

The Impact of Visual Anomalies on the Barrier Properties of Metallized Biaxially Oriented Polypropylene Film

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ABSTRACT

A variety of defects in metallized biaxially oriented polypropylene films have been correlated with barrier. Visual anomalies examined include pinholes, scuff marks, shading, scratches and crazing. It has been found that not all of these anomalies result in poor barrier. In many cases, the surface may appear severely damaged and still produce excellent moisture and oxygen barrier. Reasons for these visual anomalies, their impact on barrier as well as surface characterization methods are discussed in this paper.

BACKGROUND

Biaxially oriented polypropylene (OPP) films are metallized with aluminum to provide moisture, oxygen and light barrier properties for food packaging applications. Common theories of metallized OPP barrier films invoke aluminum adhesion and aluminum resistance to permeation as critical parameters. The most common and simplest method of metal deposition for packaging food applications is thermal vacuum aluminum coating. Based on physical vapor deposition theory, the coated film properties are controlled by the coating crystalline morphology. In turn, the crystalline morphology of the coating is controlled by the vacuum deposition process and the "receptivity" of the substrate surface [1].

Control of the aluminum coating in the vacuum evaporation process can be impacted by many variables. It is widely accepted that the condition of the film substrate surface is one critical variable. The lack of surface contamination and appropriate degree of surface oxidation are prerequisites to achieving satisfactory barrier properties. Generally, damage to the metal surface (pinholes, crazing, etc.) or a poorly oxidized surface will compromise barrier properties. We wish to report here that surface anomalies do not always have a detrimental impact upon moisture and oxygen barrier.

SURFACE ANOMALIES

In thermal vacuum deposition, visual film surface anomalies have always been a concern. Defects such as pinholes, crazing, scratches, shading, metal pick and scuff marks are not only aesthetically displeasing but often have a negative im-

act on barrier. If metal crystalline morphology and surface "receptivity" are essential to good barrier, then a disturbance of the metal surface should result in poor barrier. However, we have developed proprietary surface technology which can give a metallized film where visual surface anomalies do not impact barrier.

Scratches

Thermal vacuum deposited surfaces tend to be very fragile and can be easily scratched. These scratches can result from rough idler rolls on a slitting machine or hard additives in the film surface against which the metallized surface winds. The most common source of metal scratching is from particulates used as antiblocks in the film. These scratched areas can negatively impact barrier by providing areas of permeation. Two aluminum metallized film surfaces, "A" (a commercial metallized OPP) and "B" (a new surface technology metallized OPP), were intentionally scratched with a hard particulate antiblock. The hard antiblock caused visual damage on both samples. Surface "B" did not show any loss in barrier. A softer antiblock was used to scratch these same surfaces. In this case, the barrier of neither surface was significantly affected. Data is given in Table I.

TABLE I
OTR of Scratched Metallized OPP Films

SAMPLE	OTR (cc/m ² /atm/day)		
	No Antiblock Scratches	Hard Antiblock Scratches	Softer Antiblock Scratches
Surface "A"	51.2	124.0	57.4
Surface "B"	14.0	17.1	17.1

Crazing

Metal crazing can be defined as a fracture of the metal surface. A variety of opinions exist as to the cause of metal crazing. It is agreed among those in the field of metallization that crazing will increase moisture and oxygen permeation rates significantly. One explanation is a debonding of the metal from the film surface resulting in increased permeation. Another possible explanation is that oxygen and moisture molecules permeate metal coatings by migration along a tortuous path of aluminum crystallite interfaces. Crazing likely disrupts the crystallite packing and shortens the migration path and thus results in increased permeation. In either case, barrier should decrease if crazing is present.

Figure 1 is a micrograph of a metallized OPP film which was heavily crazed during lamination. This film utilizes our new proprietary surface technology. OTR and WVTR data are given in Table II for this metallized OPP film before and after crazing.

Light crazing is a visual surface anomaly which does not normally result in poor barrier.

