Pigmented laminating adhesives for flexible packaging

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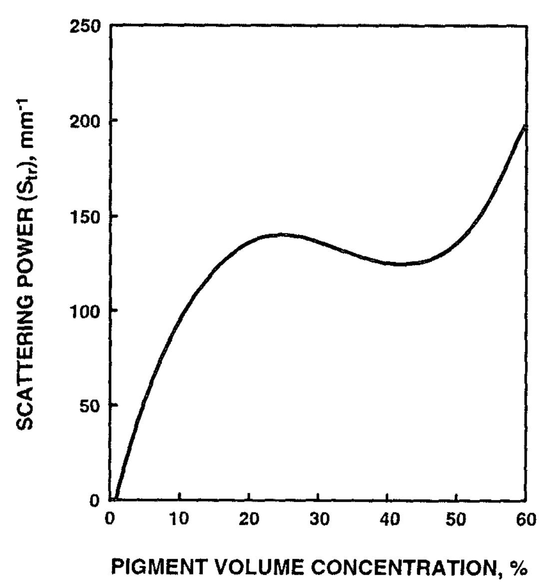
Converters impart color to flexible packaging structures by using pigmented films or clear films printed with compatible inks. Pigmented urethane adhesives are an attractive third option.

Pigmented laminating adhesives are an economically viable option for producing opaque packaging constructions in a variety of colors. Converters who require a laminated construction with overall opacity typically rely on one of two alternatives: they either purchase pigmented film or print clear films with ink to achieve the same results. The former requires inventory of costly pigmented films, while the latter can involve multiple printing and drying steps and can result in a surface that provides less-than-optimum compatibility with the laminating adhesive. Pigmented urethane adhesives provide the converter with a third option for the manufacture of opaque constructions in many colors without compromising performance.

With pigmented adhesives, the converter can opacify and bond a laminate construction in a single step. Savings in process utilities, converting time, and solvent emissions can be substantial. This article describes the use of pigmented adhesives in opaque or colored film/film and film/foil laminates and contrasts their use with the conventional methods that are typically used to achieve similar results.

1. Scattering power as a function of pigment volume concentration



Advantages of opaque packaging

There are myriad reasons for wanting to produce a nonclear package. Product protection is a major incentive, since visible light can discolor or bleach the packaged product. Some wavelengths, particularly in the ultraviolet range, are energetic enough to degrade organic material. Appearance is another reason. Products that are not particularly attractive are often sold in an opaque package. Color is appealing, and many end users choose a package for aesthetic reasons.

Color is often used to identify the product. Disposable diapers, for example, are packaged in pink for girls and blue for boys. Packages also can be colored to achieve some specific effect. During the Gulf War, for example, there was speculation that the olive-drab camouflage color of the MRE (meals ready to eat) pouches would be changed to a desert brown. These are but a few of the practical and aesthetic considerations that guide the choice of an opaque or colored laminate.

Methods of imparting color

There are three ways of obtaining a colored or opaque laminated construction.

1. Laminate with a pigmented film.
2. Print a clear film with ink and then laminate.
3. Use a pigmented laminating adhesive to bond a clear film to the substrate.

Pigmented film

Pigmented films are available from many suppliers at a premium over their clear counterparts. While the use of pigmented films appears to be an attractive, straightfor-

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I. Peel adhesion for a PET-foil laminate

Pigment content, %	*Initial*	*24-hour Room temp.*	*24-hour 150°F*	*7-day (room temp.)*	*14-day (room temp.)*
0	205	265	205*	265*	195*
9	175	125*	...	185*	185*
18	150	215	200*	285*	...

Peel adhesion, g/cm

* Stock tear.

II. Peel adhesion for a PET-foil laminate

Adhesive	*Initial*	*24-hour (150°F)*	*7-day (room temp.)*	*14-day (room temp.)*
Clear	195	285*	300*	325*
Olive drab	105	230*	230*	250*

Peel adhesion, g/cm

* Stock tear.

ward option, there are penalties exacted from both the manufacturer of the film and the converter who chooses to use it.

The manufacturer of pigmented films faces several difficulties (*1*).

- Extrusion of a film loaded with pigment causes abrasive wear of the extrusion screw and the blowing die.
- The screw can require a mixing element.
- Pigment-rich degraded material tends to plate out on the screw and die.
- Changing colors (or reverting to clear film) requires long purge times.

The converter who uses pigmented film typically encounters one or more of the following problems.

- Surface roughness, streaks, graininess, and variable opacity caused by poor mixing of pigment and film
- Variations in heat sealability and coefficient of friction caused by nonuniform pigment dispersion
- Need for additional slip additives to maintain the desired coefficient of friction
- Reduced film strength
- Increased film porosity, providing channels for transport of gases and liquids through the film
- Tendency for pigmented films to stain by picking up color from packaged material.

Printing and laminating

The conventional way of achieving opacity or overall color in a laminated construction is by using inks at 100% coverage. Inks are essentially dispersions of colored pigments in a suitably dissolved or emulsified polymeric binder. In addition, inks usually contain smaller amounts of plasticizers, waxes, driers, and miscellaneous additives. In the flexible-packaging industry, inks are applied to transparent films via flexo or gravure printing. This is followed by a thermal process to remove the carrier solvent or water and set the ink. The inked web is then rewound for further processing, lamination for example.

Inks are efficient opacifiers of transparent films because of their high pigment loading, which translates into a high concentration of pigment in the dry ink film. Hiding power, or the ability of a pigmented film to obscure a surface, depends on the film's light-scattering power. The magnitude of light scattering is related to (a) the ratio of the refractive index of the pigment to the binder (rutile TiO_2 is usually the pigment of choice for opacifying a white film because of its very high refractive index, ≅2.75), (b) the pigment particle size, and (c) the particle size distribution.

