Improve Barrier Properties and Significantly Reduce Your Carbon Footprint with In-Line Metallizing and Top-Coating

Veronica Ataya and Dante Ferrari
Celplast Metallized Products Ltd.

Presented at the AIMCAL Fall Technical Conference
October 23 - 26, 2011

The In-Line Metallizing and Coating Process

The traditional method of preparing a top-coated metallized film using roll-to-roll processes is to carry out two separate, independent steps:

- Unwind the film under vacuum, metallize the film surface, rewind the film under vacuum, vent the chamber to atmosphere.
- Unwind the film in atmosphere, top-coat the metallized surface, rewind the film in atmosphere.

This two-step process creates certain inherent disadvantages, such as high operating and capital costs[2], which we attempted to overcome by retrofitting a traditional single zone free-span metallizing chamber with an in-line top-coating process directly after the metallizing area. We also found that barrier could be significantly improved over standard metallizing, and hence opportunities were created to assist consumer goods companies to reduce the carbon footprint of their packaged goods.

Barrier Properties of Top-coated Metallized Films

Two of the most important variables to consider when determining the shelf life of a packaged product are Water Vapour Transmission Rate (WVTR) and Oxygen Transmission Rate (OTR). They represent the rate at which water vapour and oxygen permeate through the package under steady state conditions. Top coating metallized films has been designed as a process to improve the barrier properties of metallized films by reducing the presence of defects and protecting it from scratches in downstream processing. Furthermore, metallizing and coating in a single step provides many advantages compare to a two step process, including minimal pinholing and scratches and excellent barrier properties. [1]

Different types of films were metallized and top-coated in a single step and tested for WVTR and OTR. Coat weight was in the range of 0.3-0.5. WVTR tests were performed at 37.8°C and 90% RH, following ASTM E-398 on a Lyssy L80-5000 with a lower detection limit of 0.0019 g/100in^2/day. OTR tests were performed at 23°C and 50% RH, following ASTM D-3985 on an Illinois Instruments 8001 with a lower detection limit of 0.0005 cc/100in^2/day; except for 36G PET, where 0% RH was used. Values for WVTR and OTR are reported in g/100in^2/day and cc/100in^2/day, respectively.

Tables 1 and 2 present values for WVTR and OTR of uncoated and coated metallized OPP, PLA and PET, at different optical densities. It is possible to significantly improve the barrier properties of the films by metallizing and coating in a single step and without having to work at optical densities greater than 2.0-2.3. This is a great advantage since metallizing at higher optical densities introduces high risks for pinholing and spitting, which affect negatively the barrier properties and quality of the end product.

Table 1. WVTR* values for different types of coated and uncoated metallized films

Material	Uncoated	Coated	OD	Improvement (%)	
70G OPP	0.006	0.002	3.50	66.7	Avg= 69.7
70G OPP	0.011	0.003	3.50	72.7	SD= 4.3
80G PLA	0.282	0.107	1.40	62.1	Avg= 63.1
80G PLA	0.240	0.086	2.05	64.2	SD= 1.5
36G PET	0.081	0.027	2.40	66.7	
48G PET	0.070	0.007	1.25	90.0	
48G PET	0.060	0.007	1.80	88.3	
48G PET	0.050	0.006	2.10	88.0	Avg= 85.3
48G PET	0.040	0.006	2.20	85.0	SD= 6.3
48G PET	0.040	0.005	2.30	87.5	
48G PET	0.011	0.003	3.20	72.7	

*Values in g/100in^2/24h at 37.8° and 90%RH

Table 2. OTR* values for different types of coated and uncoated metallized films

Material	Uncoated	Coated	OD	Improvement (%)	
70G OPP	1.480	0.273	3.50	81.6	Avg= 84.8
70G OPP	2.600	0.310	3.50	88.1	SD= 4.6
36G PET**	0.046	0.016	2.40	65.2	
48G PET	0.060	0.010	2.00	83.3	
48G PET	0.070	0.008	2.10	88.6	Avg= 85.1
48G PET	0.060	0.009	2.20	85.0	SD= 2.7
48G PET	0.060	0.010	2.30	83.3	

*Values in cc/100in^2/24h at 23°C and 50%RH
**Value measured at 0% RH

For coated OPP, an average improvement of 69.7% in WVTR can be achieved over uncoated metallized film at an optical density of 3.5, reaching a final steady value of 0.002-0.003 g/100in^2/day. For OTR, an average improvement of 84.8% was observed at the same optical density.

