DuPont Packaging & Industrial Polymers

Bonding "Unjoinable" Polymers

WHITE PAPER

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Introduction

Although almost everything consumers buy comes in a package, they seldom give packages a second thought… unless there is a problem. Consumers take a lot for granted in their soon-to-be-discarded packages: convenience, product protection, shelf life, damage resistance and tamper evidence, for example.

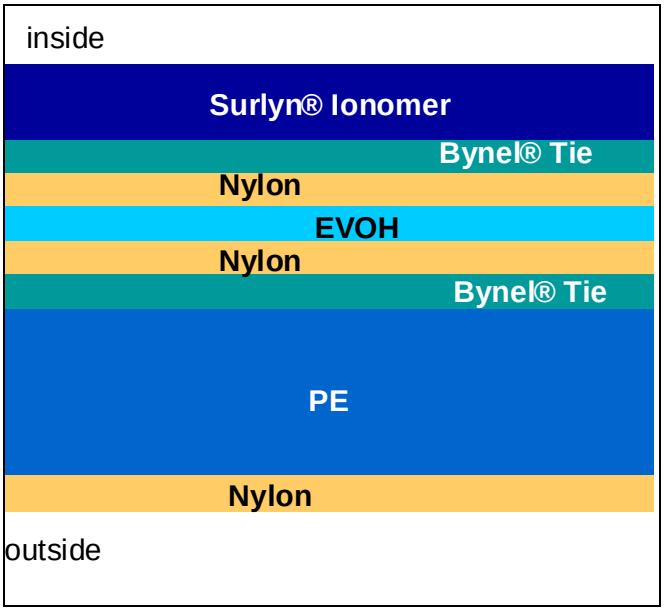
The package must perform on the packager's filling lines, as it moves through distribution, on the store shelf and in the consumer's hands. The diverse requirements throughout the value chain can be met by using multilayer structures containing a variety of polymers to perform different functions or combinations of functions.

Multilayer Packages

Every multilayer package needs a structural polymer that's strong and tough, has the right degree of flexibility or rigidity and provides bulk. This material is frequently the outside layer of the package, so it has to look good, and feel right. In many cases it has to accept high-quality printing, or be laminated to a reverse-printed oriented substrate.

Most film structures are fabricated into a package by some form of heat-sealing of the inside layers to each other along the package perimeter. This polymer must seal reliably on a high-speed package forming and filling line, resist degradation by the product itself and, in the case of food packages, comply with regulatory requirements for food contact. In some cases, an easy-opening seal is an important additional requirement.

Figure 1. Typical Barrier Structure



Food packages often need a highly impermeable gas and flavor barrier to maintain freshness and to extend shelf life. Polar polymers such as ethylene vinyl alcohol or nylon serve that purpose.

Other polymer layers may be added to provide better formability or to improve toughness of the package.

Adhesive layers are essential whenever the different materials in the structure don’t adhere to one another.

Figure 1 shows a typical multilayer structure of a package.

Figure 2. What Sticks and What Doesn’t

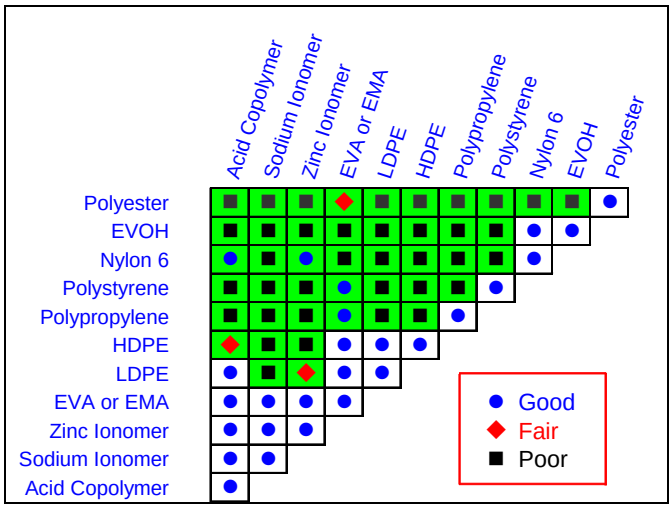


Figure 2 shows a grid of polymers commonly used in packaging. The diagonal at the right of the grid, marked by filled circles, shows good adhesion when polymers stick to themselves. The other filled circles on the grid show dissimilar polymers that bond well to each other. However, much of the grid shows polymer combinations with poor affinity for each other. For example, it is possible to coextrude a polyester with an acid copolymer, but these layers easily separate from each other.