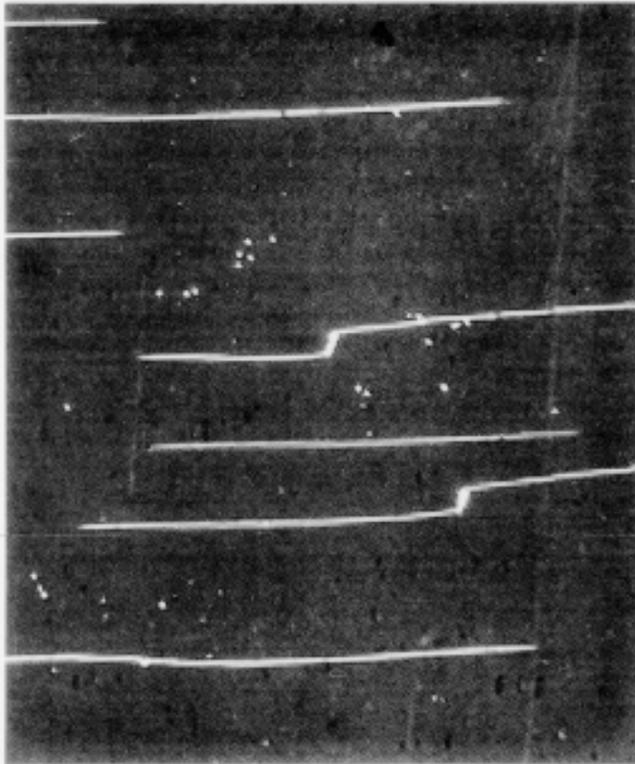


Figure 1: Magnification 67x 250 μm
Micrograph of Metallized OPP Film

TABLE II
Permeation Rates

BEFORE CRAZING		AFTER CRAZING	
OTR	WVTR	OTR	WVTR
30.85	0.1395	29.45	0.124
OTR - cc/m ² /atm/day		WVTR - gms/m ² /atm/day	

Shading

Shading is a variation in the optical density of the metal coating which is related to metal thickness variation. Most metallized OPP films have a minimum optical density target to achieve good OTR and WVTR. Shading (or railroad tracking) is often seen in film metallized in supported web vacuum chambers. Film flatness or uneven COF on the nonmetallized side of the web are the most common contributors to the uneven deposition of the aluminum.

Shading can sometimes result in poor barrier. The degree of the effect can be impacted by the type of surface that is metallized. Table III lists OTR and WVTR values for 3 different surfaces which, when metallized, experienced severe shading. Surface "C" and "D" are commercial metallized OPP films. Surface "E" is our new proprietary surface technology.

The OTR and WVTR of all metallized films are not necessarily equally affected by the surface anomaly of shading.

TABLE III
Permeation Rates

SAMPLER	OTR cc/m ² /atm/day	WVTR gms/m ² /atm/day
Surface "C"	101.37	0.449
Surface "D"	110.05	0.481
Surface "E"	13.17	0.124

Pinholes

Pinholes arise from surface roughness under a limited range of vapor deposition angles, or from the dislodging of coated, particulate, surface contaminates. For this discussion, pinholes are defined as an area in which no metal deposition appears to have occurred. Figure 2 shows one possible way a pinhole can result from surface contamination. In this picture, a shadow is formed where a particle shields the surface from metal vapor deposition.

This type of visual surface anomaly, especially if large, seems to affect barrier no matter what type of metal bonding surface is chosen. This is not surprising if no metal is deposited in the shadow. However, it appears that not all pinholes are formed this way because we have observed samples with a large number of visual pinholes that still exhibit good barrier. These good barrier results suggest that something, perhaps aluminum oxide, is present in the pinhole areas.

Two different metallized OPP films were examined for pinholes. OTR was tested on samples with no visible pinholes and with a large number of pinholes. Table IV summarizes these results.

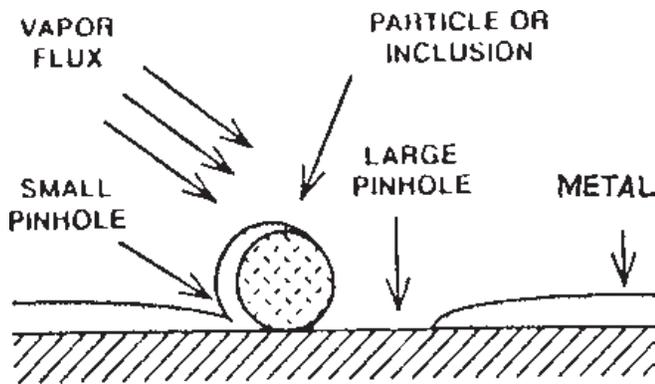


Figure 2: Pinhole From Surface Contamination

TABLE IV
Effect of Pinholes on Metallized OPP Film

SAMPLE	OTR (cc/m ² /atm/day)	
	No Visible Pinholes	Visible Pinholes
1	23.3	158.1
2	26.3	58.9

