Extrusion Coating with PVOH to Produce High-Barrier Paper-Based Packaging

Presented by Aquapak Polymers Ltd., Mica Corporation and SAM North America

Abstract

In this paper, we will discuss the process of extrusion coating polyvinyl alcohol (PVOH) to produce high-barrier paper-based packaging. As flexible packaging companies look to replace traditional multi-layer packaging with recyclable or compostable alternatives, many are considering the use of paper-based packaging and biopolymers or bio-based resins to achieve similar properties with improved end-of-life options. Another consideration is that extrudable PVOH is fully water soluble in the recycling process. Incorporating paper and extrudable PVOH in the extrusion coating process comes with a unique set of challenges. In this paper, we will present a solution for extrusion coating PVOH on paper, including the processing parameters, equipment, water-based primer and conditions necessary for success. We will also discuss opportunities for making more advanced structures, building on this solution.

Introduction

As the demand for sustainable flexible packaging increases globally, companies are taking steps to replace traditional multi-layer plastic packaging with recyclable or compostable alternatives to improve end-of-life options. This has driven rapid development of new packaging materials and formats utilizing paper substrates and functional coatings.

Compared to plastic packaging, paper has a higher recycling rate and ability to degrade in nature or an industrial composting facility. However, lack of barrier properties and poor mechanical strength are obstacles to using thin paper in packaging.

The introduction of an extrudable PVOH resin provides a way to make paper-based barrier packaging due to PVOH's excellent barrier properties against oxygen, oil and grease, its heat seal properties and very good mechanical strength. Additionally, thermally processible PVOH is compatible with paper recycling and repulping processes. [1] It is fully soluble in warm water at 40°C without leaving a residual of microplastics and is also non-toxic and safe for marine life. [2]

Despite the many advantages shown by extrudable PVOH resin, adhesion of PVOH resin to paper substrates can be challenging due to its rapid crystallization rate. Common methods used to increase adhesion of LDPE, such as corona, flame, ozone or high air gap, do not work with PVOH. Increasing the melt temperature seems to be effective in improving adhesion, but PVOH can degrade at high temperatures (>220°C). Research has been done to address this challenge related to PVOH extrusion.

In a previous contribution to TAPPI on PVOH extrusion [3], results show that polyethyleneimine (PEI) based primers can improve the adhesion of PVOH to paper. Using primer to improve adhesion between dissimilar packaging materials is an integral step in the extrusion coating process. Water-based PEI primers can form hydrogen bonds with a variety of polymer materials including PVOH. It may also help the penetration of PVOH into the paper matrix.

Since the publication of the previous work, more studies and trials have been conducted to further improve the technique. Properties such as solids content and coat weight of the PEI-based primer and processing parameters such as line speed were further investigated and optimized. We have discovered a way to improve the adhesion of PVOH to a variety of papers to the same level as that of LDPE (Figure-1) by adjusting extrusion speed and the application of a water-based primer.

Figure-1 Comparison of PVOH coatings on paper

In the new study, we also conducted the coextrusion of PVOH and LDPE and evaluated the limits for downgauging. Coextruding PVOH with other polymers such as LDPE can be done to create structures where improved resistance to water or water vapor is required. Additionally, we will discuss opportunities for making more advanced structures, building on this solution.

Experimental Design

The experiment in this study consisted of three phases conducted at Mica Corporation, Aquapak Polymers and SAM North America.

- Phase I: Evaluate PVOH adhesion with various water-based extrusion coating primers
- Phase II: Test adhesion of PVOH on various primed paper substrates
- Phase III: Determine machine and coat weight parameters and processing conditions

In the following sections, each phase of the experiment is described in more detail.

Phase I: Evaluate PVOH adhesion with various water-based extrusion coating primers

In the first phase of the experiment, the PEI-based primer identified from the previous study was further evaluated against other primers of various solids contents and chemistries.

The study was conducted on a lab-scale Randcastle extrusion coater which consists of three heated and cooled barrel zones and a 1” (25 mm) general purpose screw with L/D ratio of 24. It is equipped with a 10” (25 cm) width slot die.

Seven primers were evaluated against the control and bare substrate, including PEI-2 (polyethyleneimine, 12% solids), EAA-1 (ethylene acrylic acid,10% solids), VAE-1 (vinyl acetate ethylene, 50% solids), PU-1 (polyurethane, 30% solids), POE-1 (polyolefins, 40% solids), PVOH-1 (polyvinyl alcohol, 8% solids), ACR-1 (acrylate, 40% solids). The control was PEI-1 (polyethyleneimine, 5% solids).

Sheets of a 68 gsm kraft paper were used as substrate for PVOH coating. They were corona treated, hand coated with primer using wire wound rods and then dried. The coat weight of the primers was controlled by the size of the rods.

The PVOH resin has a density of 1150-1250 g/cm^3, MFR of 10.0-14.5 g/10 mins and melting temperature of 170-180^{o}C. It was extruded at 410°F (210°C). The rpm of the extruder (35 rpm) and line speed (33 fpm or 10 mpm) provided ~1 mil (25.4 µm) coating thickness. The adhesion level was checked immediately and after one day of coating by the degree of fiber tearing.

Phase II: Test adhesion of PVOH on various primed paper substrates

In the second phase, various paper substrates and finishings were evaluated with selected water-based primers and PVOH resin on a lab-scale extrusion coater which consists of five heated and cooled barrel zones and a 25 mm general purpose screw with L/D ratio of 24. It is equipped with a 20 cm width slot die.