Adhesion Solutions from DuPont

To hold incompatible polymers together, DuPont has developed a variety of solutions to adhesion needs. Most of them are part of the DuPont™ Bynel® family of extrudable adhesive resins. Other DuPont products such as DuPont™ Surlyn® ionomer, DuPont™ Nucrel® acid copolymers and DuPont™ Entira™ coat resins can also act as bonding agents.

The Bynel® portfolio contains more than 50 individual grades using various chemistries and technologies. They are formulated to provide and maintain the adhesion level critical to package integrity at every stage of manufacture and use: film production and converting, package forming, distribution and use by the consumer.

Bynel® can work in film coextrusion processes including cast film, blown film, double bubble and coextrusion coating. Thermal lamination of films containing Bynel® resins is also an option. Rigid extruded product processes using Bynel® include cast sheet, blow molding, tubing and pipe. Bynel® grades for multilayer injection molding and injection stretch blow molding are also available.

The adhesion level in a multilayer structure depends on three factors in addition to the composition of the tie layer, i.e., Bynel®.

First, the design and structure of the multilayer package affects bond strength. Changes in tie layer thickness, total film thickness, polymer type, and additives such as anti-fog agents, for example, can alter adhesion level.

Next, the converting process plays an important role in determining the level of adhesion. Some processes have lower residence time, or exert higher stress on the structure than others. With the same compositional structure and gauge of film, a given adhesive provides different levels of peel strength in a cast or blown film process, for example.

The third factor is the packaging process, which can involve temperature extremes and physical stress that can affect adhesion. In packaging processed meats for example, a film may be highly stretched or formed in the solid state, requiring a more robust adhesive than one that is not stretched in any way.

Bynel® adhesive resins use a range of polymers with different chemistries and functionalities and various modifiers and additives. Acid functionality, for example, provides adhesion to aluminum foil, metallized films, paper, nylon and ionomers. Anhydride functionality is vital for bonding EVOH and nylon. Ethylene vinyl acetate based adhesive polymers are useful for bonding a wide range of polymers, including PVC, PVDC, PET, PET, PP, polystyrene and ionomers. Acrylate polymers bond well to these same materials and to inks.

With Bynel®, converters get more than a bag of resin. DuPont specialists work closely with them to get the most out of Bynel® in their process. We also provide training modules to teach their key people the principles and practice of melt bonding.

Figure 3. Good Adhesion in PE/PA Structures

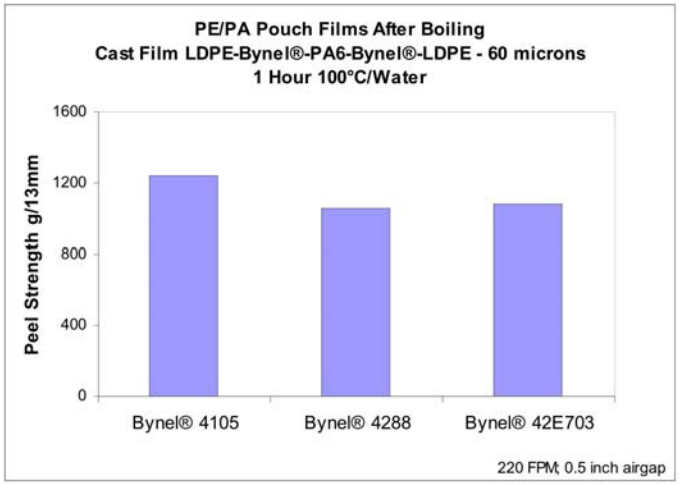
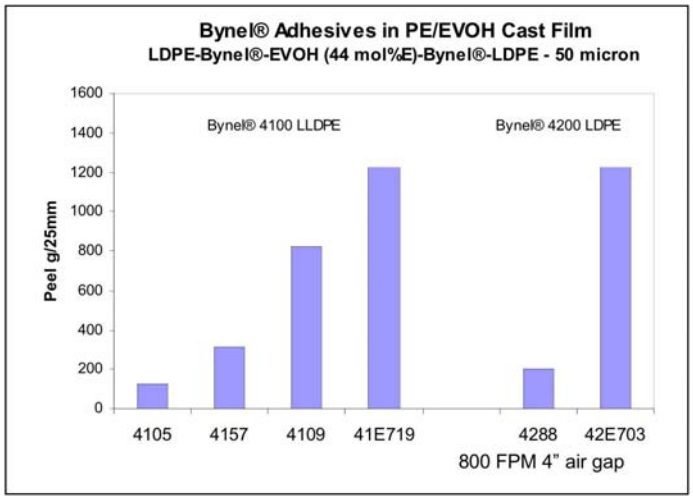


Figure 4. Adhesion in PE/EVOH Structures



To help converters select grades of Bynel® suitable for particular applications, DuPont has developed a selector guide. The guide uses a grid similar to that in Figure 2 but with links to a database of grade recommendations. The user simply clicks a grid box for a particular material pair and a screen showing different grades for different processes comes up.

