TECHNICAL BULLETIN

USE OF POLYETHYLENE IN FILM LAMINATION

POLINTER

1 Introduction

Polyethylene (PE) is a semicrystalline polymer which is extensively used in many applications due to its properties, cost and easy processability. All polyethylene grades manufactured by POLINTER are polymeric resins with or without antioxidants. Other additives, such as processing aids, slip agents and anti-blocking agents are added to impart specific properties.

Polyethylene resins can be transformed into products by a wide variety of manufacturing techniques, such as film and sheet extrusion, injection molding, blow molding, rotational molding, pipe extrusion and profile extrusion. Film application represents one of the first commercial uses given to polyethylene. Also it is the segment of highest demand in polyethylene market [1]. This bulletin refers to the processes of obtaining multilayer films by extrusion coating, extrusion lamination and adhesive lamination films, where polyethylene grades manufactured by Poliolefinas Internacionales C.A. are present. Several examples of structures of certain applications are also presented here.

2 Extrusion coating, extrusion lamination and adhesive lamination.

Extrusion coating, extrusion lamination and adhesive lamination of substrates are conversion processes which allow obtaining a multilayer structure. In these techniques diverse substrates of different materials are combined to get one film (see Figure 1). Materials involved in these multilayer structures include plastics, paper, cardboard and / or aluminum foil (2).

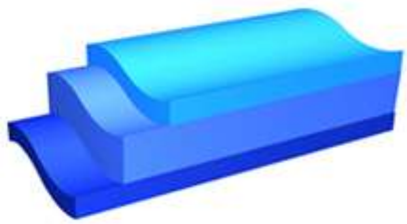

Figure 1. Multilayer Structure.

2.1 Applications

Extrusion lamination and extrusion coating lines are usually tailor-made manufactured to fit customer requirements. These production lines can be configured for a variety of applications such as: liquid packaging, aseptic beverage containers, flexible packaging, toothpaste tubes, medical packaging, industrial packaging, insulating materials for cooking, plastic-coated cloths, and bags for several products such as cement, cereal grains and dry chemicals.

Coating and lamination processes produce a combined substrate whose single layers are very difficult to separate. This substrate (multilayer structure) inherits improved physical properties and barrier protection from each single component.

2.2 Process Description

In the ***extrusion coating process***, a melted polyethylene layer is used as coating onto a continuous substrate through a heated slit die to produce a coated permanent structure [3].

The coated substrate passes between a series of counter-rotating rolls to press the coating against the substrate achieving full contact and adhesion. Figure 2 shows an example of this process with paper/polyethylene coating. [4].

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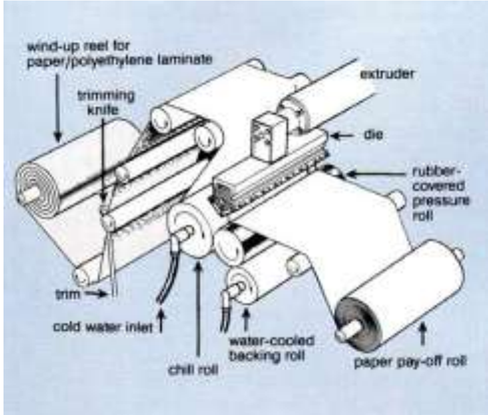

Figure 2. Typical extrusion coating line for paper/polyethylene laminates.

Many substrates, like paperboard, BOPP, PET, aluminum foils, fabrics, metal sheets, and foams are commonly coated by this process.

The ***extrusion lamination process*** is similar to extrusion coating, wherein a layer of molten material is extruded between two substrates. The molten polymer acts as adhesive agent.

Figure 3 shows a sketch of the extrusion lamination process from the combination of two substrates and a layer of a molten polymer.

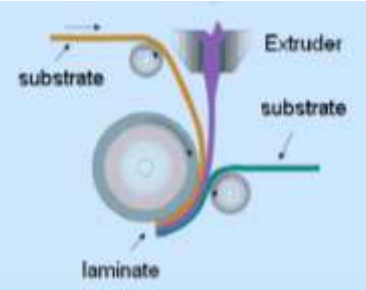

Figure 3. Extrusion Lamination Sketch.

