Flexible Packaging Division Newsletter

Volume 17, Issue 2 August, 2017

Society of Plastics Engineers D-44

See full FlexPackCon2017 Program on p. 3

FlexPackCon2017 with AIMCAL Roll2Roll Conference
Sunday Oct. 15-Wednesday Oct 18
Naples Grand Hotel, Naples, FL
Registration:
https://aimcalscassoc.wliinc35.com/events/2017-R2R-Conference-USA-82/register

Flexible Packaging Division of SPE

The Flexible Packaging Division strives to provide, with clear focus and good repute, an industry-recognized forum that facilitates the timely exchange of technical knowledge and business information in the market-driven, fast-evolving, multi-disciplinary field that encompasses the arts and the sciences of production and processing of plastic materials, fabrication and conversion of films and sheets, and enclosure and protection of goods in end-uses.

THIS ISSUE

New Chairman for the Flexible Packaging Division

At its meeting during ANTEC 2017, the Board welcomed the new Chairman for 2-17-2018, Chris Kerscher. Chris is Market Development Manager at A. Schulman, Inc. where he leads the marketing organization for its Masterbatch Solutions business unit . He has been a frequent presenter at Division and SPE conferences, and has organized the technical program content for several FlexPackCon sessions.

Prior to Chris' seven years with A. Schulman, he worked in R&D for Milliken (2002-2006) and for Pactiv (1998-2002). Chris earned a BS Chem E from VPI and his MBA from Emory University's Goizueta Business School

Chris' message to Members:

On behalf of the Flexible Packaging Division Board and Members, I would like to recognize and thank Barry Morris for his leadership last year. During Barry's term, our Division continued to provide technical content and networking opportunities through FlexPackCon, ANTEC, and a films session at SPE Polyolefins. We also made important steps toward an endowed student scholarship program. The formation of a Finance Committee will ensure invested funds are managed appropriately. The newly formed Scholarship Committee is focused on giving back to our industry by supporting students making strong commitments to plastics beyond standard coursework. Our inaugural scholarship was awarded to Logan Tate, a rising junior at the Pennsylvania College of Technology majoring in Plastics and Polymer Engineering. Congratulations to Logan!

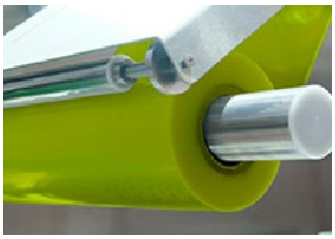
The Flexible Packaging Division will build on this momentum to provide relevant content and opportunities to engage our membership. Our next technical conference, SPE FlexPackCon 2017, will take place October 15-18 in Naples, Florida. This multi-track event is coordinated with The Association of Industrial Metallizers, Coaters and Laminators (AIMCAL) to provide a range of seminars covering technical and business trends. A special thanks to Donna Davis (General Operating and Program Chair) and Dave Constant (Exhibitors and Sponsors Chair) for their work organizing this event. Check out the agenda and make your travel plans today.

The state of our Division is strong and we have the opportunity to continue growing and engaging our membership. In 2018, we will take new steps to work with Academia and Industry to benefit our members. I invite each of you to share ideas and get more involved with our community. We have immediate openings on several committees and are looking for volunteers to share their skills. Please reach out to me, or any Board Member, if you would like to help with: technical programs, events, scholarship, university relations, web design, social media, or any other division functions. We welcome your ideas and input.

Thank you for your support of The Flexible Packaging Division, and enjoy the rest of your summer!

Naples Grand Beach Resort

Building on a successful 2016 conference with nearly 400 attendees, over 100 presentations and more than 75 exhibitors, the Flexible Packaging Division and the Association of Industrial Metallizers, Coaters, and Laminators (AIMCAL) again present a combined event in 2017. A single registration provides full access to both the AIMCAL and FlexPackCon sessions – pick and choose what suits you best! The partnership offers attendees the choice of up to 4 concurrent technical sessions.



During the day on Sunday, the event offers four optional ½ day short courses and 1 full day short course. One of these sponsored by the Division is by Matt Dingee, Co-founder and President-COO of OnPoint2020, a consultancy offering Packaging Insights and Services to growth minded brands of all sizes. (Additional fees apply.)

Two informal evening receptions (Sunday, 7:00-8:30 PM and Monday, 6:00- 7:30 PM) feature over 80 tabletop exhibitors from top suppliers, converters and consultants in the Industry. These informal settings provide a great way to meet others in the industry. We encourage all attendees to take advantage of the receptions to meet your peers. Food and drink are provided.

On Monday, Tuesday, and Wednesday, the parallel conference tracks address extrusion, coating, lamination, metallization, converting, and performance requirements driving design for flexible packaging. Presentations include recent developments in machinery, materials, and packaging designs targeted to an assortment of applications from food to electronics to transportation. Issues facing consumer product companies from food preservation to supply chain security are program considerations.

