

Metallized Polymer Films as Replacement for Aluminum Foil in Packaging Applications

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ABSTRACT

As metallized polymer films such as oriented Polypropylene (oPP) or Polyester (PET) provide improved performance in terms of oxygen, water, and aroma barrier, they become a more interesting alternative to aluminum foil. Cost, performance, and ecological reasons are listed as reasons that push the metallized film as a replacement for foil. This presentation will look at the challenges, opportunities, and pitfalls that one encounters on the way to replace foil with film. Examples that have found their way into the industry will illustrate these challenges.

INTRODUCTION

For many years the Flexible Packaging Industry, specifically the producers of metallized polymer films, has had an eye on applications that use aluminum foil in its structures. This is understandable, considering that aluminum foil has a share of over 30% in the barrier packaging market worldwide. Any application where metallized film can replace the foil, holds the promise of considerable growth for metallized polymer films. Over the years, the most used approach for replacement of aluminum foil has been to engineer polymer films that achieve the outstanding oxygen and barrier performance of aluminum foils in order to strive for a direct replacement of foils. Presentations such as that given by Ferrari [1], and raising the question "Can You Finally Get Foil Barrier Properties With A Metallized Film?" bear witness of this direct 1:1 approach. Considering all the inherent properties of aluminum foil, as well as looking at the requirements and history of specific applications, it becomes obvious that such an approach only works in some instances. There are applications where metallized polymer films can replace aluminum foil almost instantly, while there are others where a series of factors need to be considered, barrier, stiffness, processability, and economics, to name a few. This presentation will look at some foil replacement issues, successful transitions, and possible future opportunities.

THE WORLD OF ALUMINUM FOIL IN BARRIER PACKAGING

In 2000 the yearly consumption of aluminum foil in packaging applications was about 1.53 million tons. The majority of this foil, about 800 ktons or 53%, was used in wrapping. The majority of this is standard household wrap that you will find in your kitchen. 240 ktons or 15% have been used for trays, while approximately 4% or 61 ktons have gone into other applications. That leaves roughly 28% or 430 ktons, which was used in Barrier Packaging Applications. Comparing this to the overall Barrier Packaging Material Consumption in 2000, this amounts to 32% share in a market that uses about 1.34 million tons of barrier packaging material worldwide. The largest consumer is North America, with a share of 23% of the foil usage in barrier packaging applications, followed by Europe with 22% and Japan with 13%. The other 42% are used throughout the rest of the world (ROW). The Annual Growth Rate (AGR) is predicted to be around 2.8% and 2.9% in North America and Europe, respectively, while it is expected that the ROW will have an AGR of about 3.9%. Japan, however will see a decline in the use of aluminum foil in barrier packaging applications, partly caused by environmental legislation.

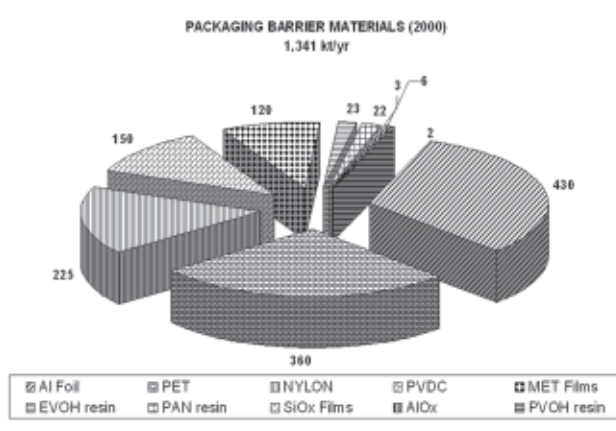


Figure 1: Worldwide Usage of Materials in Packaging Applications.

Of the 430 ktons of aluminum foil globally used in flexible packaging, 94 ktons (22 %) are used for packaging of Dry Mixes and 60 ktons (15%) go into confectionary applications. Pharmaceutical applications require 60 ktons (14%), mostly for the push through characteristic of aluminum. Other interesting areas are condiments, with 20 ktons or 5% of the foil used in flexible packaging, and about 34 ktons or 8% of the world use in dairy applications.