For both processes, substrates and molten material are pressed in a bonding station. This station is composed by series of water-cooled rolls and rubber rolls, where temperature and pressure balance determine the appropriate adhesion level between them.

The final product is rewound as a permanently bonded multi-ply laminated structure.

The ***adhesive laminating process*** is used to join two or more reels of flexible substrates through the bonding agents use. Generally, an adhesive is applied on less absorbent substrate. Then, a second substrate is placed and joined by applying pressure against the first laminate; thereby a multilayer structure is obtained.

This process is mainly used to improve the appearance and barrier properties of the final structure.

The type of adhesive agent used to produce laminates defines the machinery characteristics used for laminate manufacturing. Depending on the adhesive nature, there are many lamination processes, listed below:

- *Wet bonding laminating:* the adhesive is still in liquid form during substrates bonding. It is used in paper/aluminum laminates manufacturing for flexible packaging.
- *Dry bonding laminating:* the adhesive agent is dissolved into liquid (water or solvent) and applied to one substrate, after that it is evaporated in a drying oven. Then, the first substrate is laminated to another substrate using heated rolls and rubber rolls to generate high pressures defining the laminate resistance of the structure (bonding strength).
- *Wax laminating:* the adhesive agent is wax or hot melt which is applied in molten state to one of the two substrates. This process is preferred in paper to paper lamination or aluminum foil to paper laminates manufacturing, and it is widely used on biscuits and baked products packaging.

- *Solventless laminating:* the adhesives used do not contain solvents and they are characterized by being composed of two substances, which are mixed and react with each other to produce a joined laminate through a non-drying process.

2.3 Advantages and disadvantages of laminating processes

Extrusion-based laminating, extrusion coating and adhesive-based film laminating are different manufacturing techniques that converters can use to make a multilayer structure film. The physical properties and performance characteristics of a flexible packaging made by extrusion coating and laminating can be identical to the packaging made by adhesive-based film laminating; most of the final structure components are also the same. So, which technique should be used for a particular product package? The decision is not easy, because of equipment availability, polymer specifications and manufacturing efficiencies are some of the most important variables in this equation [5].

Table 1 shows a comparison of these three multilayer production techniques. Coextrusion process is included as another manufacturing process to obtain this type of films.

Table 1. Comparison of processes.

Advantages	Disadvantages
Extrusion-based Laminating	
Ability to apply a wide variety of films	Medium speeds
Low capital costs	Printing distortions
Low energy consumption	
High thickness	
Superior graphics	
Simple technology	
Extrusion coating	
Inexpensive raw material	Poor gauge control
Improves structure stability	High capital costs
High thickness	Little flexibility in coating types
	High energy consumption
Adhesive-based laminating	
High speeds	High capital costs
Ability to apply a wide variety of films	Medium energy consumption
High thickness	Adhesives required
Excellent print registration	
Graphics protection	
Paper, aluminum and plastics included	
High versatility	
Unlimited structure types	
Film Coextrusion (6)	
Thickness reduction	High capital costs
Costs reduction	High output required
Low steps in manufacturing	Profitable only with "commodities"
Wastes reduction	Surface printing only
Pin holes reduction	High energy consumption
Recycled material in middle layer	

Depending on consumer's requirements, such as easy-open packages, barrier properties, safety, tamper resistance, product efficacy, cost and manufacturing efficiencies, it will be directly determined which process should be chosen. Fortunately, advances in resin technology, new chemistry options in coatings, and improvements in surface modification and sealing methods will enable new high-performance structures that fulfill these challenges.

Oxygen barrier depends upon the materials used in the multilayer structure, that's why the differences between the performance of an adhesive lamination and an extrusion lamination.

As seen in Figure 4, significant improvements in oxygen barrier can be accomplished with the design of a structure by a lamination process by applying a PU-based adhesive laminating instead of an

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extrusion PE-based film laminating. On the other hand, the structure with PU adhesive is more expensive.

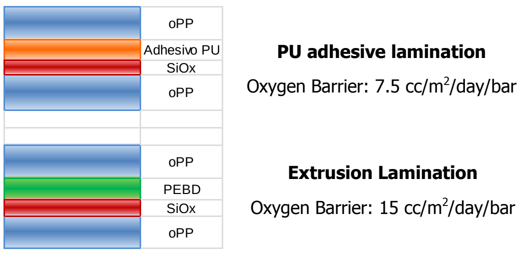

Figure 4. Example of oxygen barriers.