Monday morning features a joint plenary session with industry overviews including the State of the Industry from the Flexible Packaging Association.

Monday afternoon, the FlexPackCon Sustainability session begins with an overview of PepsiCo's "Performance with Purpose" sustainability strategy. Other presentations address packaging in a circular economy and new sustainable adhesives and coatings.

Tuesday morning's FlexPackCon agenda addresses "business trends and drivers", from mergers and acquisitions to enabling new extrusion and converting technologies. Presentations include how to take advantage of massive quantities of data to improve quality and efficiency.

Tuesday afternoon the conference offers networking opportunities at two optional activities: A Golf Scramble and a Cornhole Tournament (sponsored by VDI and Gencoa respectively

The Wednesday morning session focuses on new materials and the benefits they bring. These include new barrier substrates, new adhesive technologies, and the inclusion of unusual materials like polyketones.

Wednesday afternoon considers requirements for

Monday Morning: Joint Plenary Session

Monday morning features industry overviews of printed electronics; R2R Manufacturing of Lithium Ion Battery Cells and Other 2D Engineered Products;

9:15-10:00 AM *Flexible Packaging: State of the Industry*

Alison Keane
Flexible Packaging Assn

Monday Afternoon: Sustainable Solution	
Keynote: Performance with Purpose	Garry Kohl PepsiCo
The Evolving Role of Flexible Packaging in the Circular Economy	Donna Visioli DuPont
Water based compostable lamination adhesives	Randy Jester BASF
Sustainable Advantages of Water-Based Laminating Adhesives	Paul Kearns BASF
Cellulose Nanofibrils in Bio-Based Multilayer Films and Pouches	Mika Vaha-Nissi VTT Technical Research
The End-of-Life Challenge for Flexible Packaging - Multilayer Films, Barrier Structures and Pouches.	Terence Cooper ARGO Group International
Tuesday Morning: Business and Technology of Processing and Converting	
How mergers and acquisitions are changing the shape and nature of the flexible packaging industry	Rick Weil Mesirow Financial
Packaging 4.0 - Fiction vs. Reality	Mike Andrews Windmöller & Hölscher
Effect of co-extrusion die design on OEE	Hector Larrazabal Brampton-Engineering
Leveraging Actionable Data from Existing Equipment to Increase Throughput and Eliminate Waste	Willem Sundblad Oden Technologies Ltd.
The Effects of Surface Treatment on Heat Seal and Hot Tack	Sean Richards Lyondell Basell Industries
Profiling water-based flexible film based printing inks: Test method optimization and the effect of anilox cell size	Michael Doyle BASF
Wednesday Morning: Material Advances and Their Benefits	
BOPEF - A new bio-based high-barrier substrate film for the packaging industry	Jesper Van Berkel Synvina
New HDPE Resin Design May Offer Film Improvements	Ryan Breese Industries
Go Beyond Adhesion: The Dual Functionality of Tie Layers	Yong Zheng Dow Chemical
Understanding the Influence of Additives on Gas Fade Discoloration of Polylethylene Resins	Fraser Waldie Nova Chemicals
Superior tear resistance from a polyamide: Is the flexible packaging world ready for a LLDPA	Eric Noon BASF
Polyketone polymers - A Resins Portfolio with Unique Value Propositions For Flexible Packaging Applications	Dang Le Esprix Technologies
Wednesday Afternoon: Developments Driven by Industry and Market Trends	
Unleash E-Commerce with Packaging that Clicks	Matt Dingee OnPoint 2020
The Good, The Bad, The Opportunity for packaging and home meal delivery	Jonathan Quinn Nova Chemical
Material Advances and Their Benefits	
Development of a Finite Element Model of the Bag Drop Test	Mark Davis ExxonMobil Chemical
Interaction of Abrasion and Oil Resistance of Sealant Materials	Victoria Korbonits *DuPont*
Selecting the proper polyamide for multilayer food packaging films: intrinsic factors leading to performance considerations	Joao Costa BASF
Case Study – Multilayer Polyethylene Films For Food Service Packaging Applications	Dan Falla Nova Chemical

Division Awards Scholarship...

The division's Scholarship Committee awarded its first annual scholarship to Logan Tate; a rising junior at the Pennsylvania College of Technology majoring in Plastics and Polymer Engineering. He has a B.S. degree in Physics from Lock Haven University and a 4.0 GPA at PCT. Logan has shown a strong commitment to plastics beyond his classwork with a leading role in SPE and as a research assistant in plastics processing. His resume and body of work clearly distanced him from the other applicants.

...and our winner responds!

It is an honor to be the recipient of this award! To be honest, I was more than excited to just be considered for the opportunity and now, I am at a loss of words.