For PLA, the average improvement in WVTR was 63.1% at two different optical densities, reaching a value of 0.086 g/100in^2/day at an optical density of 2.05. This represents a great advance in metallizing PLA films, where it is very difficult to achieve WVTR values lower than 0.15 g/100in^2/day. For 36G PET, WVTR and OTR can be improved by 66.7% and 65.2%, respectively, at an optical density of 2.4.

For 48G PET, an average improvement in water barrier of 85.3% was observed for optical densities varying between 1.25 and 3.20. It is possible to reach WVTR values as low as 0.005 g/100in^2/day without having to increase considerably the optical density of the film. Oxygen transmission rate can also be decreased to 0.01 cc/100in^2/day or lower (85% improvement) at an optical density of 2.00-2.30.

Barrier properties of metallized film depend on the optical density of the sample, being higher for increasing optical densities. A sample with an optical density of 3.0 should have better barrier properties than a sample of the same film with an optical density of 2.0. Figures 1 and 2 show the improvement in WVTR and OTR of coated metallized 48G PET at different optical densities vs. uncoated metallized PET.

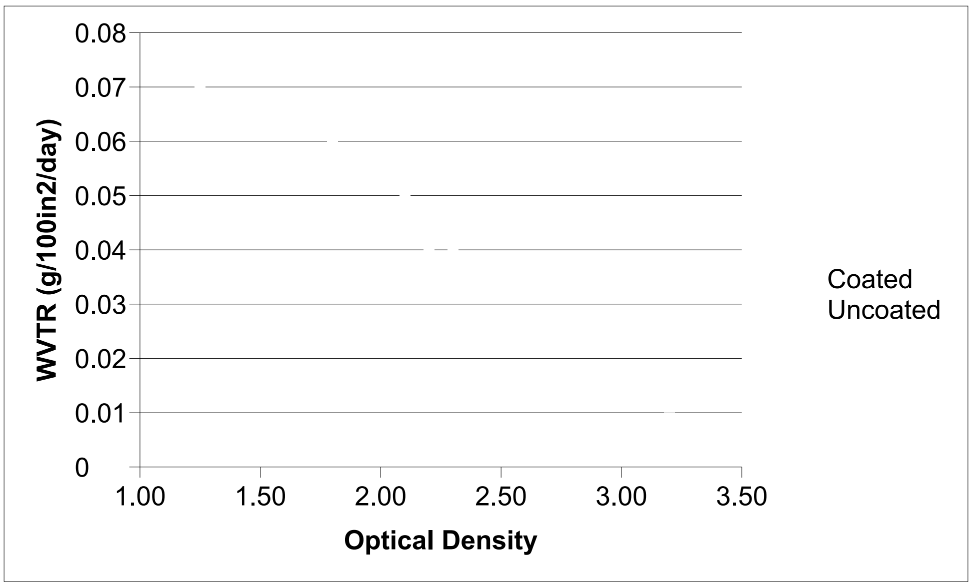

Figure 1. WVTR of coated and uncoated metallized 48G PET

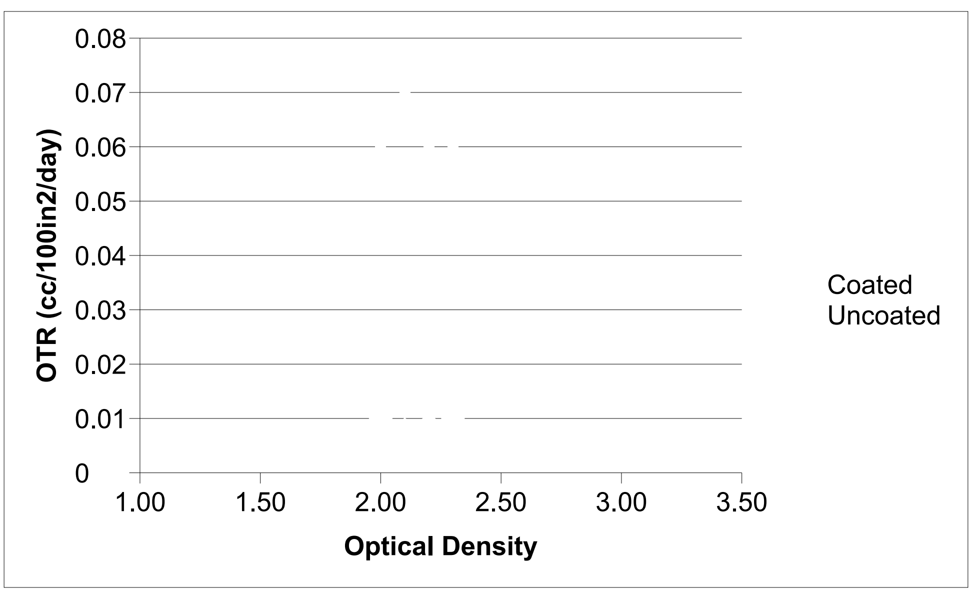

Figure 2. OTR of coated and uncoated metallized 48G PET

It can be seen that at lower optical densities the improvement is much larger than at higher optical densities, due to the fact that uncoated metallized films at optical densities below 1.5 have much lower barrier properties and there is more room for improvement. As optical density increases, barrier properties improve for the uncoated metallized film making the effect less noticeable but still providing excellent transmission rates as low as 0.003 g/100in^2/day for WVTR and 0.01 cc/100in^2/day for OTR.

Reducing Carbon Footprint

First, we need to compare the carbon footprint of the combined traditional two-step process with the one-step in-line metallizing and top-coating process.

Table 3. Energy and carbon footprint comparisons between two and one step processes

	Two Step Process			**One Step Process**	**% Reduction**
	Metallizing	**EB coating**	**Total**	**Metallizing and EB Coating**	
Energy footprint					
Line speed (fpm)	1200	600		600	