Three primers were investigated, based on the results of Phase I. They included PEI-2 that was identified having the best performance from Phase I and two controls, PEI-1 and PEI-3. PEI-I and PEI-3 have similar solid content and composition. Paper samples and finishings included the gloss and matte sides of a 50 gsm MG kraft paper, one side of a 100 gsm recycled kraft paper, the gloss and matte sides of an 80 gsm MF kraft paper, the metal side of a metalized paper and the metal side of a metalized PVOH-coated paper.

The paper sheets were first primed using three sizes of K bar. Yellow K bar (6 µm wet thickness), red K bar (12 µm wet thickness) and green K bar (24 µm wet thickness). Primed surfaces were thoroughly dried. Then, papers were extrusion coated with the PVOH resin at a temperature of 205°C and line speed of 10 mpm. The adhesion of PVOH to paper was checked for fiber tearing. Primers were compared by the minimal wet coating weights required for the onset of fiber tearing.

Phase III: Determine machine and coat weight parameters and processing conditions

The third phase of the study was conducted on SAM North America's pilot extrusion coater with priming capability. This extrusion coating line consists of three extruders which are 2 ½" (64 mm), 2" (51 mm) and 1 ¼" (32 mm) in diameter each at 34:1 L/D, through a 5-layer vane adjustable feedblock and a 40" (102 cm) NordsonEDI EPC internally deckled die. Up to two extruders were used in the study.

The priming station runs with a direct gravure applicator, a chambered doctor blade with a circulation pump and a two-zone heated air drier. The gravure cylinder used was a banded cylinder with five bands. The design and the BCM of each band are shown in Figure-2. The actual coat weight of three bands at the center of the cylinder after calibration with a PET film at line speed of 200 fpm (61 mpm) were 1.0, 1.4 and 1.2 lbs/ream (1.7, 2.3 and 1.9 gsm). The measured values for the two bands on the edge were not accurate due to the wrinkle in the film and a slight misalignment in the test.

The structures produced included a PVOH monolayer and a coextruded structure of PVOH and LDPE. Raw materials for the experiment included the extrudable PVOH, PEI-2 which was used directly without any dilution, LDPE (MFR: 5-6 g/10 mins), and MAH grafted tie resin. A blend of the LDPE and tie resin at 30% was coextruded with PVOH. Paper substrates included a 30# (48 gsm) unbleached MF kraft paper.

The extrusion was carried out at 430˚F and line speeds from 200 fpm (61 mpm) to 600 fpm (183 mpm). At 200 and 300 fpm (91 mpm), the extruder speed was adjusted proportionally with the line speed to keep the coating thickness relatively constant (~1 mil or 25.4 µm). For 300 fpm (91 mpm) and above, the extruder speed was held constant and the thickness diminished proportionally to line speed, namely 0.75 mil (19 µm) at 400 fpm (122 mpm), 0.60 mil (15.2 µm) at 500 fpm (152 mpm) and 0.5 mil (12.7 um) at 600 fpm (183 mpm). The finished paper and PVOH laminates were checked for fiber tearing and adhesion strength which was measured by T-peel.

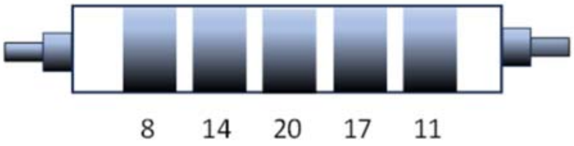

Figure-2 Schematic drawing of banded gravure cylinder used in the extrusion coating

Results

The results of Phase I are shown in Table-1 and illustrated on Figure-3. Various primers were tested against PVOH resin on a kraft paper substrate. The coat weights of primers were determined based on the recommended values for their original applications and thus different in this study. However, the coat weights of PEI-1 and PEI-2 primers were kept as close as possible, only limited by the sizes of wired rods.

It is clear from the results, that only PEI-based primers can lead to fiber tearing between PVOH resin and paper. Among them, PEI-2 which has more than twice the solids of PEI-1 showed the highest fiber tearing. Additionally, the extent of fiber tearing increased over 24 hours for PEI-2. The high efficacy of PEI priming can be attributed to its physical and chemical structures. Compared with other polymers, such as ethylene acrylic acid, polyurethane, and polyacrylate, branched PEI has very low crystallinity and high potency to form hydrogen bonds with PVOH. A structure of PEI primer is shown below (Figure-4) to demonstrate this concept. Also, the tendency to form bonds increases with the concentration of PEI given the fact that PEI-2 has higher solids content than PEI-1, but the coat weights of PEI-1 and PEI-2 were rather similar in the experiment.

It was observed that PVOH-based primers did not work with PVOH extrusion. We believe this is related to the state of PVOH in the extrusion process. The fast crystallization rate of PVOH prohibits the formation of chain entanglement. Additionally, there is no hydrogen bond acceptor such as carbonyl or secondary or tertiary amine in the structure. Thus, once solidified there is little affinity at the interface.

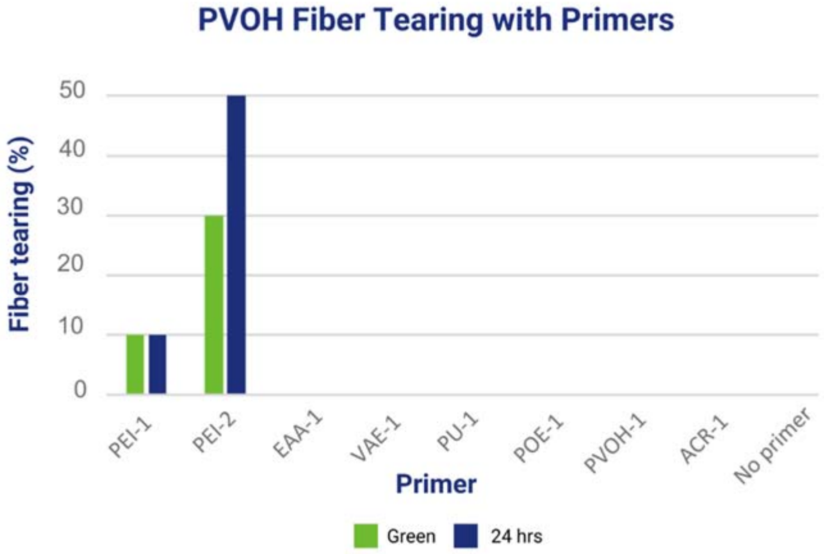

Figure-3 Fiber tearing in paper by PVOH for different primers (Phase I)

Table-1. Screening of primers for PVOH extrusion coating (Phase-I).