My dedication to the plastics industry is going to last a lifetime and I am going to be a proud advocate expressing the benefits of flexible packaging especially. As I've explored several topics throughout my education, I have found a passion for extrusion, especially films and sheets.

I would certainly like to follow-up on the possible webinar and tour. We often have members from industry visit our classes and present their companies specifically (technologies and products), but it would be even better if we were able to have someone come in and talk about the industry and the fast-evolving world of plastics.

Some ways for the division to get students involved would be a part design competition. I know that the thermoforming and blow molding divisions engage students with part design opportunities and recognition. It's very exciting to see some students step outside of what is already being produced.

Again, on my end, we are planning on having weekly topics at our SPE meetings that we will show to our classmates. For instance, one week a student can select flexible packaging, perform some research and present information to other students. This could include for example:

- advancements in technologies
- evolution of products
- processing techniques
- applications

As for a testimonial, I am more than willing to express my gratitude and sincere appreciation for the scholarship. Being a recent physics graduate and now chasing a new passion, the scholarship helps me tremendously! Thank you all for the opportunity! I don't think there are any professional organizations like SPE that are dedicated to success in the industry as well as the success of students and young professionals!

...and speaks to the Plastics Community!

(*Plastics News* identified Logan as a "Rising Star" this month by . His thoughts...

What emerging technology or market most interest you? "Flexible packaging. These products are at the forefront of innovative solutions there will always be a need to make packaging more economical reduce the carbon footprint, increase consumer convenience, and extend product shelf life."

What about the plastics industry surprises you? "The lack of young professionals entering the plastic industry. I've been to six conferences thus far, and the message is all the same: "Where are the graduates?" The industry is full of experienced professionals who are getting ready to pass the torch… But who will they pass it to?"

Flexible Packaging Division Board of Directors

2017-2018 Division Chair, Chris Kerscher presides over Board Meeting May 8 during ANTEC meeting in Anaheim , California

Division Officers and Board Election Results...

2017-2018 Officers and Board

Chair: Chris Kerscher (A. Schulman, Inc.) +1 864.616.2796 chris.kerscher@aschulman.com

Chair Elect: Ken Forziati ((Parkinson Technologies Inc)+1 401.762.2100 (x 335) kforziati@parkinsontechnologies.com

Secretary: Wayne Moras (Reynolds Consumer Products) +1 217.479.1106 wayne.moras@reynoldsbrands.com

Treasurer: John Wagner (Crescent Associates Inc.) +1 585.461.1466 jwagner5@rochester.rr.com

Membership Chair & Councilor: Dan Falla (Nova Chemicals) +1 519.312.5210 dan.falla@novachem.com

ANTEC® TPC: Paul Zerfas (Mondelez International, Inc. +1 608.576.9368 pzerfas@mdlz.com

Editor: Tom Dunn (Flexpacknology LLC) +1 404.376.4866 tdunn@flexpacknology.com

Other Board members:

Dave Constant (BASF)
Yijian Lin (Dow Chemical)
Paul Zerfas (Mondelez)
Donna Davis (Exxon Mobil Chemical)
Judy Webb (Sasol North America)
Lora Liang (Mondelez)

Division online: http://www.4spe.org/Communities/divisionsdetail.aspx?ItemNumber=5055

New Division members since April 1.

Name	Organization Name	City	State/etc.
Professional Members			
Ajay Kulkarni	McNeil Consumer Healthcare	Fort Washington	PA
Terry Jackson	Accuflex Industrial Hose Ltd	Guelph	ON
Simon Malcolm	SPDM	Mawdesley	
Bruce Van Clay	MOCON	Minneapolis	MN
Mark Davis	Exxonmobil Chemical Company	Baytown	TX
Alexander Arsic	A. Schulman Inc	canton	OH
Patrick Farrey	SPE	Bethel	CT
Erik Adams	Amcor	St. Kilda	Vic
Rafael Posada	Braskem	Bogotá D.C.	
Vikram Fotedar	Packone Solutions LLP	Mumbai,	Maharashtra
Steven Clark	Monark Equipment Tech	Auburn	MI
Martin Hoenigmann	Berry Plastics Corp.	Chippewa Falls	WI
Karen Xiao	Celgard LLC	Mississauga	ON
Daniel Tsai		Reno	NV
Hassan Eslami	Macro Engineering/Technology	Mississauga	ON
George Cooke	Plastics Color Corporation	Grapevine	TX
Laurent Matuana	Michigan State University	East Lansing	MI
Trevor Pacholok		Kelowna	BC
Douglas Rich		Hudson	OH
Mark Berard	Dexco Polymers	Plaquemine	LA
Student Members			
Ali Elaal	The British University- Egypt	Suez	
Edgar Castro-Aguirre	Michigan State University	East Lansing	MI
Young Professional Members			
Bahareh Bahramian	University of Sydney	Wentworth Point	NSW
Richard Silverwood	École Polytechnique de Montréal	Montreal	QC
Jennie Howse	Garlock printing and converting	sparks	NV
Mark Woodward	Clariant	Charlotte	NC
Lena Liu	PerkinElmer	Glen Waverley	Vic
Maxwell Sullivan	CDF Corp	Plymouth	MA

ANTEC® 2017

The plastics technology conference

May 8-10, Anaheim, CA

ANTEC ® 2017

1,350 attendees attended over 550 technical presentations at this year's ANTEC. SPE organizers tested new concepts at ANTEC with the addition of two invited topical forums: *Plasticity Forum* focused on sustainability issues and the *Industry 4.0 Forum* focused on the internet-of-things in our industry.