Average kW consumption	440	480		480	
Minutes to produce a 60,000' roll	90	100		132	
Power consumption/roll (kW-hr)	660	800	1460	1056	28%
Power consumption (MJ/ream)	27	33	60	43	28%
CO2 equivalent/roll (MT)	0.47	0.57	1.05	0.76	28%
Energy CO2 equivalent (kg/ream)	**5.4**	**6.5**	**11.9**	**8.6**	**28%**
Material footprint					
Coatings - CO2 eq. (kg/ream)	0.2	3.0	3.2	3.2	0%
Substrate yield loss - CO2 eq.(kg/ream)	1.0	1.0	2.1	1.3	40%
Material CO2 equivalent (kg/ream)	**1.2**	**4.0**	**5.3**	**4.5**	**16%**
Total carbon footprint (kg/ream)	**6.6**	**10.5**	**17.2**	**13.1**	**24%**

This comparison is based on metallizing and top-coating a roll of standard 48 g PET, 53” wide, 60,000 ft in length. For most power consumption values, a measuring and verification study was carried out at Celplast. For equipment outside the scope of this study, power consumption is based on manufacturer’s specifications, using a standardized power factor of 0.81 where applicable. An Ontario Power Generation energy footprint of 1392 kW-hr/MT CO_2 equivalent was used, based on a converter operating in the province of Ontario, Canada. It was also assumed there would be a total (MD and TD) yield loss of 5% with each of the metallizing and top-coating steps, while the single pass process would incur a total film yield loss of 6%. It can be seen that the total carbon footprint of the one-step process is approximately 24% lower than that of the two separate processes.

More importantly, since the one-step process allows one to achieve superior barrier to traditional metallizing and top-coating, it opens the possibilities for new laminated and unlaminated structures to be introduced into the marketplace. The following figures show current and new structures that are possible, with material reduction calculations shown in each case.

3-ply laminated structure		2-ply laminated structure	
Layer Description	Material Weight (g/msi)	Layer Description	Material Weight (g/msi)
SB reverse print PET	11.7		
SB adhesive lamination	0.8	SB reverse print PET	11.7
27.5 g Al foil	12.2	SB adhesive lamination	0.8
SB adhesive lamination	0.8	Metallizing and EB coating	0.8
1.5 mil sealant web	22.8	1.5 mil sealant web	22.8
Total Material Weight (g/msi)	48	Total Material Weight (g/msi)	36
	Material reduction:	**25.3%**	

Figure 3. Material Reduction for a typical dry drink powder pouch or stick pack structure.

