



BindEX™ speciality polymer **– for multilayer films (E-189)** **PRODUCT APPLICATION NOTES**

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INTRODUCTION

Packaging films play the dual role as an attractive container for products, as well as preserve the contents until use. In the latter role, packaging is supposed to have adequate mechanical and barrier properties to retain product integrity as well shelf life during transit and storage. From performance and cost considerations, multiple materials may be required to be used in multilayer structures, to meet diverse requirements like mechanical strength, printability and barrier to moisture, oxygen, odour etc.; runnability on FFS machine, heat sealability and so on. Most of the time, such properties come from chemically dissimilar materials such as paper or aluminum foil or speciality polymers like nylon, polyester or EVOH, combined with commodity polymers such as polyethylene and polypropylene.

Multilayer film structures made by lamination of the different substrates, using solvent-based or solvent-less adhesives, is a well-established practice in trade. However, co-extrusion of multiple polymers into a multilayer film in a single operation has revolutionized flexible packaging application. Some of the obvious advantages of Co-extruded multilayer films over similar laminated structures are given in the table below.

#	Characteristics	Laminated MLF	Co-ex MLF
1.	Production Time	Long- Individual Films to be made first and then laminated, sometimes in multiple passes.	A single operation.
2.	Production wastage	Higher- each operation of film making and lamination has wastage in it.	Wastage typically of a single film making operation.
3.	Product Manufacturing Cost	Higher- Cost of making each substrate and each lamination step involves wastage of film and adhesives adding to overall product cost	Lower processing cost. However, capital cost is higher.
4.	Optimum material usage	Unable to use thin individual layers due to manufacturing and handling limitations.	Very thin layers also possible to use since they get combined and supported in extrusion die.
5.	VOC concerns	Solvent based adhesives can render the film unsuitable for food packaging	Not a concern.

Co-extruded multilayer films can be made in both blown and cast varieties in oriented or non-oriented versions. To be able to combine chemically different materials in all the mentioned structures, we need to use a tie layer in-between.

BindEX™ E-189 AS TIE LAYER

Starting with minimum of 5-layers, structures with higher number of layers are made using 3 or more extruders. Higher number of layers affords flexibility of using materials more economically for a given set of mechanical and barrier properties.

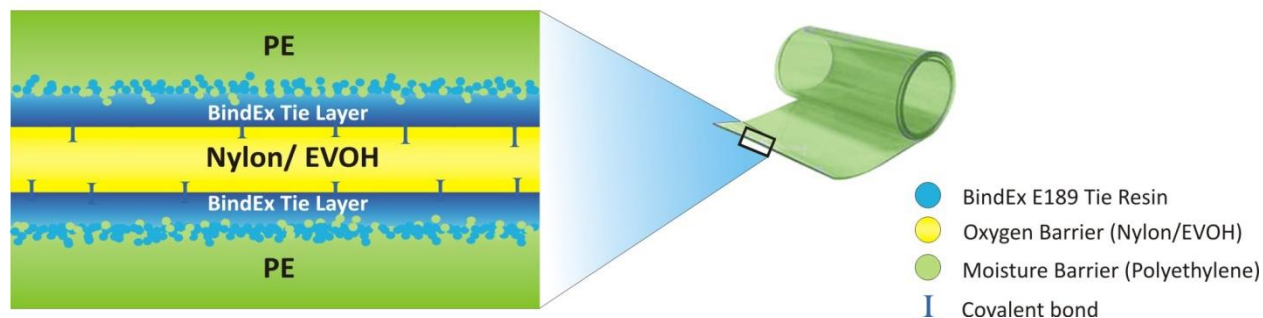


Fig. 1: Schematic Diagram of multilayer coextruded film of Nylon and Polyethylene using BindEX™ tie layer resin.

