Vacuum Coating Applications for Snack Food Packaging

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ABSTRACT

Flexible packaging is the format of choice for delivering a variety of good tasting snack foods such as potato chips, tortilla chips and pretzels to the consumer. Besides marketing the particular product with colorful graphics, the flexible package provides cost effective protection against environmental factors that can cause product degradation

Flexible packaging for snack foods has progressed from the clear cellophanes that provided virtually no barrier to the current clear plastic laminations for snacks requiring only moisture barrier, and metallized laminations that can protect snack foods from moisture, light and provide a gas barrier.

Recent efforts to optimize barrier have been focused on metallized structures accomplished with the base film manufacturer — changes to the film surface properties, coatings, corona and/or flame treatment to improve metal bond and uniformity of aluminum laydown. Attention must now be turned to the vacuum coating process for cost reduction and improved barrier breakthroughs. In addition, clear film metal oxide vacuum coatings need to be commercialized economically for those snack food applications requiring a high barrier clear printed package.

INTRODUCTION

Frito-Lay, Inc. is one of the three major business segments comprising PepsiCo, Inc., a $22.0 billion in sales, ***Fortune*** 100 corporation. Of those segments—beverages, snack foods, and restaurants—snack foods contribute almost $1.0 billion in pretax profit.

Within the snack food segments are two companies, Frito-Lay and PepsiCo Foods International. In the United States., Frito-Lay manufactures its familiar brands in 36 manufacturing plants in 22 states, and 4 facilities in Canada. PepsiCo Foods International operates in 24 countries throughout South America, Europe, the Middle East, and Asia. Virtually all the snack foods produced by Frito-Lay and PepsiCo Foods International are packaged in flexible film. Together Frito-Lay and PepsiCo Foods International produce over 12 billion snack food packages each year. To make those packages, in 1992 Frito-Lay consumed 65 million pounds, and PepsiCo Foods International 40 million pounds of polypropylene based packaging material.

BACKGROUND

The structure of the package for each product is developed to provide an optimum level of protection while integrating packaging design for unique market needs. Specifically, from a product protection standpoint, the package is designed to ensure the highest possible quality for shelf life duration, and at Frito-Lay, that means maintaining first day fresh product quality through the sale date printed on the package. For the majority of Frito-Lay snacks that total period from manufacture to last sale date is only 49 days. We accomplish that relatively short sale period by the efficiency of our store-door delivery system. Within the PepsiCo Foods International system and even Canada, that period is considerably longer with up to 90 days from manufacture to last sale date for some snack products, because of larger distribution areas per plant and local merchandising practices. That wide range of sale periods and variety of snack products for our companies has necessitated a solid understanding of shelf life and factors effecting that shelf life. We ask that thin skin flexible package to do a lot: attract the consumer with colorful graphics, resist tampering, be puncture resistant, and provide the required level of environmental barrier to maintain the product quality. We want our products to be as fresh and as flavorable as possible. Therefore, the primary objective—when specifying package materials and structures—is to protect against the controllable environmental factors of moisture, oxygen, and light that can adversely effect the product.

For snack foods, those environmental factors can be detrimental to the key attributes snack foods are judged on: texture, aroma, and flavor. After all, no one wants to eat a soggy, off-flavor potato chip.

To ensure the package films and structure specified for a particular product meet the Frito-Lay standard for quality, extensive shelf life testing is accomplished. That testing is used to simulate the conditions the packaged product will experience during storage, distribution and merchandising for its shelf life period. These tests are conducted for all new products, major product changes, and as part of the qualification process for new package material. In addition, extensive moisture and oxygen barrier, bond, seal, and machineability testing is conducted for all material qualification.

The majority of the material used for that packaging is orientated polypropylene (OPP). It is used as both the printed and barrier layers of the package, together with polyethylene as the bonding material (***Figure 1***). Since polypropylene is a relatively poor environmental barrier by itself, the polypropylene layer is coated to provide moisture, and/or oxygen, and/or light barrier.