Sample	Solids (%)	Dry Coat weight (lbs/ream) (gsm)	Green Bond (Fiber Tearing %)	After 24 hrs (Fiber tearing %)
PEI-1 (control)	5	1.6 (2.6)	10	10
PEI-2	12	1.8 (3.0)	30	50
EAA-1	10	1.0 (1.6)	0	0
VAE-1	50	4.1 (6.7)	0	0
PU-1	30	2.8 (4.6)	0	0
POE-1	40	3.3 (5.4)	0	0
PVOH-1	8	0.7 (1.2)	0	0
ACR-1	40	1.0 (1.6)	0	0
No Primer	0	0 (0)	0	0

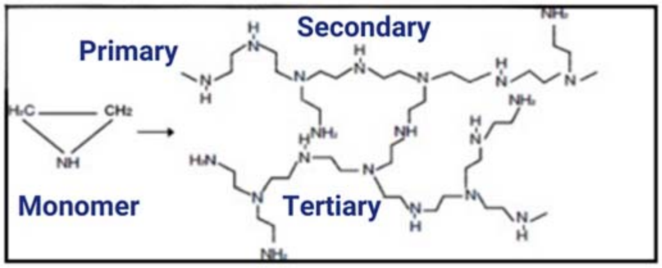

Figure-4 Structure of PEI primer

PEI-2 was further evaluated against several paper substrates and their finishings to determine their efficacy. PEI-1 and PEI-3 were used as controls in this part of the study. The results are shown in Figure-

5. As shown by the results, PEI-2 generated fiber tearing with all the substrates and consistently at equal or lower coating weight than PEI-1 and PEI-3 except for the last substrate. Using less water-based coating material to achieve the same result is advantageous in paper applications. Too much water can lower the strength of the paper and cause defects in PVOH coating. Using less water will allow for higher line speed and better productivity. The only exception is the metallized PVOH-coated paper, in which PEI-2 did not achieve fiber tearing. We believe the failure was caused by cohesive failure of PEI-2 or too much PEI-2 was accumulated on the surface of metalized PVOH-coated paper instead of penetrating into the paper. This scenario would not occur with other uncoated papers which can absorb the primer into the internal fibers of the paper.

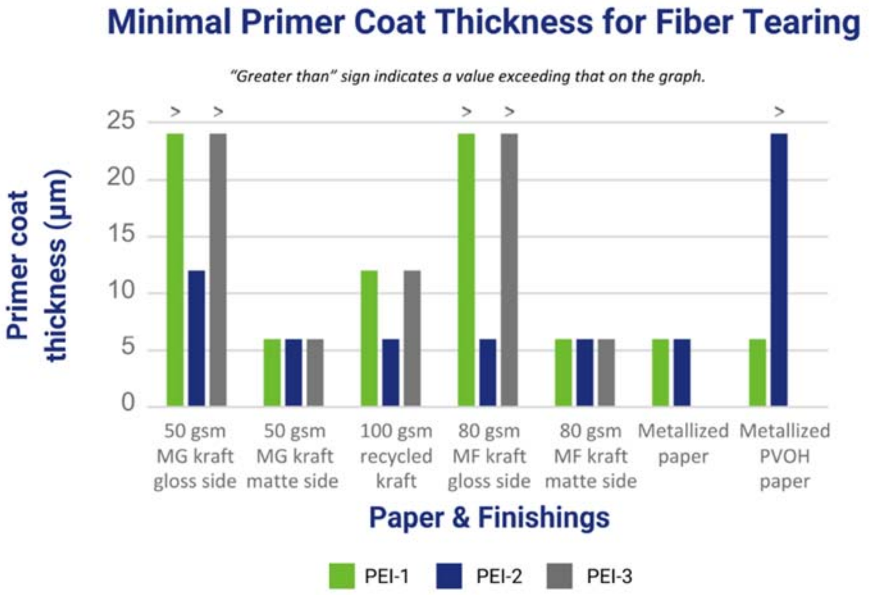

Figure-5 Comparison of primers for PVOH adhesion on different paper substrates and finishings (Phase II)

It is also interesting to note that even for the same paper, different finishings can affect the adhesion of PVOH resin. For 50 gram MG kraft paper, more primer was needed for the gloss side to achieve fiber tearing than the matte side. This was also observed with the 80 gsm MF kraft paper. This difference is probably related to the mechanism of fiber tearing. Some level of penetration of resin into the substructure is required to achieve full fiber tearing. Gloss finishing typically consisting of clay coating may slow the penetration process and thus require more primer. On the other hand, PEI-2 also seems to be more effective than PEI-1 and PEI-3 in penetrating the substrate.