BindEX™ E-189 is a maleic anhydride grafted polyethylene adhesive resin from Pluss. It is the recommended tie layer material for making multilayer films in conventional co-extrusion equipment. It has suitable pendant functional groups to bond to polar polymer layer on one side, while its polyethylene backbone has natural affinity with the non-polar polyolefinic layer on its other side in the multilayer structure. BindEX™ E-189 can be used to combine Nylon 6, Nylon 66, and EVOH for gas barrier properties with variety of HDPE, LLDPE, LDPE & PP grades for different functions like sealability, moisture barrier and providing bulk to the structure. It can be used in its pure form as well as in diluted form, depending on the degree of inter-layer adhesion required in the end-application. Dilution level can vary from 50-80% with a polyolefin compatible with the adjacent polyolefin layer in the multilayer structure.

Tie layer Mechanism

Tie layer material is so extruded as to lie between polar barrier nylon or EVOH and non-polar polyolefin material. Maleic anhydride groups present in BindEX™ chemically react with amine groups of nylon or hydroxyl groups of EVOH at processing temperatures, on one side, while polyethylene part of BindEX™ adheres naturally with polyethylene on the other side, thus giving a composite structure. At processing temperature, strong adhesion between tie layer molecules and the barrier polymer molecules results, due to formation of covalent bonds between the anhydride functional group on tie layer resin and hydroxyls (-OH) or amine (-NH₂) functional groups of EVOH or nylon barrier layer, as shown in the diagram below.

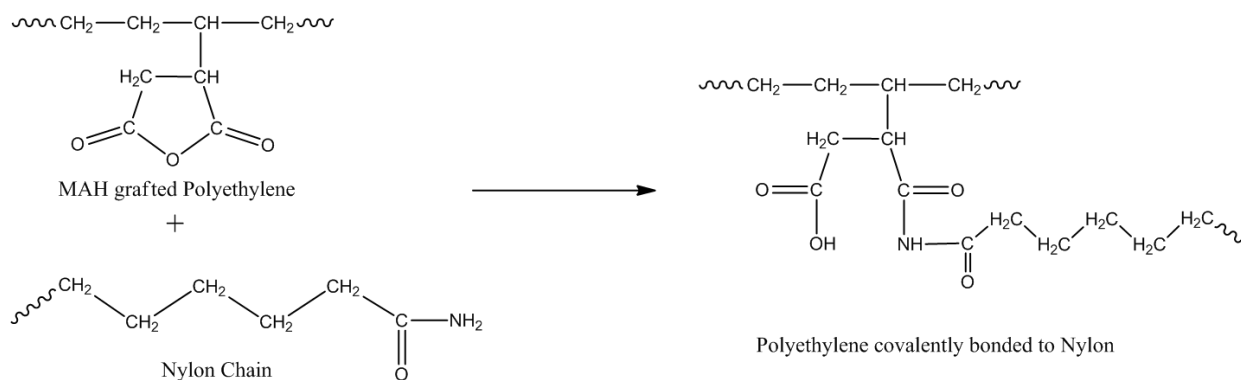


Fig. 2: Reaction of Maleic Anhydride grafted Polyethylene with Nylon

On the other side, polyolefinic backbone chains in BindEX™ E-189 are able to diffuse into compatible polyolefinic chains of the moisture barrier or sealant layer and form strong bond due to chain entanglement, as the two layers co-crystallize in cooling.

For chain entanglement to occur, the adjacent materials must be in the melt state, be physically and chemically compatible and have sufficient contact time. Diffusability of the materials is related to the wettability of the materials. If the resins have similar surface energies and are compatible, the resins are considered to have good wettability. The polar functional groups in BindEX™ E-189 facilitate its wetting of the barrier layer.