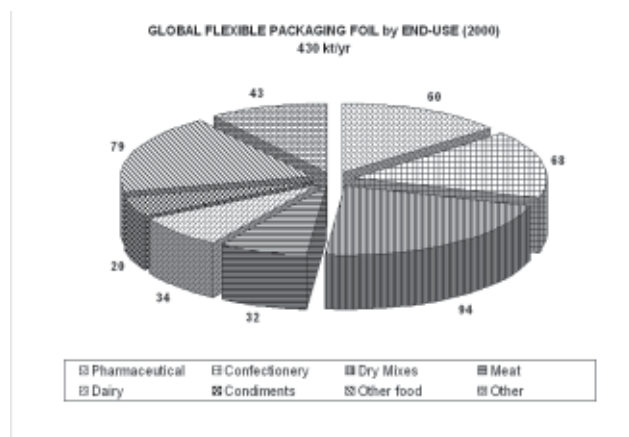


Figure 2: Areas and Usage of Foil in Barrier Packaging Applications.

Looking at these numbers one can understand the desire of the metallizing community to capture shares of these markets. The combined amounts of material used for dry mixes and condiments, for example, almost match the global use for metallized polymer films in packaging applications. In other words, if it is possible to fully convert these applications into metallized polymer films, the use of metallized film would essentially double. That is a very promising outlook.

But how will it be possible to capture these markets? How will it be possible to achieve the outstanding barrier properties of aluminum foil? By looking closer into the actual requirements of the barrier material in different packages, and why aluminum foil is used, one is actually surprised that barrier is either not a major obstacle or, sometimes, not even required at all.

THE PROPERTIES OF FOIL, OR WHY IS IT USED SO EXTENSIVELY?

When asked why aluminum foil is used in packaging applications, the most common answer is because of its outstanding barrier properties. Although this is one of the great features of aluminum foil, it is not the only reason why it is used for packaging. There are several attributes that make foil a choice:

1. **Oldest Barrier Material:** It was the first high barrier material available to flexible packaging.

2. **Nearly Perfect Oxygen and Moisture Barrier:** The oxygen and moisture barrier of a 7 mm thick aluminum foil is typically one to two magnitudes better than any barrier based on vacuum coated polymer films.
3. **Light Barrier:** Zero Transparency allows for perfect shielding against light.
4. **Push Through:** A main reason for its use in pharmaceutical packaging.
5. **Dead Fold Characteristics:** Good for wrapping applications such as confectionaries.
6. **Conductivity:** Allows the use of inductive sealing systems.
7. **Stiffness:** Young's Modulus is 16–20 times higher than oriented polypropylene or polyester.
8. **Heat Resistance:** Aluminum does not degrade in steam sterilization.

While some applications simply “hang on” to aluminum foil because it has historically been used in this particular application, others use aluminum foil for a combination of its advantages. For some applications these advantages are pure perception. By overcoming these market perceptions, metallized films have a chance of replacing foil. In addition, aluminum foil has some inherent disadvantages that should allow metallized film to make inroads into certain applications by overcoming these shortcomings:

1. **Crease Resistance:** Aluminum foil cracks easily when bent and folded, leaving large pinholes that effectively destroy the barrier property.
2. **Lack of Transparency:** Although an advantage in some applications, it is a disadvantage in others, even if a residual transparency (< 1%) is required.
3. **Thermoforming:** Aluminum foil cannot be thermoformed.
4. **Dimensional Stability in Thin Gauges:** As economics dictate use of thinner gauge foil, it becomes more susceptible to tear and pinholing.
5. **Recyclability:** Once laminated to polymer films, it is almost impossible to fully recycle the laminate.
6. **Economics:** Metallized films show cost advantages of 10% and more over aluminum foil.

WHICH APPLICATIONS ARE FIT FOR REPLACEMENT?