The selection of the process to be used is very complex. It should be based on: available assets, the ability to invest, the converter's core competencies (interests, products, etc.), and market opportunities, which enhance the return on investment

3 Trends and sustainability

The existing packaging is constantly under competitive or manufacturing cost-pressure, which is passed on through the supply chain. The demand is for low-cost substrates and metallized or printed films. One of the ways that some of this cost reduction has been achieved is by down gauging (thinning) the substrate, but with the expectation that the overall multilayer structure performance is not reduced at all [7].

Nowadays, technological advances aimed at developing new technologies in the production of adhesives and new products for lamination, focused on meeting the established sustainability goals, aspect of great relevance currently. Life cycle inventory (LCI) analysis is an example. Evaluating current extrusion lamination products through an LCI analysis makes it possible to measure both energy consumption and CO_2 emission. LCI analysis demonstrates that compared to an extruded lamination, a solventless adhesive package lamination uses 85% less energy and emits 80% less carbon. Select a waterborne adhesive for package lamination and energy consumption drops 50%, while the amount of CO_2 emitted is 40% less. Plus, either of these adhesive lamination solutions saves additional production cost through lower raw material use [8].

4 Polyethylene resins selection

Polyethylene resins are used for many coating applications. It is important to select the proper resin in accordance to the particular end-use requirements. It is up to the package designers, converters, and processors to determine the essential end-use properties that are required and match them with several available resins, keeping in mind other consideration such as cost and processability.

Two properties often used for resin selection are melt flow index (or melt flow rate) and density. These two properties are indicators of extrusion coating performance and finished physical properties. [9]

4.1 ¿How does melt flow index affect the extrusion coating process?

Melt flow index is an indication of polymer's viscosity and an indirect measurement of its molecular weight. As the melt flow index of a resin increases its viscosity decreases. Higher melt flow index resins are generally used for lower coating weights, but it would produce higher neck-in compared to lower melt flow index LDPE grades. Higher melt flow index resins also provide stronger adhesion, improved hot-tack and heat-seal properties, lower back pressures, and less motor loads than low melt index resins. Generally, it is recommended to select the lowest melt flow index resin to do the job for coating extrusion process.

4.2 ¿How does density affect the extrusion coating process?

Density is an indirect measurement of the amount of crystallinity in polyethylene. Polyethylene resins with higher densities have more closely packed molecules and they are stiffer in nature. Molecules in lower density polymers are more loosely packed and the polymer becomes more flexible. Lower density polyethylene resins offer lower seal initiation temperatures and higher abuse resistance. Whereas, higher density polyethylene polymers offer better abrasion, temperature, and grease resistance, lower COF properties, and improved moisture barrier.

Figure 5 shows the impact on the properties of a laminate with the change of MFI (melt flow index) and density polyethylene resins selected.

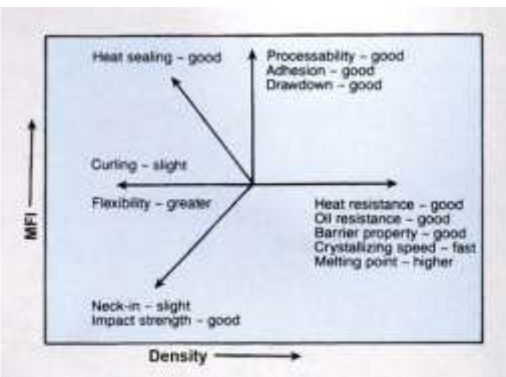

Figure 5. Influence of LDPE MFI and density on processability and laminate properties.

5 Use of polyethylene in laminating – typical laminated films.

Polyethylene coating increase tear resistance and scratch resistance, improves chemical and grease resistances, provides a suitable surface for a heat sealing and a good water and gases barrier. Because of processing challenges, linear low density polyethylene (LLDPE) has had only limited application in extrusion coating and lamination. However, its superior mechanical properties and sealability would be beneficial in many laminate structures. These benefits are likely to be achieved through the use of blends of LDPE and LLDPE. (3).