The Flexible Packaging Division sponsored 2 full sessions, *Barrier and Sealability* and *Defect Detection, Sustainability, Emerging Technologies.* Each included 7 individual presentations to well-attended audiences. The division owes Paul Zerfas (Mondelez) a large debt of gratitude for his continuing efforts as the Division's "Technical Program Chair" for ANTEC.

After the conference, Paul continued his work by organizing and conducting the "Best paper" selection process among the Board of Directors. The winner is Guojun Zhang (A. Schulman, Inc.), "High Gas Barrier Materials with Multilayer Morphology for Packaging Applications"

Dr. Zang successfully fabricated extruded a compounded LLDPE and EVOH into 3-layer cast coex films with 10% LDPE skins. With good dispersion and appropriate blend processing (no compatibilizers), domains in the blend elongated to accomplish 33-layer multilayer film morphology [The subject of his previous research,2015,Polymer 57,, 117-124). This layer-like morphology enables the blend to yield barrier properties similar to actual multilayered films. LLDPE domains within the blend provide protection for EVOH from moisture as well as adhesion between skin layers, allowing the blend to embedded easily in a 3 - layer structure.

Based on the same blending techniques, blown and cast films with compounded LDPE developed enhanced WVTR barrier properties. This technique offers an opportunity for those who would like to enter the barrier applications but without a capability of producing more than 3 layers. His research represents product development evaluations of "BAR" series materials for use in 5-layer or 9-layer structures as well. Balanced with both good oxygen and WVTR barrier, these materials are suitable for packaging applications.

His full paper follows in this newsletter.

High Gas Barrier Materials with Multilayer Morphology for Packaging Applications

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A. Schulman, Inc.
1183 Home Ave, Akron, OH 44310, USA

Abstract

Multilayer films are widely used in packaging industry to fulfil different applications. It is well known that multilayer structure is essential for high gas barrier packaging using EVOH, because moisture has negative effects on EVOH's barrier properties [1, 2]. In order to effectively use EVOH in barrier applications, usually a moisture barrier layer and a tie layer are required [3, 4]. In this study, specially prepared polymeric compounds based on EVOH and polyolefin with good dispersion, proper compatibility/incompatibility and viscosity match are prepared. These special materials all yield a morphology that is similar to multilayered structure after the resins are extruded into thin film. Different from some previous researches [5, 6, 7], our technique involves with a pre-compound process, which ensure the multilayer morphology to form after resins are extruded into thin films.

With multilayer-like morphology inside, EVOH phase is extended and protected. Therefore, good gas barrier (both OTR and WVTR) properties agreeing with series model calculation are reported for all film samples. These materials with multilayer-like morphology have also shown decent adhesion with different PE reins, so 3-layer instead of 5-layer films are successfully fabricated, which are applicable in barrier packaging applications in terms of barrier and optical properties. It is expected that these special materials with multilayer-like morphology inside can be used as monolayer films or a layer in multilayer structures to enhance the barrier performance as well as process flexibility of EVOH resins.

Introduction

Ethylene vinyl alcohol (EVOH), as the barrier layer widely used in packaging industry has drawn a lot interests in the past decade because of its excellent oxygen barrier property [1, 2]. Although it owns extraordinary oxygen barrier, it is very sensitive to moisture, as water molecules are known to increase EVOH's molecular chain mobility [1]. Therefore, EVOH, as the oxygen barrier layer, is usually embedded in multilayered structures [3, 4]. However, the process for fabricating multilayer structure is expensive and complex [1]. In the contrast, polymer blends are easy to produce. It would be valuable, if people can simply use polymer blends to replace or reduce the number of layers in multilayered structures. It is actually a traditional method for improving gas barrier property of a polymer by blending it with another higher barrier polymer.

The key concern is: whether polymer blends can yield the maximum barrier for given compositions.

