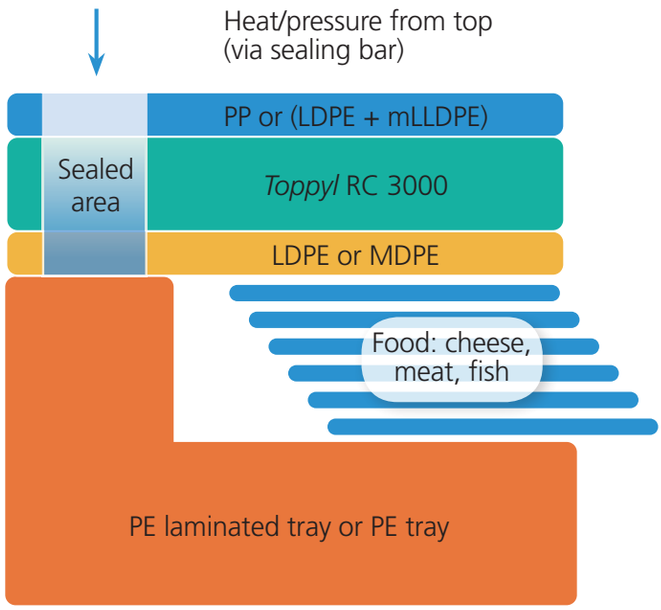
PB-1 technology has been also successfully used by customers in the production of for easy peel able bags and pouches. Typical applications in this segment are: rice packaging, biscuits/cookies, cereals, coffee, coffee pads packaging, lap seal applications

Toppyl RC3000 the LyondellBasell solution for seal peel reclosable packaging

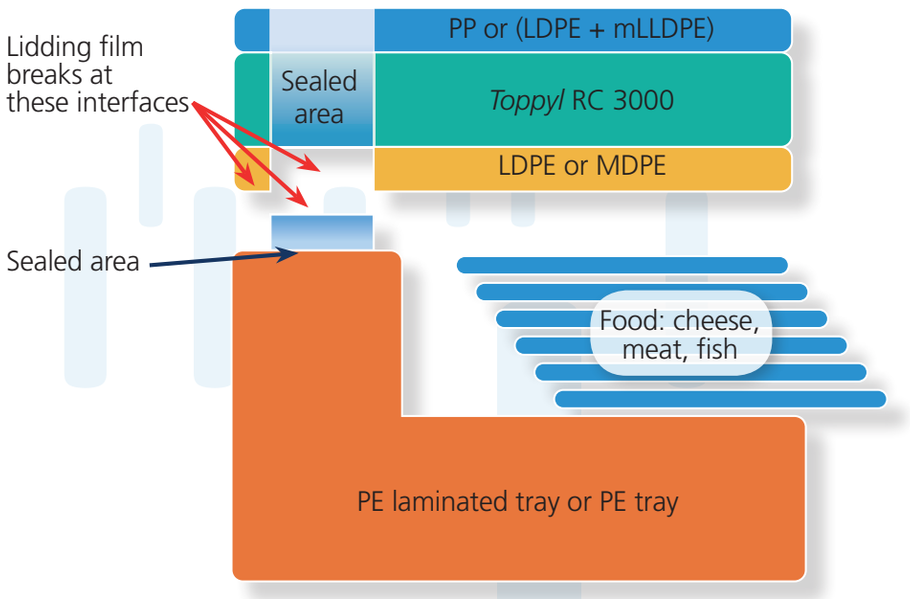
How many times we opened a try with slices of ham or slices of cheese and we were not able to eat all the product in the packaging? And all the time we are faced with the same question: How can I keep the remaining food fresh for the next time?

Part of the answer to this question is *Toppyl* RC3000, this latest addition to the *Toppyl* range. 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 solutions; 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.

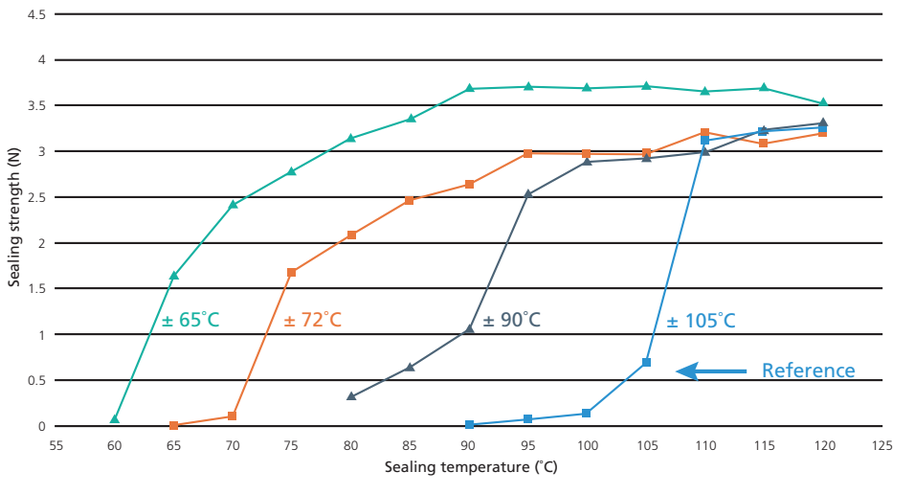


Customers report that the film produced with *Toppyl* RC3000 is very transparent, which allows the consumer to identify the product inside the packaging, providing a perception of freshness and safety of the food.