Figure-6 and 7 show the results from Phase III in which PVOH was extrusion coated onto a kraft paper in a pilot trial. For the simplicity of presentation, only adhesion data for two of the five bands, 14 and 20 BCMs are reported here. Figure-6 shows the results of adhesion as a function of dry primer coating weight at different line speeds. While solid lines represent the monolayer of PVOH, dashed lines are associated with coextrusion of PVOH with LDPE, with PVOH against paper. Additionally, the adhesion at 200 fpm (61 mpm) was measured without heat seal of two substrates. The adhesion above 200 fpm was the peeling force of the heat seal between polymer-to-polymer coating.

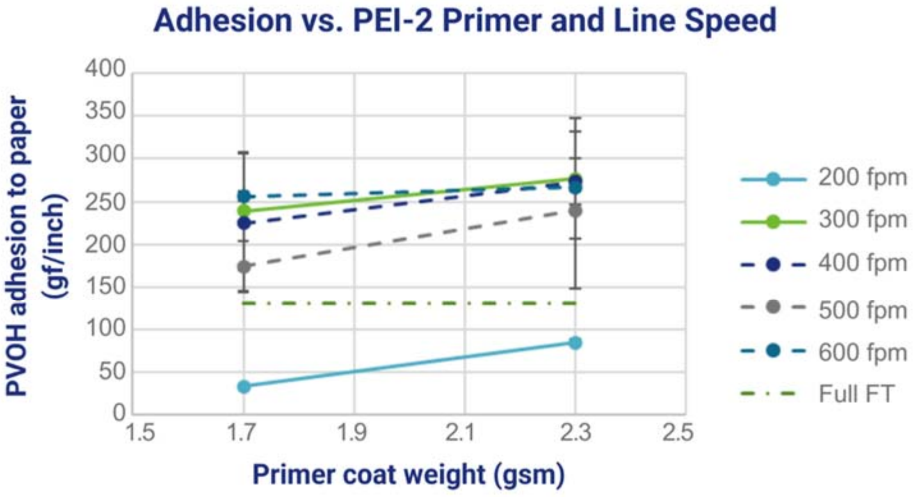

Figure-6 Dependence of PVOH to paper adhesion on primer coat weight and line speed. Green dashed/dotted line corresponds to the estimated fiber tearing seal strength (Phase III).

Results in Figure-6 indicate that both primer and line speed are important parameters to obtaining full fiber tearing of paper. Adjusting PEI-2 coat weight can increase the adhesion of PVOH to paper. For example, the bond was increased from 32 to 84 gf/inch by increasing primer coat weight from 1.7 gsm to 2.3 gsm. But PEI-2 alone cannot achieve full fiber tearing without increasing line speed which reduces the time in air gap (TIAG). After line speed was increased from 200 to 300 fpm (61 to 91 mpm), full fiber tearing was achieved at both coat weights. On the other hand, even at high line speed, the effect of primer on adhesion are still apparent when comparing the bond strength at 1.7 and 2.3 gsm.

The notion that more primer is required to achieve better adhesion on paper is not new. A large portion of primer solution applied will be absorbed by the paper, and thus more is needed to be available to form bonds with the extrudate. On the other hand, increasing line speed to achieve better adhesion with PVOH is somewhat counter intuitive to the common wisdom of extrusion coating of LDPE. This is probably because oxidization of PVOH in the airgap is not as important as the penetration of molten state of PVOH into paper. If solidified without sufficient penetration, strong bonds cannot be formed even with the presence of primer.

The film thickness of coatings at 300, 400, 500 and 600 fpm (91, 122, 152, 183 mpm) are gradually reduced as line speed increases. When comparing their adhesion levels, they are very similar within the experimental errors. This result confirms that PVOH can be extruded by itself or in coextrusion with LDPE without significant effect on adhesion.

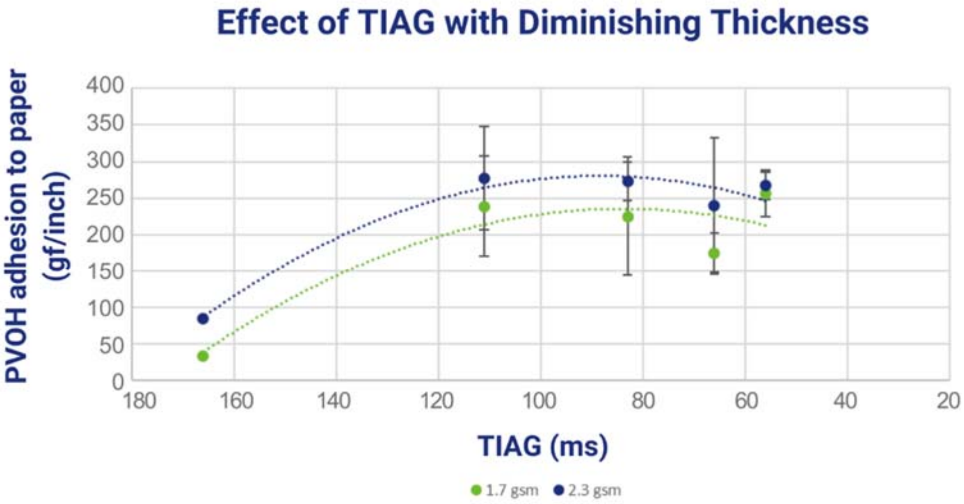

Figure-7 Effect of Time in Air Gap (TIAG) on adhesion of PVOH to paper (Phase III)

Figure-7 plots the adhesion of PVOH versus TIAG or time in air gap. TIAG is a function of extrusion speed, air gap and line speed. In the graph, the value of TIAG is plotted in reverse order. It is clear from the plot that as TIAG decreases, adhesion increases. Foederer & Morris studied the effects of TIAG on cooling and re-solidification and the interaction between line speed and thickness [4]. Their study indicates that high extrusion speed, high line speed and small airgap favors higher temperature at nip, which is important for PVOH to achieve good adhesion with paper. Clearly, without the reduced thickness, the bond will be further increased.