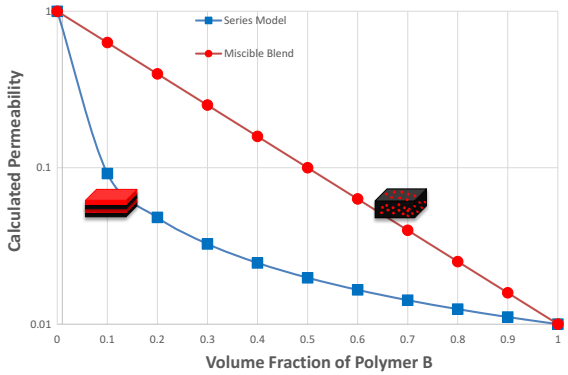

Figure 1. Comparison of series model calculation and miscible blend model calculation, with assumption of each polymer component having the same barrier property as its bulk control.

According to Fig. 1, assuming polymer A and B has OTR permeability of 1 and 0.01 (barrer) respectively, the layered morphology always shows better barrier property than miscible blend morphology for a given composition. This gives a reason why people generally prefer layer structure for barrier applications regardless of the cost and complexity.

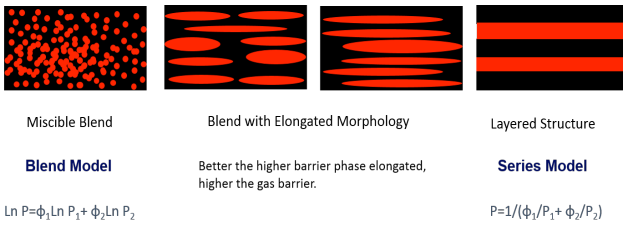

Figure 2. Different morphologies of polymer blends.

Based on Fig. 2, it is clear that when polymer blends have different morphologies, they can yield distinctive barrier properties. It is well known that polymer blends can form various morphologies as a result of different

compositions and process techniques [8-15], and therefore are suitable for different applications. For a polymer blend film, under certain conditions, a layer-like morphology can be achieved. This means polymer domains are extended to their maximum degree. In this case, a polymer blend shows characteristics of a multilayered film, which could be beneficial for gas barrier applications.

A specially prepared LLDPE and EVOH blend with specific composition and good dispersion but without any compatiblizer was first prepared and studied. Due to the reasonable compatibility and proper immiscibility between LLDPE and EVOH, extended and layer-like morphology appears after this pre-compound resin is extruded to fabricate thin films. Because of the morphology, the extruded thin film shows good barrier properties following the series model calculation. Given the barrier property, the blend of LLDPE-EVOH can be possibly used to replace multilayered structure or reduce the number of layers in a multilayer film. The LLDPE domains behave similar to moisture barrier layers, which are protecting EVOH from affecting from moisture. Moreover, the LLDPE domains in the blend film also provide us with enough adhesion to some other polymers. Thus, three-layer films without tie-layers are successfully fabricated.

The LLDPE-EVOH blend was named as EXP BAR2400 available in A. Schulman's portfolio. Based on these fundamental findings, a series of materials containing similar internal multilayer-like morphology as EXP BAR2400 were developed as well. With the balance of excellent oxygen barrier and good WVTR (water vapor transport rate) barrier, these EXP BAR materials are expected to be suitable for food packaging applications.

Materials and Experiments

Linear low density polyethylene (LLDPE,) and Ethylene vinyl alcohol (EVOH with 44% of ethylene) were used to fabricate EXP BAR2400. Resin and sample information is listed in **Table 1.**

Generic names were used throughout this paper to label samples.

Table 1. Materials studied in this paper.

Sample	ASI internal name	T_m/ °C	T_c/ °C
LLDPE	LLDPE	124	115
EVOH	EVOH	159	140
B24	EXP BAR2400	Compound of LLDPE and EVOH	
B25	EXP BAR2500	PE cast film	
B26	EXP BAR2600	PE blown film	

All compound resins were prepared by a twin-screw extrusion system at A. Schulman Inc., Akron, OH, USA. Sample B24 from the table was first investigated.

Before extrusion process, B24 resin was dried in a vacuum oven for overnight at 80 °C. A single-screw cast film line was utilized to fabricate monolayer thin films with final film thickness of ~25 μm. The process is demonstrated in a diagram shown in **Figure 3.**

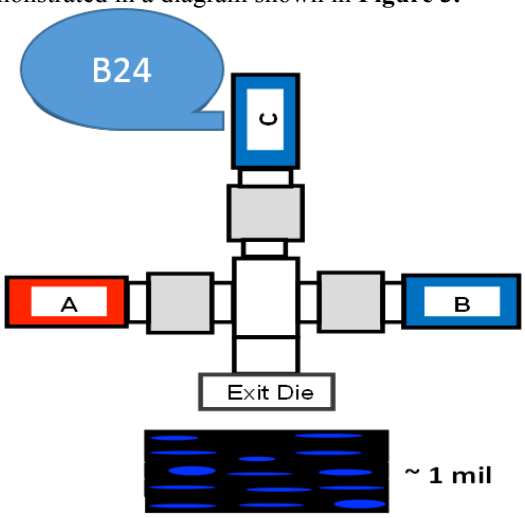

Figure 3. Melt process for sample B24.