Process Examples

Bynel® adhesive resins perform successfully in various extrusion, molding and lamination processes. A few examples follow.

Cast Film and Extrusion Coating. These processes typically produce barrier films that combine PE layers with polyamide or EVOH layers. Applications include meat webs, pouch films and barrier-coated boardstock for juice cartons.

Such structures have three to nine layers and range from 10 to 100 microns in total thickness. Several grades of Bynel® based on functionalized LDPE or LLDPE are suitable for this process.

Figure 3 shows the high adhesion strength achieved with three grades of Bynel® in PE/polyamide films.

Figure 4 shows adhesion results in a more demanding situation with PE/EVOH cast film on an extrusion coating line at high speed. In this case, Bynel® 41E719 and 42E703 are clearly the best choices.

Coinjection Molding. Kortec Inc. has pioneered the development of a process and equipment to make thin-wall barrier containers for shelf-stable packages for fruit, vegetables, meat, fish, pet food and prepared foods. ***Figure 5*** shows some containers made with the process.

Advantages of the Kortec process include:

- High barrier structure of PP/EVOH/PP that can be retorted;
- Full encapsulation and consistent distribution of the barrier layer;
- Precise dimensional control, especially in the flanges, an advantage for high-speed filling and sealing;
- Design flexibility for different shapes;
- Less scrap than thermoforming;
- Lighter container weight than glass or metal.

To provide adhesion of the PP and EVOH layers, Bynel® 50E803 is blended into the PP skin layers. It provides the right balance of functionality, rheological control, quality and food contact suitability to assure good adhesion

Figure 5. Containers Made by Kortec’s Process

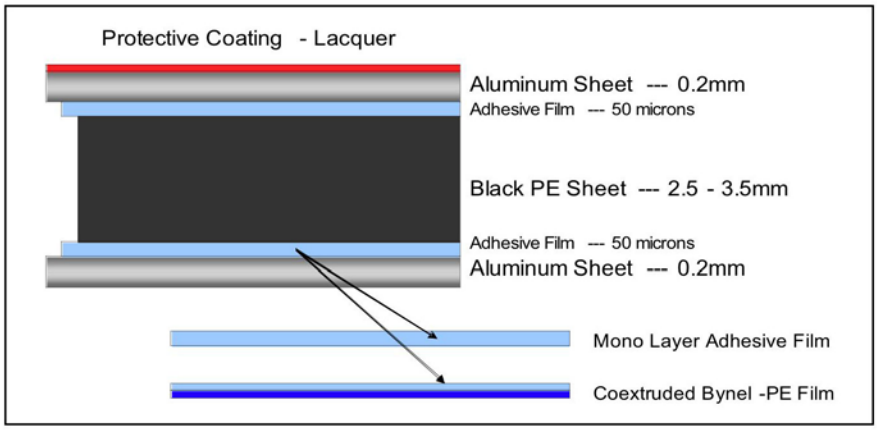
Figure 6. Barrier Containers for Pesticides

while maintaining the properties of the PP skin layer.

Coextrusion Blow Molding. Bynel® 4104 assures adhesion in pesticide bottles with HDPE as the outside layer to provide mechanical strength and a water vapor barrier, and polyamide as the inside layer for a solvent barrier (***Figure 6***). Completely miscible with HDPE, it can also compatibilize PE and polyamide regrind. This is a key advantage in maintaining the properties of the regrind so that it can be used in the structure to provide bulk and avoid waste. Bynel® 4104 also works well for extrusion blowmolded PE containers using EVOH as a barrier.

Thermal Lamination. Bynel® has also proven its value in heat-laminating polymers to metal. In making building or truck body panels (***Figure 7***), either a monolayer film of Bynel® or a multilayer film with Bynel® on one surface is used to laminate PE sheeting to aluminum with heated nip rolls. In many instances, a key requirement in testing is for cohesive failure to occur in the tie layer when the structure is pulled apart. Bynel® 30E753 and 41E755 have been specifically developed for this market.

Figure 7. Construction Panel Using Bynel®



Bynel® Grades Serving Multiple Applications

Here are two examples showing the versatility of Bynel® resins:

1. **Multipurpose Grade**. Bynel® 41E687, an anhydride-modified LLDPE adhesive, works well in a wide range of structures. Applications include deep-draw thermoforming films, films with anti-fog and biaxially oriented shrink bags and casings.