In the graph, the result also shows that increasing primer favors adhesion, regardless of monolayer or multi-layer coextrusion. The use of primer provides a guarantee for good fiber tearing for extrusion coating of PVOH on paper.

Figure-8 displays some indicative OTR barrier performance of 20 gsm of PVOH on a 40 gsm recycled kraft paper. Like EVOH, PVOH shows a drop in barrier performance as humidity increases.

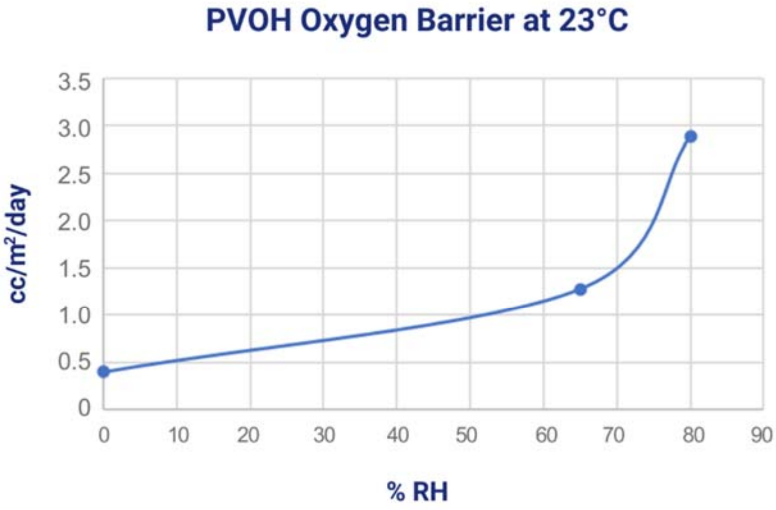

Figure-8 Example oxygen barrier of PVOH coated paper

Discussion and Conclusions:

As flexible packaging shifts to paper substrates as an alternative to traditional plastics, new polymer-based technologies are being developed to deliver both performance and alternative end-of-life options. PVOH is water-soluble and completely dissolves in warm water without leaving a trace, but it has issues adhering to paper due to its rapid crystallization rate. In three phases, this study identified and tested a water-based primer to promote adhesion between PVOH and paper and determined machine parameters and processing conditions necessary for success.

Phase I identified PEI-2 as the water-based primer with the highest efficiency. In Phase II, PEI-2 was further verified on several paper substrates and finishings. In Phase III, the data confirmed that with the application of PEI-2 in combination with optimized line speed, it is fully possible to achieve full fiber tearing of paper with PVOH.

We also can derive that at 1.7 gsm of PEI-2, full fiber tearing can be achieved at 130 ms of TIAG. At 2.3 gsm of PEI-2, full fiber tearing could be achieved at 150 ms of TIAG. Line speed and airgap can be adjusted accordingly to achieve the desired results.

Overall, this study discovers and confirms conditions to achieve full fiber tearing of PVOH resin on paper. It paved the way for many applications to replace multi-layer and multi-polymer packaging with paper-PVOH laminates. The potential applications include downgauged mailer bags, pet food packaging, dry food packaging and confectionary and condiments sachets.

An example of a basic structure being used and developed today may include 50 gsm MG Kraft / Primer / 15 gsm PVOH. Such structures have been proven successful on standard vertical and horizontal form fill seal machinery and are suitable for light weight e-commerce applications, dry fatty foods and confectionary.

Should additional barrier to liquid water or water vapor be required, PVOH can be co-extruded with other polymers such as LDPE. PVOH film thickness has been achieved as low as 3 microns in thickness and can be used as a release layer in complex structures to improve separation of materials in recycling and increase fiber yield.

Metalized paper may also be beneficial for improved water vapor barrier for moisture sensitive foods such as potato chips. PEI primer is also very effective at creating excellent bonds between metalized paper and PVOH.

References:

1. Internal test based on the Cepi recyclability test method version 2, and then evaluated to Aticelca MC 501:2017 and 4EG fibre-based packaging recyclability protocol: Beta version Dec 2022.

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3. Davids Meadows, "Using Aquapak's Hydropol polymer in extrusion coating for functional packaging design and multiple end of life options", 18th Biennial TAPPI European PLACE Conference, Oct. 10-12, 2022.

4. Beth M Foederer & Barry A Morris, "Use of IR technology to model temperature loss in the air gap", TAPPI PLACE Conference, May 13 -15, 2014.

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Outline:

- Background of study
  - Benefits of PVOH functional coating
  - Challenges associated with PVOH extrusion coating
- Experiment and Results

Phase I: **Evaluate PVOH adhesion with various water-based extrusion coating primers**

Phase II: **Test adhesion of PVOH on various primed paper substrates**

Phase III: **Determine machine and coat weight parameters and processing conditions**

- Conclusion

Background of study

- Demand for sustainable flexible packaging is increasing globally
- Companies are shifting to paper-based substrates and biopolymers, bio-based resins, or water-soluble PVOH
- PVOH is an excellent alternative to traditional plastics

Benefits of Extrudable PVOH

Functional
- Excellent barrier against oxygen, oil and grease
- High heat seal strength and mechanical strength

Compatible
- With extrusion coating process
- With paper recycling and repulping process

Sustainable
- Fully soluble in warm water (at 40°C)
- Compostable and marine safe

Examples of Extrudable PVOH Applications

- Light weight mailer bags
- Paper based air pillow
- Pet food packaging
- Confectionary packaging
- Snack food packaging

Challenges of PVOH Extrusion

- Low adhesion to paper under normal conditions
  - High crystallization rate, high crystallization temperature and low processing temperature
- PVOH degrades at temperature >220°C

Solution

This study will identify a water-based primer to promote adhesion and determine machine parameters, coat weights, and processing conditions necessary for success.