When looking into replacing foil with film, three major requirements need to be fulfilled:

1. **Function:** Does the film provide all the required properties?
2. **Economics:** Does the film provide any cost savings?
3. **Feasibility:** Is it possible to run film on the same equipment without major modifications?

Only if all three questions can be answered positively is it even worth looking into replacing foil with film. As with everything, the devil may lay in the details, and—as will be explained below—it may take some careful consideration to come to the right answers.

Function: Does the film provide all the required properties?

- **Barrier and Barrier Durability:** The first function that comes to mind is the barrier provided by foil, and so the question is: Can film provide the barrier I get from foil? How does the film structure handle stress, is the barrier as durable as foil? By looking into some of the applications where foil is used as a barrier, one will find that barrier requirements of foil are often times overstated. Two examples:

- Dairy products such as yogurt, cottage cheese, cream cheese, etc. are packaged in single- or multi-serve trays manufactured from Polystyrene (PS) or Polypropylene (PP), covered with a lid made from 60–65 μm aluminum foil. The oxygen permeability for PP is about 0.15

$\frac{\text{cm}^3}{\text{m}^2 \text{ atm}}$, a 500 mm thick wall therefore has a permeation

rate of about $300 \frac{\text{cm}^3 \text{ O}_2}{\text{m}^2 \text{ atm}}$. The permeability for the lidding foil is equal to zero. Considering, however, that only about 16 to 20% of the total package is covered with the high barrier material, the barrier function of the aluminum is questionable.

- Pouches for dry mixes such as hot cocoa mix, use Paper-Poly-Foil-Poly structures for the pouch material. The foil provides good barrier as long as the pouch is not handled. However, the pouch material wrinkles easily, and upon handling of the pouch, causes pinholes and cracks in the metal layer. At this point a Paper-Poly-MoPP-Poly structure outperforms the foil laminate, as the film can handle more stress without losing its barrier performance. It also was found through taste tests, that the film laminate achieves the same shelf life expectation as the foil laminate. The bottom line is that the assumed barrier requirement for the pouch material was too high, and that a lower, but more durable barrier, will do the job.



Figure 3: Samples of cheese in PP Cups: Lids of the two left samples are made from 60 – 65 mm aluminum foil. The right lid is a Poly-Foil-Poly laminate with a total thickness of ~80 mm. This type of lid typically shows better printing.



Figure 4: Samples of Paper-Poly-Foil-Poly Pouches. Wrinkles on the pouches were present when taken from shelf.

- **Light Barrier:** Most metallized films are metallized to an optical density in the range of 2.3 to 2.5. This means that the transmission rate for light in the visible range is reduced to about 0.4%, while UV penetration is practically eliminated. If laminated to paper, this transmission rate is further reduced. For almost all food applications, this light blocking characteristic is sufficient. Only certain technical applications, such as wrap for undeveloped photographic film, could require the absolute light block that thicker gauge aluminum foil provides.
- **Push Through Characteristic:** This is a requirement mostly coming from the pharmaceutical market, and it actually utilizes one of the weak points of aluminum, its low tear resistance in thin gauge. Unless a film can be found that provides similarly low tear resistance, foil will hold its place in this application. The required barrier can be met with standard metallized film, as the blister package typically is not a high barrier material.

- **Conductivity:** This feature is required where induction sealing is used to seal packages. By applying a high frequency electromagnetic magnetic field eddy currents are generated in the foil, which heat the foil. Because of the heat resistance of the foil, this temperature can be high enough to activate the sealant in the laminate. Current induction sealing equipment is not capable of creating the same effect in metallized film, but development work is underway.
- **Heat Resistance:** Some packaging applications require steam sterilization of the package prior to filling and sealing, or while hot filling. Metallized film will not withstand the heat and moisture during this process and will rapidly degrade. Films with clear barrier based on oxides, however, do withstand this process, and if light barrier is not a requirement they offer an alternative in those applications.
- **Dead Fold:** Film typically does not have the same dead fold characteristics that foil has, which – again – makes it difficult to replace aluminum foil in applications where dead fold is a major criterion, such as chocolate wrap or confectionary packages.