   Bynel® 41E687 provides excellent adhesion to EVOH, polyamide, PE, ionomer and ethylene copolymers. It can serve in a 100% Bynel® tie layer in the most demanding applications. It can also be blended into PE to provide adhesion to polyamide or EVOH under less demanding circumstances.

   Thanks to its versatility, converters can simplify their adhesive inventory by relying on Bynel® 41E687 to make both standard and high-performance films.

2. **Polyester Bonding Solutions**. DuPont offers a wide selection of adhesives for different types of polyester extruded and coextruded multilayer structures made by different processing techniques. As shown in ***Table 1***, grades run the process gamut from extrusion coating or lamination onto a solid substrate of oriented polyester to coextrusion of polyester to barrier polymers followed by in-line co-orientation. From a materials perspective, we have adhesives that bond to homopolyesters, copolyesters (including PETG) and aliphatic biopolyesters, such as PLA.

Table 1. Tie Resins for Multilayer Polyester Structures

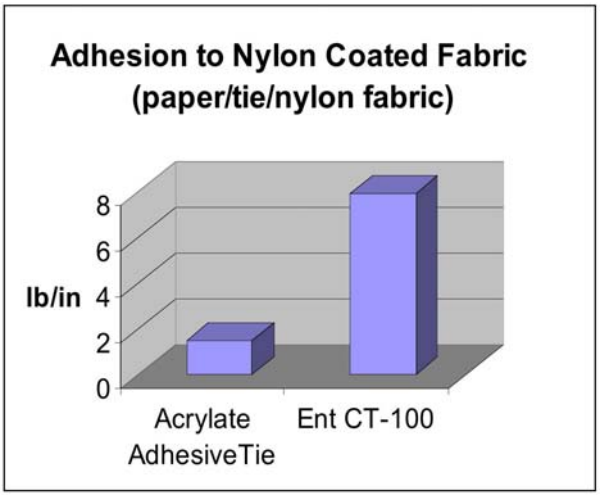
Biaxially Oriented PET	**Extrusion coating/lamination**	**Bynel® 22E757**
PET/PE	**Blown film coex**	**Bynel® 22E780**
	Cast film coex	**Bynel® 22E804**
PET/Barrier	**Blown film coex**	**Bynel® 21E810**
	Cast film coex	**Bynel® 21E830**
	Double bubble	**Bynel® 21E787**
Copolyesters	**Various coex**	
PETG & Others	**< 250°C processing**	**Bynel® 3861**
	> 250°C processing	**Bynel® 21E810**
Biopolyesters		
PLA/PE	**Coextrusion**	**Appeel® 20D828**
PLA/Barrier	**Coextrusion**	**Bynel® XB892-1**

More DuPont Tie Resin Solutions

While the Bynel® product line meets a wide range of needs for extrudable adhesives, other DuPont products can be used as tie resins. We highlight two examples of DuPont polymers offering demonstrable benefits in bonding nylon fabric and aluminum to various substrates and in producing transparent containers.

1. Bonding Nylon Fabric. DuPont™ Entira™ Coat 100 has proven its effectiveness a tie layer for nylon fabric and paper. A key advantage is that it provides stronger adhesion to the fabric than an acrylate tie resin (***Figure 8***). In this case, 10% PP is blended with Entira™ Coat 100 to provide more heat resistance.

Figure 8. Entira™ Increases Fabric Adhesion



The resin also bonds to metal, polyolefins, unprimed OPP, urethanes and PET, and it is RF- weldable. Entira™ Coat 100 is a functionalized EMA polymer.

Clear Containers

In squeezable cosmetic containers (***Figure 9***), another acid copolymer grade, Nucrel® 0903HC, makes the grade as a tie layer for DuPont™ Surlyn® and PE. It provides strong adhesion to the other layers, processes easily and has outstanding clarity.

Figure 9. Bynel® Ties PE to Surlyn® in Clear Cosmetics Containers

Summary

In multilayer packaging structures, different polymers are used in packages that meet the different and various needs of packaged goods manufacturers, retailers and consumers. These polymers are frequently incompatible and will not adhere well to each other. For bonding those “unjoinables”, DuPont offers a range of extrudable adhesive solutions. Bynel® extrudable adhesives provide good adhesion between many polymers in structures produced by various coextrusion, extrusion and laminating processes. Other DuPont polymers also serve to bond dissimilar materials in applications involving nylon fabrics, aluminum foil and cosmetic containers.

For more information about DuPont Packaging’s resins, capabilities and service, please visit www.packaging.dupont.com.

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