The same 3-layer cast film line was also employed to fabricate 3-layer films with sample B24 in the core.

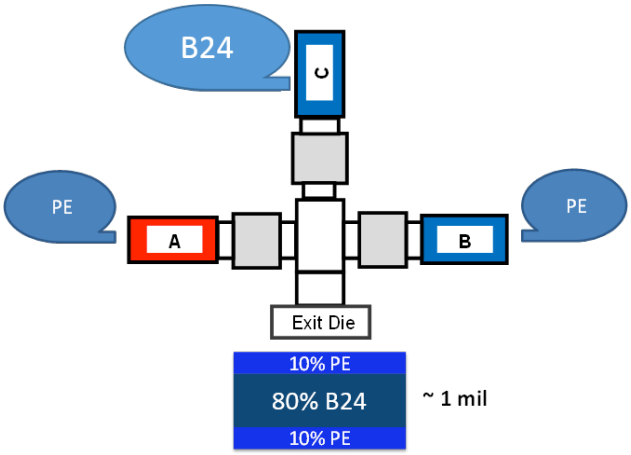

Figure 4. Melt process for making 3-layer film containing B24 in the core.

Atomic force microscopy (AFM) was employed to investigate the morphology of the extruded thin films. Small pieces of specimen were embedded in epoxy (5 Minute Epoxy, Devcon, Rivera Beach, FL) and cured for 24 hours at room temperature. Cross sections were prepared by microtoming at both extrusion direction (ED) and transverse direction (TD) after cooling the samples to -120 °C in liquid

nitrogen. AFM images were obtained with a commercial scanning microscope probe (Nanoscope IIIa, Digital Instruments, Santa Barbara, CA) with normal tapping mode. The spring constant was 50 N/m and resonance frequency was in the 284-362 kHz.

Thermal properties of extruded thin films were characterized using a Perkin Elmer (Boston, MA) Pyris differential scanning calorimeter (DSC) unit at a heating/cooling rate of 10˚C/min.

Oxygen flux J(t) rates were characterized by a MOCON (Minneapolis, MN) OxTran L 2/22 unit under 1 atmosphere pressure at 23 °C (+0.1) with a 0% relative humidity. The instrument was calibrated at 23 °C with a NIST-certified Mylar film with known oxygen transport characteristics. Water vapor transport rate (WVTR) was measured by a MOCON (Minneapolis, MN) PERMATRAN-W® Model 3/34 unit under 1 atmosphere pressure at 37.8 °C (+0.1) with a 100% relative humidity. The instrument was calibrated at 37.8 °C with a NIST-certified Mylar film with known water vapor transport characteristics.

The light transmission rate of the extruded film was measured by an ultraviolet-visible spectrometer. Haze was tested under ASTM D1003.

The same methods were employed to determine the properties of B25 and B26.

Results and Discussion

Morphology and Gas Barrier.

AFM images were shown in **Fig. 5**. By comparing with an actual 33-layer multilayer film, it appears that the morphology of extruded B24 is very similar to a layer-like structure. Both LLDPE phase and EVOH phase are extended with thickness around several hundred nanometers.

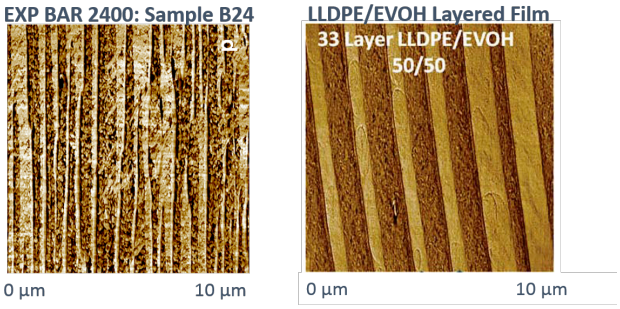

Figure 5. AFM images of partial cross section of extruded B24 (left) and 33-layer multilayer film of LLDPE and EVOH (right).

As a result of layer-like morphology, good barrier property is expected for B24 extruded thin film. The OTR barrier data is listed in **Table 2.**

Table 2. Oxygen permeability for films.

Extruded blend film	P O2/ Barrer	P O2/ Barrer based on blends model	Improve ratio
LLDPE control	3.7±0.1	/	/
EVOH control	0.0015±0.0001	/	/
B24	0.0034±0.0001	0.07	21
33-layer LLDPE-EVOH multilayer film	0.0030±0.0001	/	/

$$LnP_{blend} = \varphi_1 LnP_1 + \varphi_2 LnP_2 \quad (1)$$

$$\frac{1}{P_{Film}} = \frac{\phi_1}{P_1} + \frac{\phi_2}{P_2} \quad (2)$$

Where P_1 and P_2 are the oxygen permeability of LLDPE control and EVOH control respectively; φ_1 and φ_2 are the volume fraction of LLDPE control and EVOH control respectively. Equation (1) is miscible blend model. Equation (2) is series model that is used to predict permeability for layered films.