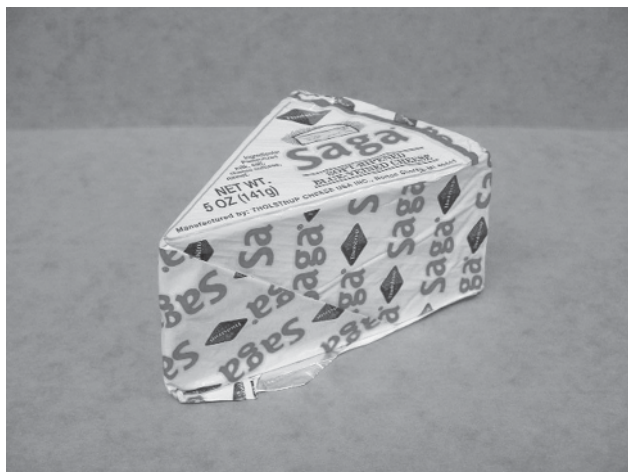


Figure 5: Poly-Foil-Poly Structure used in a wrapping application.

Economics: Does the film provide any cost savings?

Table 1 lists some of the metallized oPP and PET films that compete against aluminum foil. As one can see, metallized film does offer cost and yield advantages of up to 30% and more, depending on the type of foil replaced and the replacement film used. The table does not include, however, other cost savings that can be realized by using film. One example is the fact that aluminum foil needs to be primed prior to lamination to achieve the required adhesion. Some metallized film does not require priming, thus it not only eliminates one process step but also reduces the cost for consumables (i.e., the primer). Another aspect of cost savings not detailed here may play a role in the European area, where the “Green Point”

imposes a tax on packaging material based on its weight. With the yield advantage that most films present, this tax will be lower.

Table 1: Cost Comparison between Foil and Metallized oPP and PET.

RAW MATERIAL COMPARISON									
FOIL'S				35.30 TORAY (TPEu) MET. PET.					
Thick µm	Yield	Price	MSI	Thick µm	Yield	Price/kg	MSI	Savings	
6.35	58.45	\$ 3.97	\$ 0.07	12	58.79	\$ 4.52	\$ 0.08	-\$0.009	-13%
7.24	51.20	\$ 3.86	\$ 0.08	12	58.79	\$ 4.52	\$ 0.08	-\$0.001	-2%
7.62	48.64	\$ 3.86	\$ 0.08	12	58.79	\$ 4.52	\$ 0.08	\$0.0024	3%
8.89	38.20	\$ 3.75	\$ 0.10	12	58.79	\$ 4.52	\$ 0.08	\$0.0212	22%
FOIL'S				MB61N TORAY (RI) MET. PET.					
Thick µm	Yield	Price	MSI	Thick µm	Yield	Price/kg	32.62	Savings	
6.35	58.45	\$ 3.97	\$ 0.07	12	58.79	\$ 3.64	\$ 0.06	\$0.0060	9%
7.24	51.20	\$ 3.86	\$ 0.08	12	58.79	\$ 3.64	\$ 0.06	\$0.0135	18%
7.62	48.64	\$ 3.86	\$ 0.08	12	58.79	\$ 3.64	\$ 0.06	\$0.0174	22%
8.89	38.20	\$ 3.75	\$ 0.10	12	58.79	\$ 3.64	\$ 0.06	\$0.0362	37%
FOIL'S				MB35N TORAY (RI), 34.10 TORAY (TPEu) MET. PET.					
Thick µm	Yield	Price	MSI	Thick µm	Yield	Price/kg	35.3	Savings	
6.35	58.45	\$ 3.97	\$ 0.07	12	58.79	\$ 3.86	\$ 0.07	\$0.0023	3%
7.24	51.20	\$ 3.86	\$ 0.08	12	58.79	\$ 3.86	\$ 0.07	\$0.0097	13%
7.62	48.64	\$ 3.86	\$ 0.08	12	58.79	\$ 3.86	\$ 0.07	\$0.0137	17%
8.89	38.20	\$ 3.75	\$ 0.10	12	58.79	\$ 3.86	\$ 0.07	\$0.0325	33%

Feasibility: Is it possible to run film on the same equipment without major modifications?