LLDPE resins have the following superior properties in comparison to LDPE:

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- Excellent sealability.
- Excellent hot tack performance.
- Superior tear resistance.
- Better abrasion resistance.
- Improved adhesion on aluminum and polyester films.
- Low Water Vapor Transmission Rate (WVTR)
- Higher softening point.
- Higher heat resistance.
- Better stretchability.
- Lower suitable thickness.

In Table 2 the most common commercial applications of coating and extrusion laminating processes are summarized.

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Table 2. Typical laminated films. [3]

Construction	Benefits	Application
PE/kraft	Strong, water-proof, heat sealable, low cost with excellent moisture resistance.	From heavy to light duty packaging. Used in frozen foods, agricultural and fishery products and other foods.
PE/kraft/PE /kraft/ PE/kraft	Strong, water and moisture proof, chemical resistant, good gas barrier properties.	Heavy duty packaging only (fertilizer, fodder, cement, agricultural and industrial chemicals, sugar, salt and grains).
PE/high quality paper	Moisture proof, low cost and heat sealable. Good printing surface.	Light duty packaging. Simple moisture proof packaging for pharmaceuticals, moisture-absorbing foods and ready-to-serve foods.
PE/glassine	Moisture-proof, good oil and chemical resistance, semi- transparent and heat sealable.	Light duty packaging for oiled foods, pharmaceuticals, candies and machine parts.
PE/Al foil	Excellent moisture barrier, gas barrier, UV light barrier, outstanding fragrance preservation and heat sealable.	Light duty packaging for pharmaceuticals, candies, photo film packaging, industrial parts and machine parts.
PE/Al foil/high quality paper, PE/Al foil/kraft, Al foil/PE/Al foil, PE/high quality paper/Al foil.	Perfect moisture and gas barrier, chemical resistance, heat sealable, light shading and adaptable for automatic fill packaging. Good printing surface.	Light packaging for moisture-absorbing foods, detergent, candies, photo sensitive paper, photo films, spices and food additives.
PE/Cast polypropylene PE/Oriented polypropylene	Heat and oil resistance, moisture barrier, water proof, see-through and heat sealable.	Light packaging for pharmaceuticals, candies, oiled foods, moisture absorbing foods, table salt, sugar, seasoned foods, preserved foods and medical supplies.
PE/polycarbonate	Outstanding heat and oil resistance, moisture and water proof, outstanding for low temperature properties, see- through, excellent gas barrier and heat sealable.	Light packaging for seasoned foods, preserved foods, frozen foods. Also used in gas-fill-packaging and vacuum packaging for heat sterilisation.
PE/polyester	High strength, water proof, moisture proof, gas barrier properties, outstanding low temperature properties, see- through and heat sealable.	Light packaging for seasoned goods, preserved foods, processed meat, frozen foods, medical supplies and ready-to-serve foods. Also used for vacuum packaging for heat sterilisation and gas-fill packaging.

In the local market assisted by POLINTER (Poliolefinas Internacionales C.A.), polyethylene resins with the highest commercial use in the manufacture of lamination films focus on the following LLDPE grades: Venelene® 11E1, Venelene® 11PG1 and Venelene® 11PG4. In same sense, LDPE grades for this applications are: Venelene® FB-3003, Venelene® FB-7000, Venelene® FA-0240, Venelene® FD-0325, Venelene® FD-0348 and Venelene® LA-0903.

Table 3 lists the major uses of local polyethylene resins in extrusion laminating, extrusion coating and adhesive-based laminating processes. The structures shown correspond to a coating or

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extrusion lamination to substrates separated by a single inclined line, for example, the PE / paper structure; while the double line corresponds to the adhesive-based laminating process, for example PE // BOPP.

Table 3. Typical laminate structures made with POLINTER resins.

Laminate Structure	Venelene® Grade	Application
PE/Paper	LA-0903	Packaging Wrappers
PE/aluminum foil	LA-0903	Labels
PE//LLDPE	LA-0903//11PG1	Diapers Backing
PE (blends)//BOPP	(FB-3003+11PG1)//BOPP	Industrial bags
PE//BOPP	(FA-0240+11PG1)//BOPP	Oat packaging
PE//PE	(FA-0240+11PG1) // (FA-0240+11PG1)	Rice packaging

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