2-ply laminated structure		Single ply structure	
Layer Description	Material Weight (g/msi)	Layer Description	Material Weight (g/msi)
SB surface print	11.7		
48 g metallized PET	10.9	SB surface print	11.7
SB adhesive lamination	0.8	Metallizing and EB coating	0.8
1.5 mil sealant web	22.8	1.5 mil sealant web	22.8
Total Material Weight (g/msi)	46	Total Material Weight (g/msi)	35
	Material reduction:	**23.6%**	

Figure 4. Material Reduction for a typical fractional coffee pouch

2-ply unprinted laminated structure		Single ply unlaminated structure	
Layer Description	Material Weight (g/msi)	Layer Description	Material Weight (g/msi)
Unprinted 60 g OPP	8.8		
8.5 lbs LDPE adhesive	8.9	Metallizing and EB coating	0.8
Metallized layer	0.0	Heat sealable 140 g OPP	20.5
Heat sealable 60 g OPP	8.8		
Total Material Weight (g/msi)	27	Total Material Weight (g/msi)	21
	Material reduction:	**19.5%**	

Figure 5. Material Reduction for a typical bag in box pouch

Similarly, converting energy[2,3] and carbon footprint[4] balances can be compared between each structure. These are shown in the examples for the 2-ply extrusion laminated OPP versus 1-ply metallized and top-coated OPP pouch structures.

Layer Description	Energy Usage (MJ/ream)	Layer Description	Energy Usage (MJ/ream)
Unprinted 60 g OPP	0		
8.5 lbs LDPE adhesive	162	Metallizing and EB coating	43
Metallized layer	27	Heat sealable 140 g OPP	0
Heat sealable 60 g OPP	0		
Total Energy Usage (MJ/rm)	189	Total Energy Usage (MJ/rm)	43
	Energy reduction:	**77.2%**	

Figure 6. Converting energy reduction for a typical bag in box pouch

Layer Description	CO2 Equivalent (kg/ream)	Layer Description	CO2 Equivalent (kg/ream)

Unprinted 60 g OPP	12.9		
8.5 lbs LDPE adhesive	77.8	Metallizing and EB coating	13.0
Metallized layer	6.6	Heat sealable 140 g OPP	30.1
Heat sealable 60 g OPP	12.9		
Total CO2 Equiv. (kg/ream)	106	Total CO2 Equiv. (kg/ream)	43
Carbon footprint reduction:	**60.9%**		

Figure 7. Carbon footprint reduction for a typical bag in box pouch

Similar calculations were carried out to determine the converting energy and carbon footprint of each of the other two typical structures examined here, both with the traditional structure and the new structure with the one-pass metallizing and EB coating. Table 4 summarizes the material, converting energy and carbon footprint reductions that are potentially achievable with each structure.

Table 4. Material, energy and carbon footprint reductions of top-coated metallized structures

Traditional Structure	New Structure	% Reduction		
		Material Weight	Energy Usage	CO2 Footprint
Surface Print Met PET / LLDPE	Top-coat met LLDPE	23.6	43.2	43.6
Rev. Print PET / Al Foil / LLDPE	Rev. Print PET / Top-coat met LLDPE	25.3	26.3	39.6
Clear OPP / Met OPP	Top-coat met OPP	19.5	77.2	60.9

Conclusion

It is possible to achieve excellent WVTR and OTR values for PET, OPP and PLA films by metallizing and coating in a single step. Barrier properties for a single coated metallized sheet can be as low as what it is normally obtained by laminating many layers together, therefore reducing material consumption. The process is more cost effective than the traditional two step process; it reduces power consumption and provides great carbon footprint reductions. Moreover, the combination of both exceptional barrier properties and carbon footprint reductions opens the doors to new unlaminated and laminated structures with enormous potential in the converting industry.

References

1. Dante Ferrari. “Properties of EB Top-Coated Metallized Films Prepared in Vacuum”. *AIMCAL Fall Technical Conference* (2010).
2. Dante Ferrari, “What Sustainable Packaging Means to Brand Owners, and What We Can Do About It”, *AIMCAL Fall Technical Conference* (2009).
3. Rick DiMenna, “Life Cycle Inventories for Flexible Packaging Lamination”, *Rohm and Haas Technical Bulletin.*
4. I. Boustead, “Eco-profiles of the European Plastics Industry”, *Plastics Europe* (2005).