Factors affecting inter-layer adhesion

T- peel adhesion strength is generally measured as g/25mm width of the film sample. Inter-layer adhesion strength in a coextruded multilayer structure depends on various factors such as:

1. Proportion of reactive functional groups in tie layer composition.
2. Tie layer thickness: Higher tie layer thickness yields higher adhesion strength up to a limit and then it levels off.
3. Processing conditions: Adhesion is clearly a factor of processing temperature during film making. Depending on the barrier polymer used, the temperature can be high or low. Reaction between anhydride functional groups on BindEX™ E-189 and amino or hydroxyl groups of nylon or EVOH barrier layer, is faster at higher temperature. Inter-layer adhesion can be increased by increased melt and die temp, due to enhanced rate of chemical reaction and rate of diffusion leading to chain entanglement. However, temperature is limited by polymer degradation which may otherwise cause gel formation, colour, black specks or loss of mechanical properties.
4. Storage Conditions after film production: Adhesion strength after co-extrusion initially increases with time, then levels off. It may deteriorate over a period of time, depending on storage conditions, among other factors. Exposure to heat and significant levels of moisture have particularly detrimental effect. It is recommended that T- peel adhesion strength is measured only 72 hours after extrusion.
5. In adhesion test, the site of failure should be observed carefully. Sometimes the barrier resin may fail during testing cohesive failure, rather than the adhesive bond.

Optimizing performance-to-cost ratio

While we may want maximum adhesion in a multilayer structure, it would mean using a thicker tie-layer or a resin with higher proportion of reactive chemical groups. Both these options tend to increase cost. The preferred approach then is, to figure out the minimum adhesion required for the given application environment and choose layer thickness as well as dilution level. Safety margin should be added to account for machine inconsistency in maintaining tie-layer thickness variation.

Property Chart of BindEX™ E-189 - Typical Specification:

Property	Unit (SI)	Test Method	Observed values
Physical			
Density	g/cc	ASTM D792	0.890
Melt flow Index (@190 °C/2.16 Kg)	g/10 min	ASTM D1238	1.3
Bonded MAH	%	Pluss Internal Method	Medium
Yellowness Index	-	ASTM E-313	3.0

Mechanical			
Tensile Strength (Break)	MPa	ASTM D638	11.0
Elongation (Break)	%	ASTM D638	700.0
Tensile Modulus	MPa	ASTM D638	38.0
Durometer Hardness			
Shore D		ASTM D 2240/ISO868	40
Shore A		ASTM D2240	98
Thermal			
Melting Temperature	°C	DSC	114 °C

HANDLING & STORAGE

BindEX™ E-189 is packed in moisture-proof bags and should be stored in a dry, cool and well-ventilated area protected from direct sunlight. Improper storage conditions may cause deterioration, and can adversely affect physical properties of the product.

BindEX™ resins should be stored in a cool, dry place. When stored properly, BindEX™ E-189 resins have a shelf life of at least 12 months. They should be stored in closed bags and not subjected to high levels of moisture. Drying of BindEX™ resins is generally not required. In case the need be, it should be dried in good temperature controlled oven or hopper dryer at 80± 5 °C for at least 2hours.

PROCESSING GUIDELINES:

BindEX™ E-189 can be processed on most of the standard extrusion equipment designed to process conventional polyolefins. Maximum processing temperature should not exceed 280 °C. In case of shutdown, care should be taken to leave extruder filled with polymer other than BindEX™; otherwise gels may appear in subsequent production. For the tie layer extruder shutdown, best practice is to use one of the polyolefin components of the film under production. In case of short duration stoppage, ideally the extruder should be kept running at minimum possible throughput to avoid generation of gels.

Extrusion temperatures for BindEX™ E-189 are typically kept between 195-215 °C.

A typical case study

Machine type: Windsor-Kuhne make 5-extruder, 5-layer coextruded blown film plant

Total Film Thickness: 100 - 105 µm;

Output: 200 Kg/hr.

