Film Structures Incorporating Benefits Delivered by New Moisture Barrier HDPE

Thomas J. Schwab
Lindsay Corcoran

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Introduction

- Blown film producers and users have numerous requirements for moisture barrier applications
  - Moisture barrier (Water Vapor Transmission Rate – WVTR)
  - Toughness
    - Machine Direction (MD) tear, Puncture, Dart
  - Resistance to curl
  - Film appearance
    - Dusting, melt fracture

- Resin choice, resin design, and structure design affect these various film properties

Project Goal: Determine most critical variables to optimize overall film performance depending on end-use

Experimental

- Produce four-layer films with 1.8-mil gauge
  - Blow-up Ratio = 2.5:1; Die Gap = 95 mil

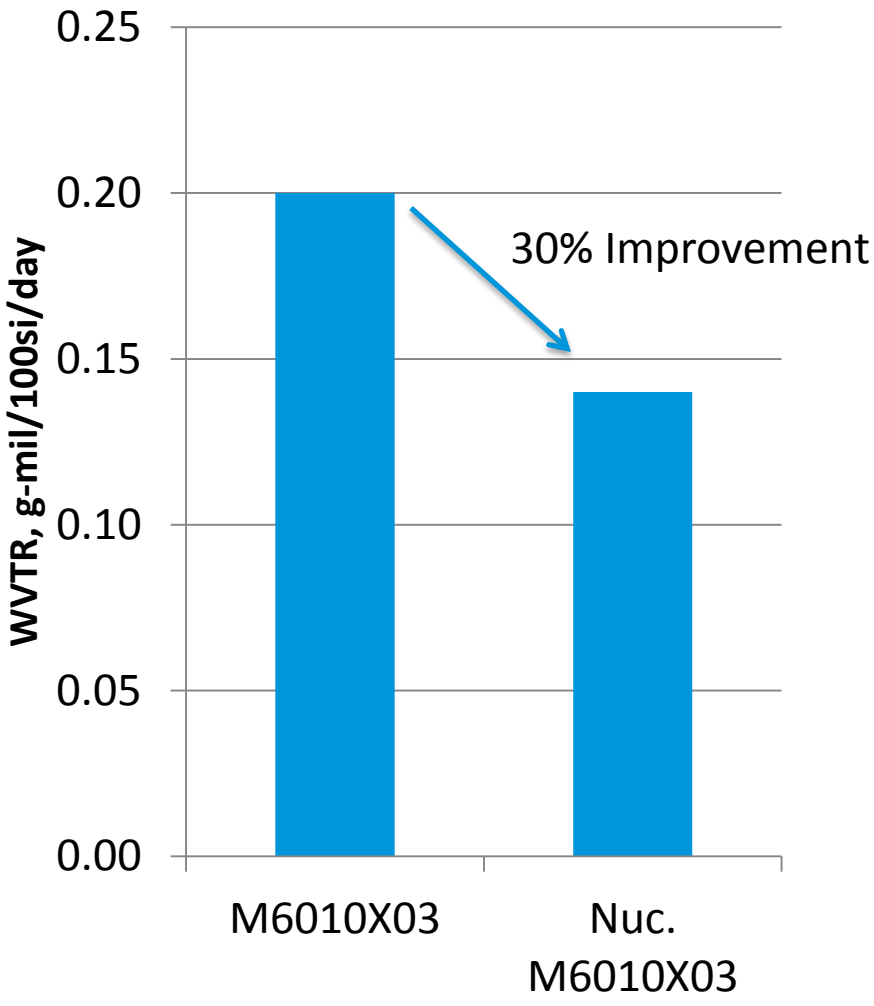
Product	Resin Type	Melt Index (g/10 min.)	Density (g/cc)	Product Function
UE637000	EVA	3.2	9% VA	Sealant
L5485	HDPE	0.85	0.954	Toughness
M5410	HDPE	1.15	0.954	Toughness
GM1210BE	mLLDPE	1.0	0.912	Toughness
M6010X03	HDPE	2.7	0.962	Barrier
Nuc. M6010X03	HDPE	2.7	0.962	Barrier

    - » Nuc. M6010X03 = Nucleated M6010X03

- Film structures designed for fundamental comparison of barrier and toughness layers

Nucleated HDPE

- Use of organic salt nucleator may improve WVTR of HDPE
- Nucleator changes crystal growth in polymer during cooling
- Changes in crystal orientation can create a more torturous path for water vapor
- Leads to potential improvements in barrier
  - Haze properties typically improve as well



Normalized data from 1.25-mil monolayer films

Film Structure Design and Comparison Groups

Sealant Layer (15%)	Inner Core (28%)	Outer Core (28%)	Outer Skin (29%)
Location of barrier HDPE layer			
UE637000	M6010X03	M6010X03	L5485
UE637000	M6010X03	L5485	M6010X03
UE637000	L5485	M6010X03	M6010X03
Location of nucleated HDPE layer			
UE637000	Nuc. M6010X03	Nuc. M6010X03	L5485
UE637000	Nuc. M6010X03	L5485	Nuc. M6010X03
UE637000	L5485	Nuc. M6010X03	Nuc. M6010X03
Type of core layer material			
UE637000	Nuc. M6010X03	L5485	Nuc. M6010X03
UE637000	Nuc. M6010X03	M5410	Nuc. M6010X03
UE637000	Nuc. M6010X03	GM1210BE	Nuc. M6010X03