A general obstacle to convince converters to use film instead of foil is the concern on how film will perform on the existing equipment. Any kind of cost savings that film can provide would be obliterated if it requires major investments the modification of existing or the purchase of new equipment. One major difference between foil and film is the difference in stiffness, which may require changing tension settings throughout the converting line. The lower rigidity of the package may also pose some problems in the fill stations, thus requiring readjustments or modifications in this area. Paper-Film laminates have a higher tendency to roll up than Paper-Foil laminates, which may also cause problems.

In many cases, these problems can be overcome with early involvement of the equipment manufacturer. Using their experience, long-term problems or early disappointment in the performance of film on the existing equipment can be avoided. With the higher tear resistance of most films when compared to foil, it is even possible to reduce failure rates due to tear in the converting lines. Applications that use inductive sealing or dead folding, however, may still face larger obstacles. Only if the manufacturers of inductance sealers can

come up with a way to modify their equipment in a cost effective way to work with metallized film, and the film manufacturers and metallizers come up with a film that provides the required functionality, it will not be possible to replace foil in these areas. At the present time this is valid for dead fold applications as well.

It requires a good analysis of the three issues above to make a case for film vs. foil. But with the advantages that film can offer—e.g. higher barrier durability (even if the flat sheet barrier is lower), better economics, and the possibility to use film in the existing equipment—there are lots of opportunities for metallized film.

CASE STUDY: COCOA MIX POWDER POUCHES

This case will demonstrate the typical process that one will face when going through the foil replacement process.

The targeted structure is a paper-poly-foil-poly laminate that is folded, sealed on the side, filled, and then top sealed. This structure used a thin gauge aluminum foil and was targeted to be replaced with one of Toray's PC products.

Economics were promising. Using a Toray PC product, a cost advantage of almost 28% was expected. Additional savings were possible since the metallized oPP does not require primer in the lamination.

Function was compared by producing a limited amount of laminates and filling pouches for a comparative shelf life test. Some bags were exposed to additional handling, creating wrinkles in the original structure. No difference could be seen in terms of taste and freshness on the non-wrinkled samples, indicating that the barrier property of the proposed structure is sufficient. On the wrinkled samples, there was a high failure rate with the original structure, while there were none on the proposed structure, proving that the foil does fail under stress. Overall, the tests showed that the proposed metallized oPP would provide the barrier properties that are required.

On the **feasibility** side, it was clear that modifications were required. Changing the tensions on the converting system was done early in the project. One of the properties of the foil laminate allows the pouch to be opened and positioned on a transport belt (similar to the dead fold characteristics), could not be replicated with the film laminate. Modifications on the filling line and a small additional device were required to blow the pouch open prior to filling. The higher tear resistance of the film laminate also made it more difficult to rip open the pouch, so that a notching device had to be added to the converting and filling line. This modification, however, was viewed as a benefit, as it was found that the pouch now opens more defined and with less chance of spilling. All the modifications, however, did not exceed the expected savings, and were accepted because of the additional benefits.



Figure 6: Hot Cocoa Mix Pouches.

The bottom line is that the proposed structure has replaced the aluminum foil in this application. The overall appearance of the pouch, although thinner by the touch, is more attractive as it does not wrinkle anymore. Total time for the project, however, was close to two years, demonstrating that despite the final results success does not come easily.

OPPORTUNITIES FOR FOIL REPLACEMENT

The major objection against using metallized film is still the perception of the barrier that might be required for a specific application. As was shown in the case study, this requirement might not be as stringent as thought, and in some cases the initially lower flat sheet barrier performance of a film laminate outperforms the foil if the laminate is exposed to certain forms of stress. Table 2 gives a list of other potential candidates where metallized film could replace foil in packaging structures. It also shows some of the hurdles that one can expect, and as explained before, some of these might be hard or impossible to overcome. Some applications such as coffee packages—with the exception of fractional coffee that is already packaged in metallized film laminates—may still require the extremely good barrier that foil provides, and will be difficult to get into without comparative films.