SNACK FOOD PACKAGE STRUCTURE

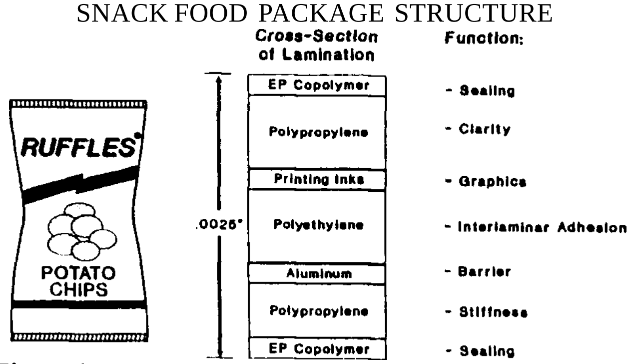


Figure 1

Corn products are packaged in clear film and generally only require moisture barrier. To provide that protection, the barrier sheet is coated with polyvinylidene chloride (PVDC). Opaque packages requiring a light, moisture and/or oxygen barrier use a barrier sheet metallized with aluminum. Of the over 12 billion packages produced by Frito-Lay and PepsiCo Foods International, over 80% require coating for barrier protection.

BARRIER HIERARCHY

If we examine each critical barrier factor relative to the protection required, it's easy to understand why barrier films are needed. Frito-Lay's criteria for potato chips will be used in the following examples. And as each of these factors is reviewed, imagine snack food packaged in clear cellophane as it was 35 years ago, and what it must have tasted like 2-3 weeks after it was made.

In the hierarchy of degradation, photo oxidation is the fastest cause of potato chip degradation. Unprotected from light, potato chips will become rancid in less than three days. Light attenuation of 98% is required to prevent this occurrence. That attenuation relates to an optical density of greater than 1.7 to achieve Frito-Lay's 49 day shelf life requirement. As indicated on ***Figure 2***, [1] metallized film meets this requirement.

BARRIER ISSUE: LIGHT
(Product Attribute: Flavor)

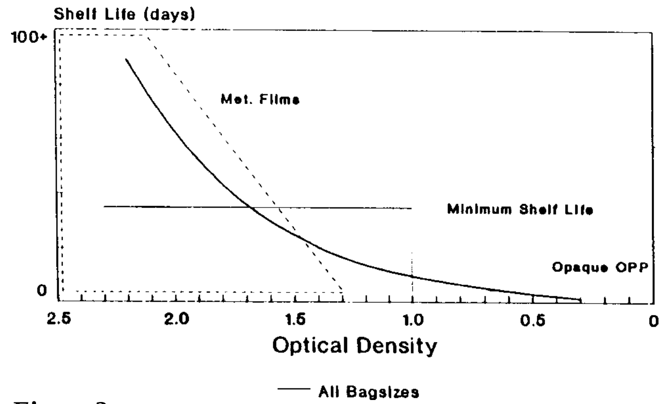


Figure 2

Continuing through the hierarchy of potato chip degradation, control of photo oxidation places moisture as the next factor to be addressed. Potato chips are typically fried to a finished moisture content of 1.3-1.8%. The stale point for moisture content, or level at which the consumer perceives the product to be stale or soft, is no more than 2.5%. Consequently, the allowable moisture gain for the period of the shelf life is minimal. For Frito-Lay's needs, the minimum protection required, expressed as moisture vapor transmission rate (MVTR), is .02 grams/100 square inches a day at 85°F/80RH. (Those conditions are a hybrid between the tropical and temperate standards.)

Overlaying film structures (***Figure 3***) [2] again indicates that metallized film laminations can provide the protection level required.

BARRIER ISSUE: MOISTURE
(Product Attribute: Texture)

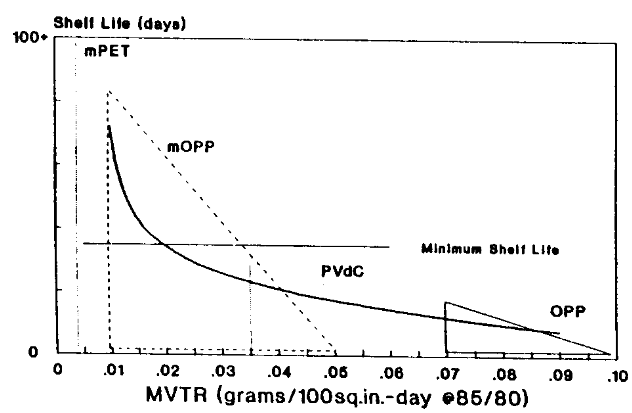


Figure 3

However, against Frito-Lay's improved standards of quality introduced in 1991, which reduced the maximum allowable moisture content for texture acceptability, one can see that the then film industry standard metallized OPP did not allow 49 day shelf life to be achieved. ***Figure 4*** [2] compares the standard versus high barrier metallized OPP.