B24 shows good OTR barrier, which is in the same scale of EVOH control. The improve ratio is 21 times when compared to the miscible blend model (the improve ratio is: calculated value/measured value). Obviously, although B24 is a compound product, it actually shows oxygen permeability close to multilayered film, which agrees with series model. This morphology is very meaningful, as it offers an opportunity for those who would like to enter the barrier application but without a capability of producing more than 3 layers.

B24's OTR performance is also studied under different RHs, which is shown in **Fig. 6.**

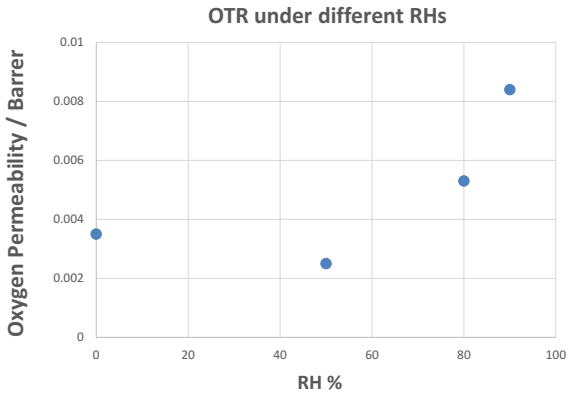

Figure 6. OTR of extruded B24 under different RHs.

When RHs increases, B24's oxygen permeability also increases. This is because EVOH phase is still more or less affected by moisture. However, compared to EVOH control, the water sensitivity has been reduced [2]. This is again because LLDPE domains are protecting EVOH domains.

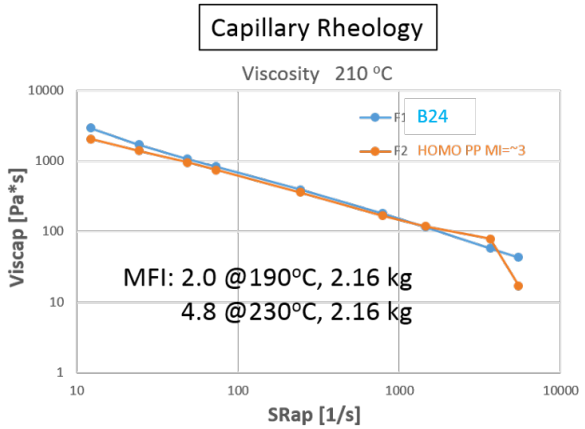

Figure 7. Capillary rheology result of B24 at 210 ˚C.

The viscosity of B24 is comparable to a homo-polypropylene with MFI of 3.0. This suggests B24 can be easily co-extruded with many other polymers

Three - layer structure of B24.

B24 is proved to have layer-like morphology and can yield good gas barrier properties. In order to practically use this material for packaging applications, 3-layer structures with different PE skins have been fabricated as well. The skin layers are expected to further protect B24 and provide us with other functions, like printability, sealability et al. The 3-layer structures are illustrated below:

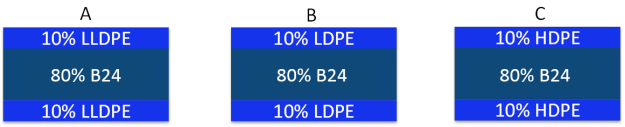

Figure 8. B24 with 3 types of PE skins.

All three films have shown decent adhesions between layers, which can be felt by peeling layers manually. Oxygen and water vapor permeability were then tested for the 3-layer films.

Table 3. Permeability of BAR2400 in 3-layer structures.

Sample	A	B	C
WVTR (g.mil/100icn2.day)	1.58 ± 0.07	1.35 ± 0.06	0.70 ± 0.01
O_2 (0% RH) Barrer	TBD	0.0041	0.0041
O_2 (50% RH)	TBD	0.0026	0.0019
Barrer			
O_2 (100% RH) Barrer	TBD	0.0090	0.0085

Based on the data from **Table 3**, it appears that with HDPE skins, the 3-layer film yields the best moisture barrier, while it still keeps very good oxygen barrier.

Besides the barrier property, haze of these three films are also investigated under the standard of ASTM D1003.

Table 4. Haze of BAR2400 in 3-layer structures.

Sample	A	B	C
Haze %	4.9 ± 0.5	9.2 ± 0.2	25.7 ± 1.2

As expected, HDPE skin increases the overall haze of 3-layer film.

Other BAR materials.

While LLDPE is not the best material for WVTR barrier application, sample B25 and sample B26 were developed accordingly with enhanced WVTR barrier. B25 and B26 were designed based on the fundamental findings of B24, but are targeted for different processing. B25 is appropriate for cast extrusion, and B26 is good for blown extrusion.