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

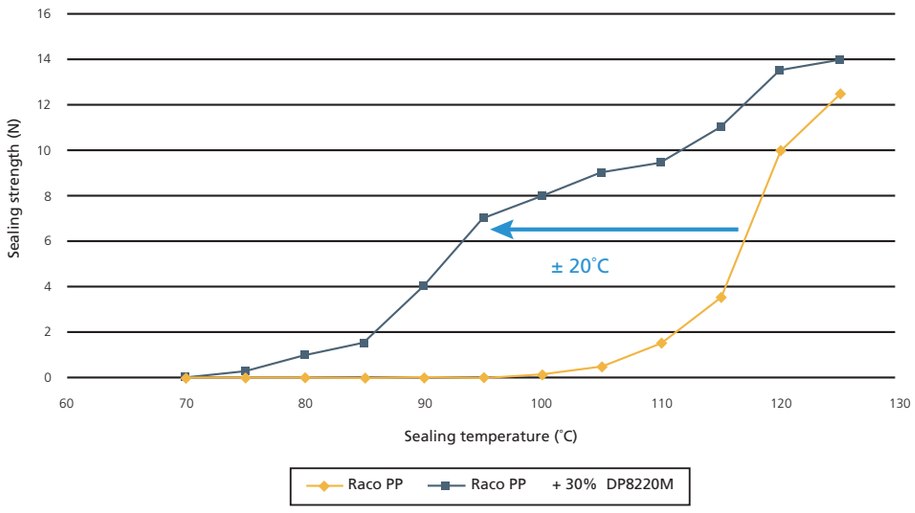
Use of PB-1 as modifier of Seal Initiation Temperature for BOPP and Cast PP Films

Polybutene-1 is fully compatible with Polypropylene and to obtain a homogenous and monophase compound, could be blended with this polymer in a variety of ways. The DP8220M grade consists of a Random Copolymer with a melting temperature of 85 °C (Tm2).



Due to this product feature, DP8220M 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 DP8820M to *Adsyl* 5C39F in the sealing layer of a film structure to further tailor the SIT.

Results measured according to Internal LYB test method



Also customers have added this product to Cast Polypropylene (CPP) film structures, where DP8220M can be added as a building block to the sealing layer of the film structure to lower the SIT as is shown on the left, where a Polypropylene Random is modified with 30 % of DP8220M.

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 application have been developed by LyondellBasell customers where DP8220M 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 the recent years, LyondellBasell has developed and industrialized a new family of high performance plastomers based on Butene-1, called *Koattro*. These products are characterized by several unique properties such as transparency, softness, flexibility (without use of plasticizers) and elasticity (without any cross-linking).

Being based on Polybutene-1, *Koattro* plastomers are fully compatible with PP and are available as free flowing pellets.

LyondellBasell offers two main *Koattro* grades:

Koattro KT AR05: this grade is produced using the traditional Ziegler-Natta catalyst technology

Koattro KT MR05: 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 AR05:

MFR (190°C, 2.16kg)	0.8 g/10 min
Density	0.89g/cm3
Flexural Modulus	25 MPa
Tensile elongation at break	> 400%
Izod, notched (23°C)	NB
Izod, notched (-20°C)	5.1 kJ/m2
Shore A	77

Koattro KT MR family

Additional Key Features:

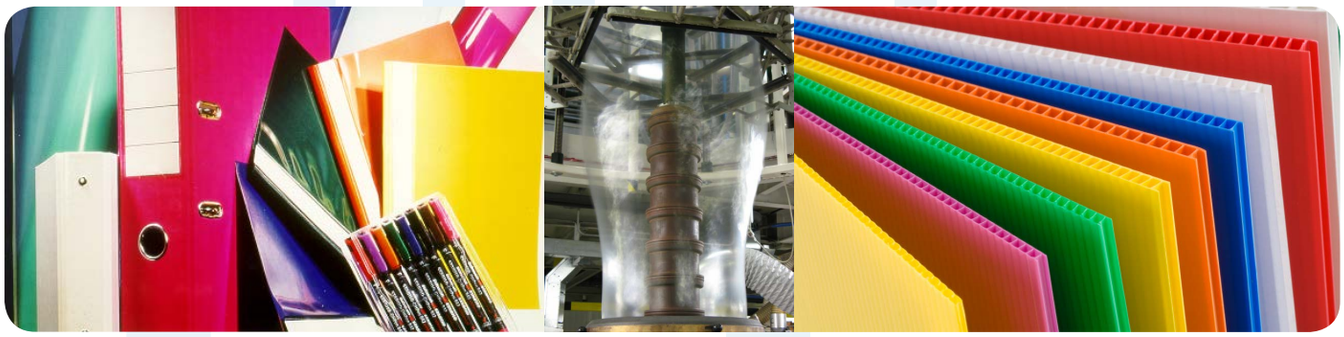
- Improved cold impact properties
- Improved flexibility
- Improved optical properties

Koattro KT MR05:

MFR (190°C, 2.16kg)	1.0 g/10 min
Density	0.87g/cm3
Flexural Modulus	< 10 MPa
Tensile elongation at break	> 700%
Izod, notched (23°C)	NB
Izod, notched (-20°C)	NB
Shore A	60

Koattro plastomers offer a broad variety of PP film modification possibilities. Customers use this resin in monolayer or multilayer film structures (3 layers or more) and the typical required *Koattro* concentration varies between 10 – 30%. Customers report that the use of *Koattro* in PP film provides an improvement in terms of flexibility, elasticity & softness, very good optical properties and good transparency, an increase of the film impact resistance and toughness, also the sealing properties are improved like seal integrity & seal strength increase up to > 100%, Hot tack properties, less stress whitening and improved film breathability.

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



From regulatory point of view it is important to underline that the products of the *Koattro* AR product family are EU Food Contact compliant but not FDA compliant. The *Koattro* MR product family is EU Food Contact compliant and the FDA compliance evaluation is in progress.

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