BARRIER ISSUE: MOISTURE
(Product Attribute: Texture)

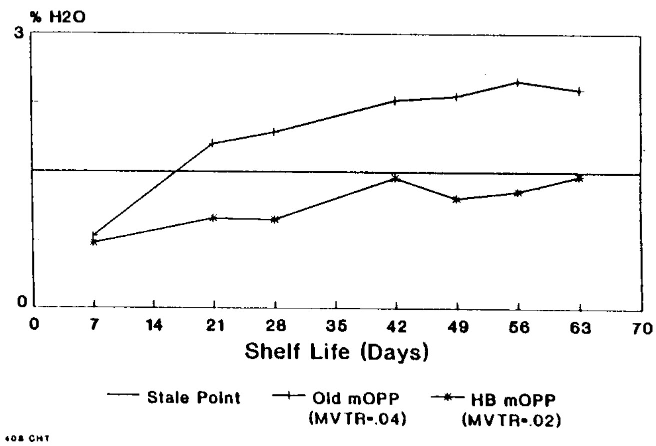


Figure 4

Providing package protection from light and moisture allows a reasonable shelf life to be achieved in an air filled package. However, to meet Frito-Lay's quality standard, an additional level of barrier to allow gas flushing was required. Referred to as oxygen transmission rate (OTR) and measured in cc/100 sq. in. at 73° F 0°RH, the state-of-the-art for metallized OPP 18 months ago (old metallized OPP) had measured values between 8 and 20+. For gas flushing applications, film with those values was useless.

Currently, when a gas flushable flexible package is specified for snack foods, the industry standard is to use vacuum metallized polyester as the barrier sheet. Although that represented a technical solution to meet Frito-Lay's need, the significantly higher cost of polyester and, most importantly, the lack of polyester film supply to meet our capacity requirements eliminated polyester from consideration.

HIGH BARRIER DEVELOPMENT

What was needed was polypropylene that could provide good gas barrier. Frito-Lay R&D found that an OTR value less than 3 was required to allow gas flushing and protection against auto oxidation for the 49 day shelf life of Frito-Lay potato chip products.

Frito-Lay R&D had previously entered into technical partnerships with its major package material suppliers as a means of directing new material development. Through this means, Frito-Lay leveraged the polypropylene film producers that supply our converters, to cause the quality of metallized polypropylene to make a step function improvement and accomplish what was by some thought to be impossible: provide good gas barrier for our specific shelf life period. Three film producers met this objective, each taking a slightly different approach that involved additives and improved surface treatment.

Figure 5 [3] indicates the range of OTR values versus resulting shelf life possible with the higher quality metallized OPP films as compared to metallized polyester film.

BARRIER ISSUE: OXYGEN
(Product Attribute: Flavor)

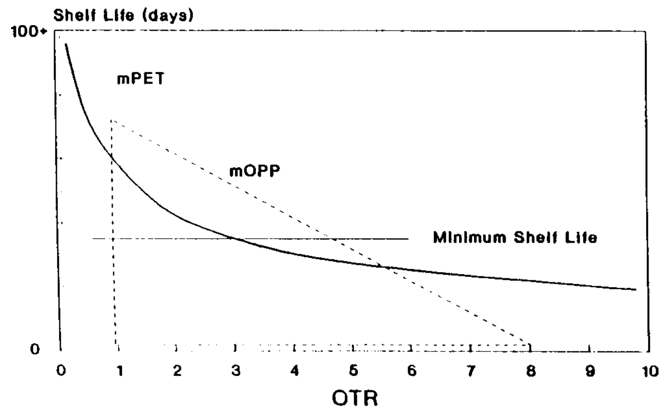
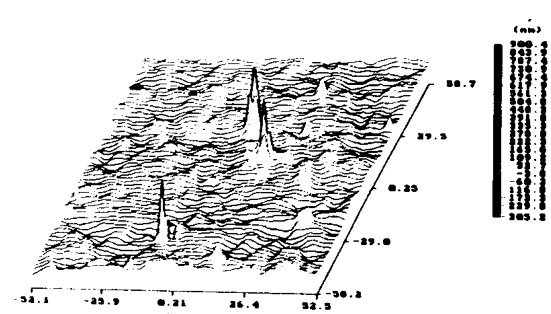