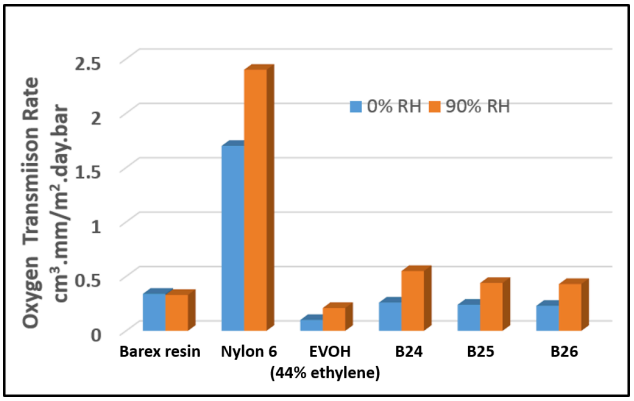

Figure 9. Comparison of oxygen barrier for BAR series materials. (All samples are cast films, expect B26 is blown film)

In terms of oxygen permeability, B24, B25 and B26 films are all comparable to EVOH (44% ethylene grade) and Barex resin. As the RH increases from 0% to 90%, oxygen permeability does not increase dramatically. This suggests that oxygen barrier performance remains at higher RHs for BAR series materials, especially for sample B25 and B26.

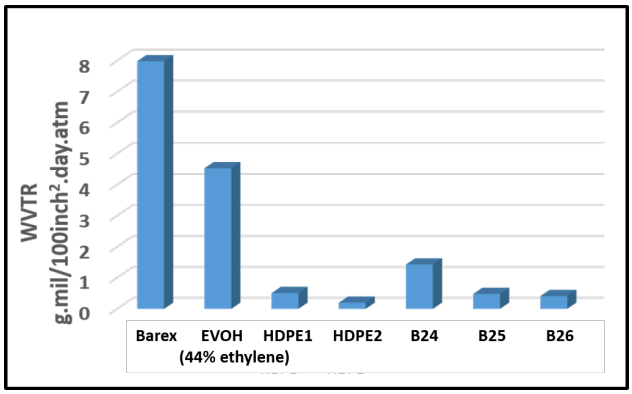

Figure 10. Comparison of WVTR barrier for BAR series materials.

More interestingly, when looking at WVTR barrier performance, B24, B25 and B26 all have shown lower permeability than EVOH and Barex resins. Especially, B25 and B26 have shown comparable WVTR barrier performance as HDPE barrier resins.

Data from **Fig. 9** and **Fig. 10** suggest that B24, B25 and B26 yield both excellent oxygen barrier property as well as WVTR barrier property, which is not always true for all barrier resin. This is again because all samples yield multilayer morphology. While the higher WVTR barrier phase offers the moisture barrier, EVOH phase is supplying the oxygen barrier. B26's morphology is checked by AFM as well, since it was blown extruded, which is different from B24 and B25.

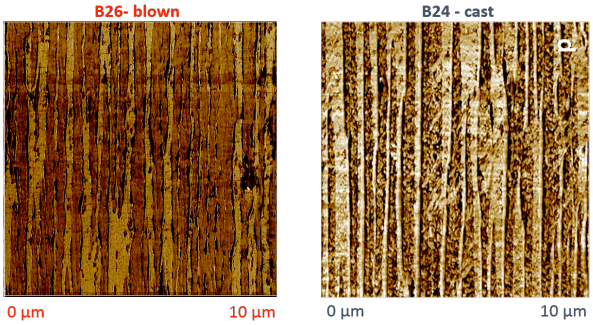

Figure 11. AFM images of partial cross section of extruded B26 (left) and B24 (right). Both samples yield layer-like morphology.

Table 5. Optical properties of BAR2500 and BAR2600.

	HAZE %	GLOSS @ 45°
BAR2500	37.2	37.3
BAR2600	48.3	32.9

Both B25 and B26 show moderate haze values and relatively low gloss values. Their light transmission rate is typically higher than 90% for most of the visible light wavelength range.

Conclusions

Extruded blend films sample B24 are successfully fabricated. Due to the good dispersion and appropriate processing, elongated and layer-like morphology is observed. This layer-like morphology enables B24 to yield similar barrier properties as actual multilayered films. LLDPE domains within B24 provide protection for EVOH from moisture as well as adhesion between skin layers. Therefore, B24 can be easily embedded in a 3-layer structure.

Besides B24, based on the same principles, B25 and B26 with enhanced WVTR barrier properties were also developed. Balanced with both good oxygen and WVTR barrier, these materials are suitable for packaging applications. This technique offers an opportunity for those who would like to enter the barrier applications but without a capability of producing more than 3 layers. At the same time, due to the barrier properties and processability, BAR series materials can also be used in 5-layer or 9-layer structures.

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