In addition, the scattering power of every pigment is considerably affected by the film's pigment concentration (C_{pigment}). This is the ratio of the volume of the pigment to the overall volume (V) of the dry film, as defined in the following equation.

$$C_{\text{pigment}} = V_{\text{pigment}}/(V_{\text{pigment}} + V_{\text{binder}})$$

Figure 1 shows that as C_{pigment} increases, light scattering rises to a maximum and then falls off in spite of increasing pigment concentration (*2*). This curious behavior is explained by the fact that as pigment concentration increases, the distance between individual pigment particles decreases. Pigment particles make their optimum contribution to scattering power when the distance between two particles corresponds roughly to the wavelength of visible light. If the distance falls below a minimum value, the resulting interaction between light waves and the pigment no longer corresponds to two separate particles but to a single larger particle, and the scattering effect decreases. The minimum at 39-44% concentration in Fig. 1 is the so-called critical pigment volume concentration. Highly pigmented inks can show such a reduction in hiding, as can pigmented adhesives. Films are usually pigmented far below the critical pigment volume concentration.

The use of inks to opacify or color a film for subsequent lamination has several drawbacks. The most important is the economic penalty. The converter must bear the cost of the ink as well as the process costs for each inking step, which includes a drying stage with attendant utilities, emissions, and cleanup costs.

The ink must display adequate adhesion to the film or foil on which it is used, and adhesion to a specific substrate can be a function of the ink vehicle. For example, the traditional resin for formulating inks used on polyethylene is a polyamide. Foils respond well to ink vehicles of nitrocellulose modified with polyvinyl butyryl, while polyester films require vinyl-based inks (*3*). Even when the ink vehicle does adhere well to a surface, its adhesion is seldom the equal of a typical lamination. In fact, peel testing of inked and laminated films usually results in adhesive failure at the ink-film interface or cohesive failure within the ink film itself, both at fairly low peel values.

Inked surfaces often cause adhesion problems on post lamination. Inks may contain waxes or other additives that can bloom to the surface, leading to wetting problems and subsequent adhesional deficiencies. For example, inks can retain hydroxyl-bearing solvents after drying, and these solvents can react with isocyanate-active species in a laminating adhesive. This reaction blocks the adhesive cure and results in poor laminate performance.

Ink vehicles—the binders in which the pigments are dispersed—are chosen for their ability to wet pigments and develop color. These polymers often cannot stand up to further processing, retorting for example. The MRE pouch suffered from this problem. The pouches, which consist of an inked foil laminated to a polyester film, failed upon retort. Failure was caused by degradation that initiated in the ink layer.

On first examination, the use of a pigmented ink to opacify a substrate for future lamination seems a reasonable choice. Inking, however, may not be cost effective because of additional processing, emissions, and cleanup. Inks can also interfere with adhesion and are prone to break down when used in constructions designed for high-temperature processing.

Pigmented adhesives

Opaque laminates can be produced using pigmented adhesives. This approach provides several important advantages.

First, and most important, a pigmented laminating adhesive requires half the processing of a similar inked construction. Inking and then laminating requires at least two on-line operations with two passes through an oven. In some cases, two inking runs are needed. Laminating with a pigmented adhesive takes only a single step, providing substantial savings in process time, materials handling, utilities, cleanup, and emissions.

Simplified processing also has a positive effect on waste management. Inking followed by a laminating process involves two separate waste streams. A pigmented adhesive effectively halves waste generated in type and volume.

Pigmented adhesives can offer real advantages in inventory control. It is impractical to maintain an inventory of films pigmented to a variety of colors. Production runs are too short and color requirements too varied to make this approach workable. The sheer variety of films laminated speaks against this practice.

Ink inventory can be a problem too. Because inks may be formulated with specific binders for specific types of film, it is impractical to inventory inks for different films. An adhesive pigmented to the proper opacity and color is, in effect, a universal ink, since the adhesive polymer binder has been formulated to adhere to the complete spectrum of packaging films.

One of the major advantages of pigmented adhesives is in the area of performance. Because the base adhesive is formulated to wet out and bond to all of the conventional films and foils, the pigmented version will do likewise. The cure profile of the pigmented adhesive is very close to that of the unmodified adhesive.

Adhesives can be pigmented with any number of pigments acceptable for use in food, drug, and cosmetic applications, so the overall FDA status of the base adhesive is unchanged. If the base adhesive is boilable or retortable, a pigmented version will have the same properties.

Table I shows adhesion values for a typical urethane adhesive without pigment and after pigmenting with titanium dioxide at two levels to obtain a white adhesive. The bonded substrates were foil and PET (polyethylene terephthalate), and all runs had equivalent coating weights of 1.95 lb/ream. The presence of pigment does not degrade the ultimate performance of the system, although pigmentation does diminish initial peel values somewhat.

In a similar study, a urethane adhesive was pigmented with a combination of pigments to Federal Color Standard 595-A (24052-24064). Results are presented in **Table II**. Again, final cure produces laminate rupture bonds, with some compromise in initial peel values.

Conclusion

Converters can construct opaque packaging structures using either a pigmented film, a printed film, or a pigmented laminating adhesive. Pigmented adhesives offer economic advantages in the form of lower material requirements, fewer processing steps, and a substantially smaller waste stream than either pigmented films or inked films. Pigmented adhesives also eliminate many of the performance compromises associated with inked or pigmented films.□

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