SURFACE QUALITY

To understand the impact of visual anomalies for metallized OPP film barrier it is important to understand the surface characteristics. The type or level of film surface oxidation is one parameter polypropylene film suppliers use to control barrier. Even though film surface treatment and film surface development are controlled, the vacuum coated aluminum is the only element that actually provides barrier.

Surface smoothness is another factor that affects aluminum deposition. Consistency of the surface can also effect aluminum deposition. Characterization of the film surface topography as well as the topography of the resulting metal surface was done to aid in understanding the affect of surface smoothness and consistency.

Two methods were used to characterize the film surface, optical metrology and surface microscopy. One method of metrology is a TOPO system. This system, a modified microscope used by WYCO Corporation in Tucson, Arizona, determines surface profiles, surface roughness, and statistical measures of surface roughness. A layout of the TOPO optical profiler is given in Figure 7 [2].

This method of optical metrology uses an interference objective to generate the interference fringes. A detector is placed at the conjugate plane to the surface. A phase shift is generated by a transducer which moves the reference surface of

the interference objective. Data are passed through an electronic interface to a computer which controls the transducer and calculates the surface profile. Measurements can be made with magnifications ranging from 1.5X to 200X.

Surface optical microscopy can be used to give a two dimensional magnified photograph of the surface. Surface microscopy together with the data generated from metrology was used to characterize film base surfaces and aluminum coated surfaces.

Two different metallized film surfaces were characterized by surface microscopy and metrology. Surface "A" (a common metallized OPP) had an OTR of 93 cc/m²/day/atm while surface "B" (our metallized OPP with a proprietary surface technology) had an OTR of 15.5 cc/m²/day/atm. Both film surfaces were metallized under similar conditions. Micrographs of the film and metallized surfaces are presented in Figures 3, 4, 5, and 6.

Surface "B" in Figure 6 appears smoother than surface "A" in Figure 5. The RMS (Root Mean Square) data in Table V, shows that both surfaces are approximately the same surface roughness. However, the standard deviation of surface "B" roughness, with or without metal deposition, is approximately one half that of surface "A".

We believe that this reflects a more consistent surface of "B" which in turn allows a more uniform aluminum deposition and better barrier.

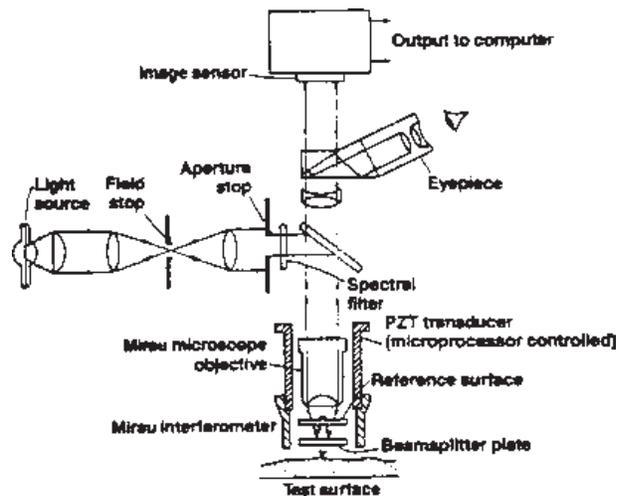


Figure 7: Optical Layout of the TOPO Optical Profiler

TABLE V
Metrology Data

SAMPLE	RMS Base Film	Standard Deviation	RMS Metallized	Standard Deviation
Surface "A"	13.90	1.50	14.10	2.78
Surface "B"	14.93	0.88	14.66	1.18