There are new developments that may overcome some of the problems:

- Recently presented were metallized films that combine barrier coatings and metallizing on polymer films they yield very promising barrier properties [1, 3]. It remains to be seen, though, whether they can compete on an economic level.
- New film types such as Poly-lactic Acid (PLA) show very good dead fold characteristics, and they are biodegradable. Currently they cannot compete on the economic level, but once availability increases they will have a chance to take applications from foil where dead fold is required.

- It may be possible to use specialty metallized films in modified induction sealing equipment. The market is ready to get away from foil in applications such as liquid paper-based packages (i.e. bricks) once this is possible.

SUMMARY

The outlook for the metallizing industry to gain business in applications that currently use foil in the packaging structure looks good. New developments in film technology that promise even better barrier properties or additional properties that mimic aluminum foil will help in this aspect. The largest barrier, however, remains the overall perception that aluminum foil is the non-plus ultra for packaging applications, and here the economics of the metallized film, paired with its inherent properties, is the main argument that will help to replace foil in packaging materials.

And the answer to the question “Can metallized film finally replace aluminum foil?” is: “It already does!”

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Table 2: Foil Replacement Opportunities and the Hurdles.

Finished Good	Current Structure:	Potential Structure(s):	Hurdles
Hot Fill Sauce Pouch	48ga Nylon/ 8# PE-EAA / 30g Foil/8#EAA-PE/ 1.75 mil LLDPE	1) 48ga Nylon/ 8# PE-EAA/45ga MOPP/8#EAA-PE/ 1.75 mil LLDPE 2) 48ga Nylon/ 8# PE-EAA/48ga MPET/8#EAA-PE/ 1.75 mil LLDPE	Hot-fill
Dry Powder Pouch	18# Tissue/10# PE /30g Foil/10# PE	1) 18# Tissue/10# PE/45ga PCF/10# PE 2) OL / Ink / 45 MOPP / Adh / 25/lb Ext. Coated Paper	Dead Fold 0.01 MVTR & 02TR
Powdered Drinks	28# Paper/5# LDPE/25 foil/8# EAA-PE	1) 28# Paper / 5# LDPE / 45ga MOPP / 8# EAA-PE 2) OL / Ink / 45 MOPP / Adh / 25/lb Ext. Coated Paper	Dead fold
Coffee	48ga PET/Ink/Adh / 35 Foil /Adh/ 60ga Nylon/Adh/ 2.75 LLDPE	1) 48ga PET/Ink/Adh/48ga MPET/Adh/60ga Nylon/Adh/ 2.75 LLDPE 2) 72ga OPP / Ink / adh / 48ga MPET / Adh / 60ga Nylon / Adh / 2.75 LLDPE	02TR .01 flat sheet 6-800 bonds to Nylon 4-600 bonds metal side
Lidstock	40ga PET/Ink/Adh/135gaAL/Peelex	(1) OL /Ink /45ga PC-2 / Adh / 35/lb Paper / Peelex (2) 120ga OPP / Ink / adh / 48ga MPET / Peelex (3) OL /Ink /48ga MPET/Adh/35/lb Paper/Peelex	Thermal Stability Tear
Stand Up Pouch	48ga PET/Ink/Adh/35g foil/Adh/400g PE	(1)48ga PET/Ink/Adh/48ga MPET/Adh/400g PE (2)32ga PET/Ink/Adh/45ga MOPP /Adh/400g PE (3)120ga OPP/Ink/Adh/45ga MOPP /Adh/400g PE	Hot-fill 0.01 MVTR & 02TR Converters feel Metal bonds need to be 800+ grams
Seasoning Pouch	Varn/Ink/35# Paper/7# PE/28.5 Foil/12# EAA-LDPE	(1) Varn/Ink/35# Paper/7# PE/45ga MOPP/12# EAA-LDPE (2) OL / Ink / 45 MOPP / Adh / 25/lb Ext. Coated Paper	Dead Fold