Film Structure: PE (41µm)/Tie resin (5µm)/Nylon-6 (8µm)/Tie resin (5µm)/PE (41µm)

Materials Used

- i. PE used in outer and inner layers was film extrusion grade (MFI: 1.0 g/10min @ 190 °C/2.16 Kg),
- ii. Nylon-6 used was film extrusion grade Ultramid B40L from BASF
- iii. Tie resin was BindEX™ E-189 diluted with 80% Sabic LLD 118 NJ

Composition

LAYER →	Outer Layer (PE)	Tie Layer BindEX™ E-189 + Sabic LLD 118 NJ (20 : 80)	Barrier Layer (Nylon 6)	Tie layer BindEX™ E-189 + Sabic LLD 118 NJ (20:80)	Inner Layer (PE)
Thickness (µ m)	41 – 42	5 – 6	8 – 9	5 – 6	41 – 42
Screw RPM	93	29	31	29	93

Process Parameters

Extruder	Z1 (Set/Act.)	Z2 (Set/Act.)	Z3 (Set/Act.)	Z4 (Set/Act.)	CA-FL (Set/Act.)	ADZ (Set/Act.)	Current	Screw RPM
Inner	195/163	225/225	225/225	225/225	230/230	230/230	36.0	93.0
	195/163	225/225	225/225	225/224	230/230	230/230	36.1	93.0
Middle	255/255	255/254	255/254	255/255	255/255	255/255	21.1	31.0
	255/255	255/254	255/255	255/255	255/255	255/254	21.1	31.0
Outer	195/195	215/215	225/225	230/230	231/231	231/231	35.1	93.0
	195/195	215/215	225/225	230/229	231/231	231/231	35.2	93.0
Tie(Inner)	195/195	215/215	-	-	230/230	230/230	13.2	29.0
	195/195	215/215	-	-	230/230	230/230	13.1	29.0
Tie(Outer)	195/195	215/215	-	-	230/230	230/230	11.0	29.0
	195/195	215/215	-	-	230/230	230/230	11.0	29.0
Die	255/255	255/255	255/255	255/255	255/254	200/260		
	255/255	255/255	255/255	255/255	255/255	200/260		

Film Properties

Depending upon the end application of the film, different properties can be tested. Film made in this case study goes for oil packaging. Properties of major importance are film surface, tackiness, waviness, gels, unmolten particles, tensile strength, elongation, heat seal strength and dart impact strength.

S. No.	Film Properties	Unit	Testing Method	Observations
1.	Surface appearance	NA	Visual	No surface defect observed
2.	Tackiness	NA	Manual	No tackiness observed

3.	Gels	NA	Visual	No disruptive gels
4.	Inter Layer adhesion	Kg/25mm	Pluss Method	Layers can't be separated.
5.	Tensile Strength at Break MD/TD	MPa	ASTM D882	25.8/19.8
6.	Elongation at Break MD/TD	MPa	ASTM D882	570 / 545
7.	Dart Impact Strength	Gram	ASTM D1709	390

AVAILABILITY

BindEX™ E-189 tie layer resin is a regular grade of Pluss Advanced Technologies, manufactured at our plant at Bawal, in the state of Haryana, India. BindEX™ speciality polymers are supplied in pre-dried form in 25 Kg (55 lbs) PE lined, HD woven cloth laminated paper bags and 750 Kg (1653 lbs) FIBC's. Depending upon customer's requirement, the bags can be further palletized for dispatch. They should be stored in cool and dry place.

The information given here is meant as a guide to determining suitability of our products for the stated applications. It is based on trials carried out by our laboratories and data selected from literature and shall in no event be held to constitute or imply any warranty. The products are intended for use in industrial applications. The users should test the materials before use and satisfy themselves with regard to contents and suitability in the desired application. Our formal specifications define the limits of our commitment. Recommendation herein may not be construed as freedom to infringe/operate under any third party patents. In the event of a proven claim, our liability is limited only to replacement of our material and in no case shall we be liable for special, incidental or consequential damages arising out of usage of our material. This datasheet is subject to change without notice.