Phase I

Evaluate PVOH adhesion with various water-based extrusion coating primers

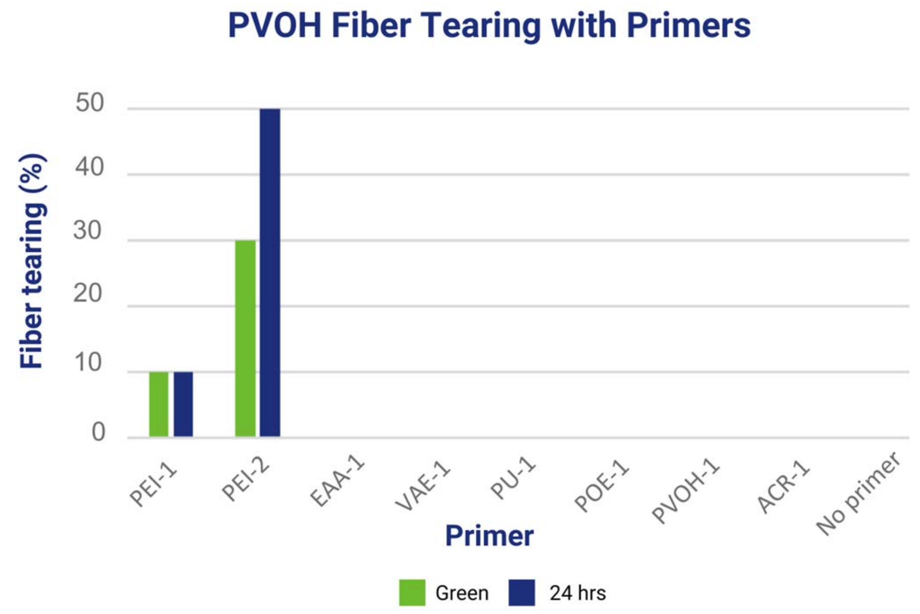
- Seven **primers** were evaluated against the control and bare substrate.

Primer	Solids (%)
PEI-1 (control)	5
PEI-2	12
EAA-1	10
VAE-1	50
PU-1	30
POE-1	40
PVOH-1	8
ACR-1	40
No Primer	0

- Fiber tearing checked immediately and one day after extrusion coating.

Experiment	
Substrate	68 gsm kraft paper, Corona treated
PVOH resin	
Density	1150-1250 g/cm^3
MFR	10.0-14.5 g/10 mins
Melting temperature	170-180°C
Extrusion (on Randcastle extrusion coater) three heated and cooled barrel zones, 1” general purpose screw with L/D ratio of 24, and 25 cm width slot die.	
Extrusion temperature	410°F (210°C)
rpm	35 rpm
Line speed	33 fpm (10 mpm)
Coating thickness	~1 mil (25.4 µm)

Results: Fiber Tearing with Different Primers


PVOH Fiber Tearing with Primers

Phase I Results

- **PEI-based primers** can help PVOH achieve fiber tearing.
- Higher solids PEI primer shows better results than the lower solids PEI primer.
- Hydrogen bond acceptors and low crystallinity of PEI molecules can be attributed to its affinity to PVOH.

Primer	**PEI-1**	**PEI-2**	**EAA-1**	**VAE-1**	**PU-1**	**POE-1**	**PVOH-1**	**ACR-1**	**No primer**
Solids (%)	5	12	10	50	30	40	8	40	0
Coat Weight (gsm)	2.6	3.0	1.6	6.7	4.6	5.4	1.2	1.6	0

Phase II

Test adhesion of PVOH on various primed paper substrates

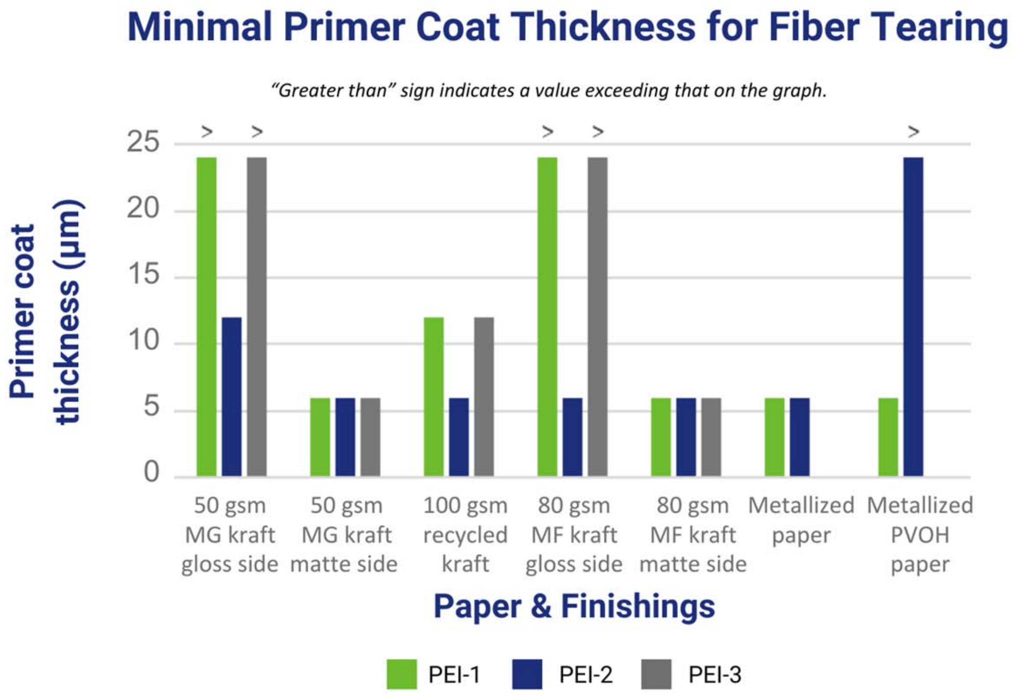
- **PEI-1, PEI-2, PEI-3** were evaluated on various papers and finishings