Figure 3: Magnification 100x 100 μm
Film Surface "A" - Unmetallized



Figure 5: Magnification 100x 100 μm
Film Surface "A" - Metallized

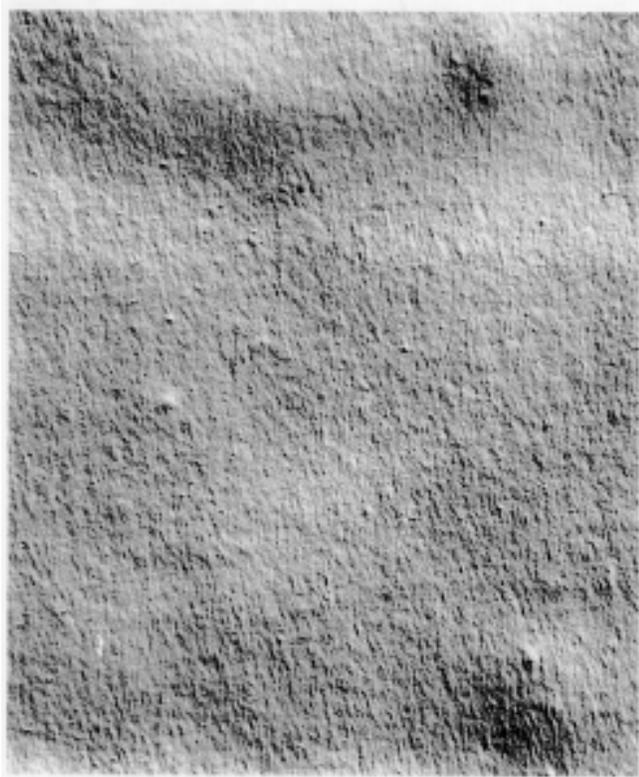


Figure 4: Magnification 100x 100 μm
Film Surface "B" - Unmetallized

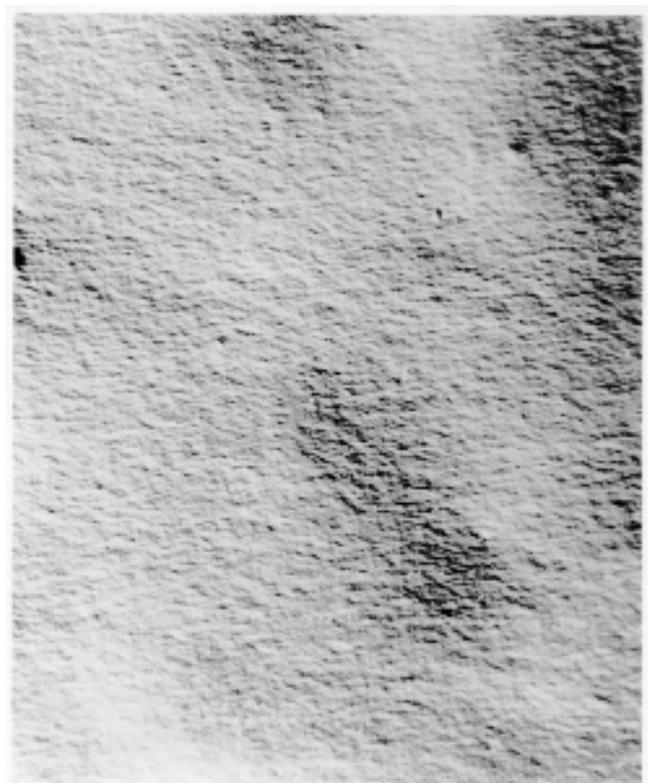


Figure 6: Magnification 100x 100 μm
Film Surface "B" - Metallized

CONCLUSION

The standard belief that optical defects in metallized oriented polypropylene films will create poor barrier is not always correct. Many “optical defects” may be seen while barrier is still excellent. One hypothesis to explain this would be that a thin layer of clear aluminum oxide exists in the defect areas.

With scratches and crazing, the damaged or fractured areas of the coated structure appear to be without metal but the barrier numbers indicate there may still be metal present. The resulting change in optical density from shading has been seen to have little or no impact on barrier properties if the film has a consistent surface. Although experience suggests that pinholes tend to increase permeation rates, samples with large numbers of pinholes have demonstrated good barrier. If the surface is properly controlled and more uniform, then metal damage has less impact on barrier.

In trying to explain good barrier in spite of optical defects, it is hypothesized that the metal layer on a more uniform film surface is more resistant to deep abrasive damage.

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