Figure 5

Figure 6 [4] shows an optical interferometer imaged 100 micron square enlargement of the surface of conventional OPP film that was surface treated using corona discharge. That treatment to oxidize the film surface is essential to create the surface conditions to achieve proper bond strength between the metal and the film and metal deposition uniformity for barrier. However, the surface of this sample is relatively rough with wide standard deviation (note the high peaks).

OLD OPP BASE FILM SURFACE
(SAMPLE C)

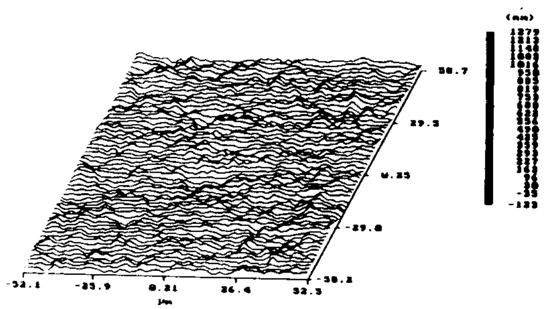


SURFACE: Avg. 31.9 nm P-P 1,206 nm

Figure 6

Figure 7 [4] shows a similarly imaged enlargement of the surface of the high barrier OPP. It has also been surface treated, but more aggressively. Note the overall smoother surface and absence of large variations.

HB OPP BASE FILM SURFACE
(SAMPLE B)



SURFACE: Avg. 22.8 nm P-P 246 nm

Figure 7

Comparing the surface roughness values of these and two additional samples against their corresponding measured OTRs, the correlation is readily apparent. The film surface can be optimized to improve barrier (***Figure 8***) [4].

SURFACE vs OTR

	SURFACE ROUGHNESS (nm)		OTR	
SAMPLE	AVERAGE	STD DEV	AVERAGE	STD DEV
A	17.8	3.2	0.8	0.6-1.0
B	23.6	0.8	1.7	0.3-0.6
C	33.3	2.1	4.1	> 1
D	45.0	6.1	10.6	> 3

Figure 8

However, this advancement in polypropylene film processing was not without cost. The premium averages 70¢/lb, higher than conventional metallized OPP.

As improved as the film surface is, the overall process to produce those results is right on the edge of current technology capability. Surface treatment improvement is a two-edged sword — with increased treatment to decrease roughness and improve uniformity, deposition becomes more uniform and oxygen barrier improves (***Figure 9***). Conversely, the bond strength between the polypropylene sheet and the metal decreases (***Figure 10***). Intersecting the graphs above the Frito-Lay specified minimum bond and OTR values required was the major challenge that the film manufactures had to meet.