Paper	Basis Weight (gsm)	Finishing
MG kraft	50	Gloss
MG kraft	50	Matte
Recycled kraft	100	--
MF kraft	80	Gloss
MF kraft	80	Matte
Unidentified Paper	--	Metallized
Unidentified Paper	--	Metallized PVOH

- Primers were compared by the minimal wet coating weights required for the onset of fiber tearing.

Experiment	
Coat weight of primer	
Yellow K bar	6 µm wet
Red K bar	12 µm wet
Green K bar	24 µm wet
Extrusion Coater (lab-scale) Five heated and cooled barrel zones, 1” general purpose screw with L/D ratio of 24 , and 20 cm width slot die.	
Extrusion Temperature	205°C
Line speed	10 mpm

Results: Fiber Tearing with Different Papers


Minimal Primer Coat Thickness for Fiber Tearing

"Greater than" sign indicates a value exceeding that on the graph.

Phase II Results

- Higher solids PEI primers were more effective across all paper substrates and finishings.
- High efficiency means less water in coating, and thus less wrinkles, higher line speed and paper strength.
- Paper finishing has an impact on adhesion. For example, fiber tearing from matte finishing requires less primer than the gloss finishing.

Phase III

Determine machine and coat weight parameters and processing conditions

- Extrusion coating trial to determine primer coat weight and processing parameters.

Fpm (mpm)	Coat weight
200 (61)	~1 mil (25.4 µm)
300 (91)	~1 mil (25.4 µm)
400 (122)	0.75 mil (19 µm)
500 (152)	0.6 mil (15.2 µm)
600 (183)	0.5 mil (12.7 µm)

- The paper-PVOH laminates were checked for fiber tearing and adhesion strength measured by T-peel.

Experiment	
Priming station	
Applicator	Direct, banded gravure (see Image-1) Chambered doctor blade
Dryer	Two-zone heated air dryer
Extrusion Coater (Pilot scale) Three extruders of 2 ½”, 2” and 1 ¼” in diameter each at 34:1 L/D, 5-layer vane adjustable feed block, and 40” NordsonEDI EPC internally deckled die.	
Extrusion Temperature	430°F (221°C)

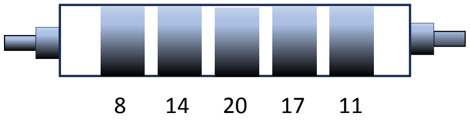
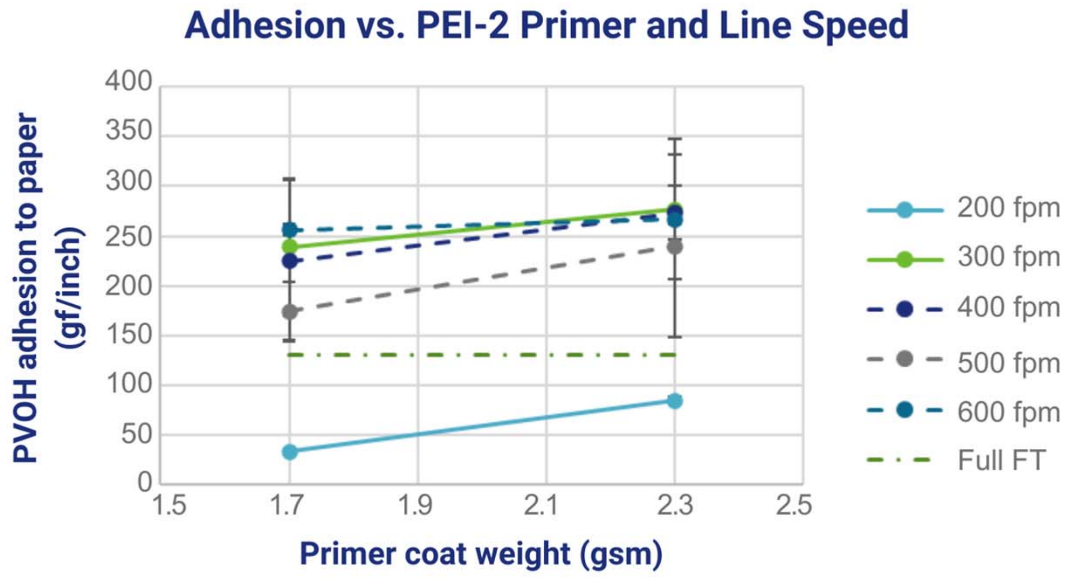


Image-1: Banded gravure patterns (BCM)