BASE FILM SURFACE: OXYGEN BARRIER

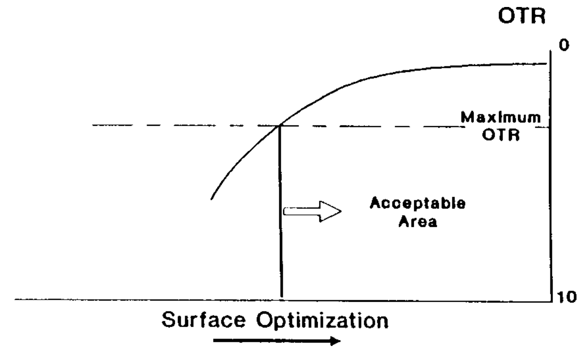


Figure 9

BASE FILM SURFACE: METAL BOND

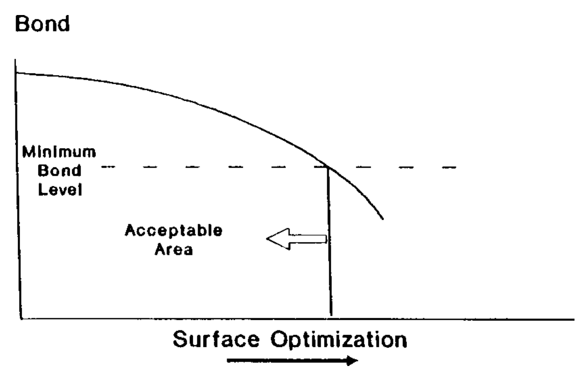


Figure 10

Emphasizing concern about the process capability is the limited overlap area within which the bond and OTR requirements are met (***Figure 11***). The cost impact to achieve this is also displayed.

BASE FILM SURFACE: ROBUSTNESS/COST

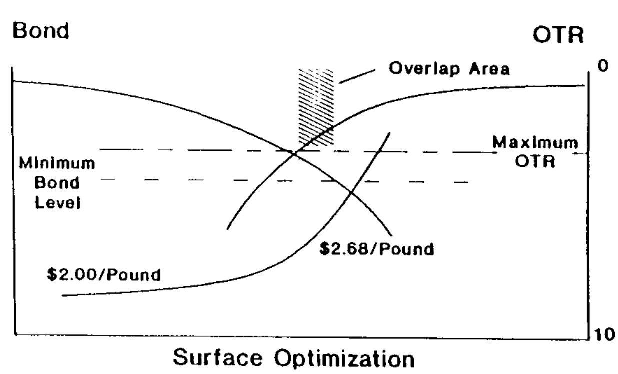


Figure 11

FUTURE DEVELOPMENT

With an understanding of Frito-Lay's needs in snack food packaging and how important vacuum coating applications are in meeting those needs, we need to look to the future.

For opaque metallized film, the overlap area to achieve high barrier results needs to be enlarged and made less dependent on the film process. Frito-Lay R&D is working with the film manufacturers to encourage further process improvement which may necessitate new process equipment. We're also working with resin producers encouraging development of "built-in" barrier properties. ..... However, potentially the greatest opportunity lies in the vacuum metallization process. Ideally, development of a more robust metallization process, one that could provide the needed barrier over a wider range of film surfaces. Such a development would allow use of lower cost base films while achieving the higher barrier specifications when metallized, and be a significant cost benefit to those snack companies like Frito-Lay that require higher barrier package materials for their products. (***Figure 12***)

BASE FILM SURFACE: OPPORTUNITY

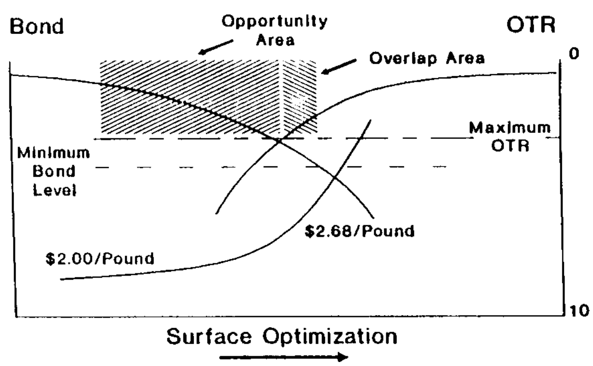


Figure 12

Frito-Lay's other key need is in the clear film area. As noted in this paper, only moisture barrier is currently required for Frito-Lay clear films. PVDC coatings provide that moisture barrier now. However, PVDC coated material is difficult to recycle, and it requires a different base film than used for metallized applications. An alternate to PVDC that Frito-Lay would find very attractive is metal oxide, but unless the economics—which right now are driven by speed through the vacuum coater—can be improved to current PVDC coated cost levels, widespread use in the snack food industry will not occur. This, then, is the challenge.

SUMMATION

The environmental protection needed by a specific snack food product is the primary determinant in barrier, and film structure selection.

Frito-Lay has developed an in-depth understanding of product shelf life and has utilized it to drive packaging film development in partnership with major suppliers.

Future opportunities for both clear and opaque barrier film development will rely on vacuum coating technology advances.

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