Results: Effects of Primer Coat Weight and Line Speed

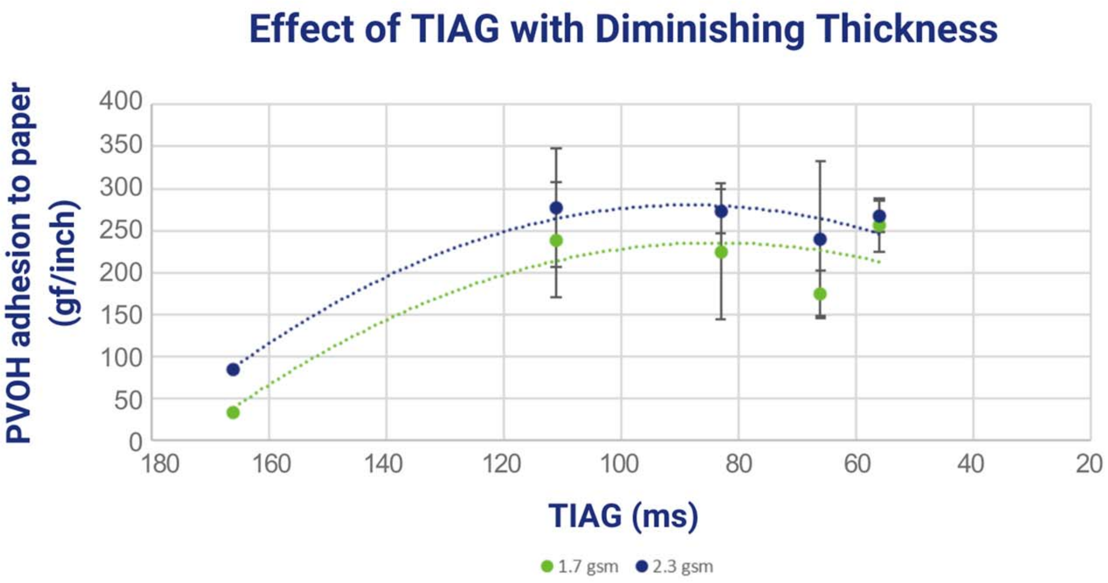


Green dashed and dotted line corresponds to the estimated fiber tearing seal strength

Phase III Results

- Both primer and line speed are important for PVOH adhesion to paper.
- Bond strength increases with the coat weight of primer.
- Primer alone cannot generate full fiber tearing without increasing line speed above 300 fpm.
- Coextrusion and downgauging does not affect fiber tearing

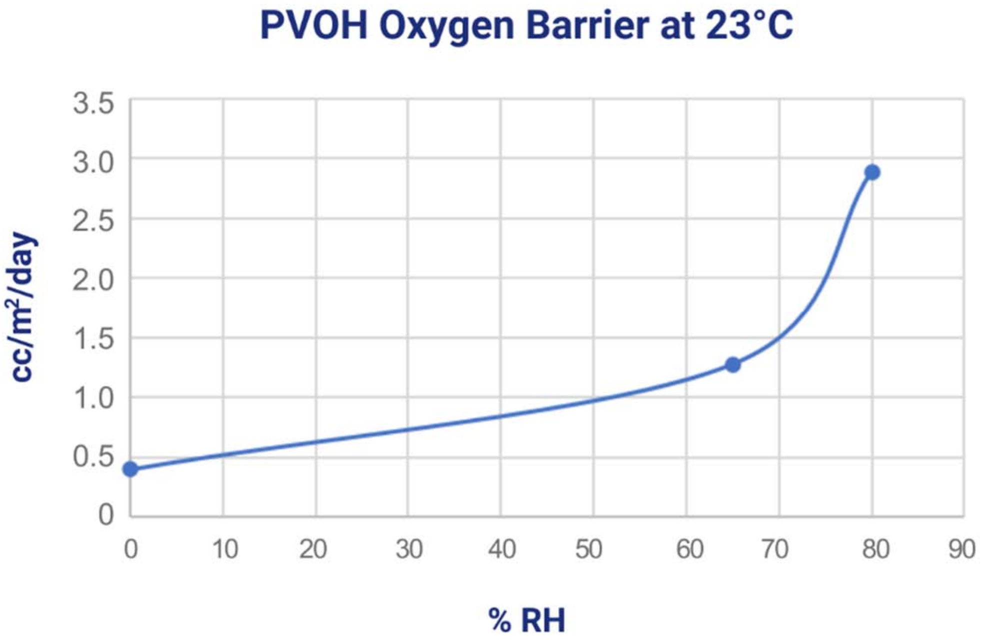
Results: Effects of TIAG



Phase III Results

- As time in the airgap (TIAG) decreases, adhesion increases.
- TIAG affects cooling and re-solidification of polymer coating.
- Small TIAG with high extrusion speed, high line speed and small airgap favors higher temperature at nip, and thus adhesion of PVOH
- Full fiber tearing can be achieved at 130 ms of TIAG with 1.7 gsm of primer or 150 ms with 2.3 gsm of primer.
- Diminishing thickness needs to be compensated by smaller TIAG and more primer.

Results: Oxygen barrier of PVOH coated paper



Phase III Results

- Paper/PEI-2/PVOH <0.5 cc/m^2/day RH=0%

Oxygen barrier of bare substrates

Bare Substrate	OTR (cc/m^2 /day, RH=0%)
Paper (25#)	>100,000
BOPP (1 mil)	1100
BOPE (1 mil)	1500
OPET (0.5 mil)	120

Conclusions

- **High line speed** and **more primer** are important for achieving full fiber tearing of paper with PVOH

- **Small TIAG**, namely high extrusion speed, high line speed, and small airgap favors adhesion via higher melt temperature at nip.

- The use of **primer provides guarantee** for good fiber tearing

- These **results pave a way for adoption of PVOH extrusion coating** for many packaging applications.
  - Light weight mailer bags
  - Paper based air pillow
  - Pet food packaging
  - Confectionary packaging
  - Snack food packaging

Thank you!

Questions?

Acknowledgements

A special thank you to Elaine Lo, Sandesh Singh, and Tammy Cheng from Mica Corporation for their support on the Phase I and Phase III studies.