Water Vapor Transmission Rate Comparison

Inner Core (28%)	Outer Core (28%)	Outer Skin (29%)	Structure WVTR
Location of barrier HDPE layer			
M6010X03	M6010X03	L5485	0.175
M6010X03	L5485	M6010X03	0.178
L5485	M6010X03	M6010X03	0.166
Location of nucleated HDPE layer			
Nuc. M6010X03	Nuc. M6010X03	L5485	0.128
Nuc. M6010X03	L5485	Nuc. M6010X03	0.132
L5485	Nuc. M6010X03	Nuc. M6010X03	0.125

Barrier layer location in structure has minimal effect on WVTR

Sealant Layer = 15% UE637000
WVTR Units = g/100 si/day

Water Vapor Transmission Rate Comparison

Inner Core (28%)	Outer Core (28%)	Outer Skin (29%)	Structure WVTR
Type of core layer material			
Nuc. M6010X03	L5485	Nuc. M6010X03	0.132
Nuc. M6010X03	M5410	Nuc. M6010X03	0.132
Nuc. M6010X03	GM1210BE	Nuc. M6010X03	0.162

Density of non-barrier layer affects structure WVTR significantly

Sealant Layer = 15% UE637000
WVTR Units = g/100 si/day

Toughness Comparison

Inner Core (28%)	Outer Core (28%)	Outer Skin (29%)	MD Tear	Puncture
Location of barrier HDPE layer				
M6010X03	M6010X03	L5485	21.6	30.4
M6010X03	L5485	M6010X03	19.9	31.1
L5485	M6010X03	M6010X03	20.8	30.9
Location of nucleated HDPE layer				
Nuc. M6010X03	Nuc. M6010X03	L5485	24.5	30.8
Nuc. M6010X03	L5485	Nuc. M6010X03	22.7	28.4
L5485	Nuc. M6010X03	Nuc. M6010X03	33.3*	30.6

*High standard deviation

Dart drop results follow similar trend.

Toughness layer location has minimal effect on toughness. However, structures usually have higher level of toughness product.

Sealant Layer = 15% UE637000

MD Tear Units = grams; Puncture Units = Newtons

Toughness Comparison

Inner Core (28%)	Outer Core (28%)	Outer Skin (29%)	MD Tear	Puncture
Type of core layer material				
Nuc. M6010X03	L5485	Nuc. M6010X03	22.7	28.4
Nuc. M6010X03	M5410	Nuc. M6010X03	23.3	28.5
Nuc. M6010X03	GM1210BE	Nuc. M6010X03	45.7	51.8

Dart drop results follow similar trend.

Density of toughness layer has significant effect on toughness. However, structures usually have higher level of toughness product.

Sealant Layer = 15% UE637000
MD Tear Units = grams; Puncture Units = Newtons

Curl Testing – Method

- Cut an 8x8 inch square from each material
- Cut a 4x4 inch “X” in the center of sample
- Tape the square to a piece of cardboard with the curl direction facing up
- Let samples sit for 20 hours
- Visually quantify the amount of curl in both the MD and TD direction
  - Slight Curl ≤ 45^{o}
  - Curl ≤ 90 ^{o}
  - Severe Curl ≥ 180 ^{o}

Curl Comparison

Inner Core (28%)	Outer Core (28%)	Outer Skin (29%)	MD Curl	TD Curl	Direction
Location of barrier HDPE layer					
M6010X03	M6010X03	L5485	Slight	None	Outer Skin
M6010X03	L5485	M6010X03	Slight	None	Sealant
L5485	M6010X03	M6010X03	Curl	None	Sealant
Location of nucleated HDPE layer					
Nuc. M6010X03	Nuc. M6010X03	L5485	Severe	Slight	Outer Skin
Nuc. M6010X03	L5485	Nuc. M6010X03	Slight	None	Sealant
L5485	Nuc. M6010X03	Nuc. M6010X03	Severe	Curl	Sealant
Type of core layer material					
Nuc. M6010X03	L5485	Nuc. M6010X03	Slight	None	Sealant
Nuc. M6010X03	M5410	Nuc. M6010X03	Curl	Slight	Sealant
Nuc. M6010X03	GM1210BE	Nuc. M6010X03	Curl	Slight	Sealant

Sealant Layer = 15% UE637000

Curl Test Conclusions

- Balanced structures show less curl
- Nucleated materials curl more than non-nucleated materials
- Films tend to curl away from the nucleated layer
- Films generally curl towards sealant layer
  - Nucleated layer effect dominates curl more than sealant

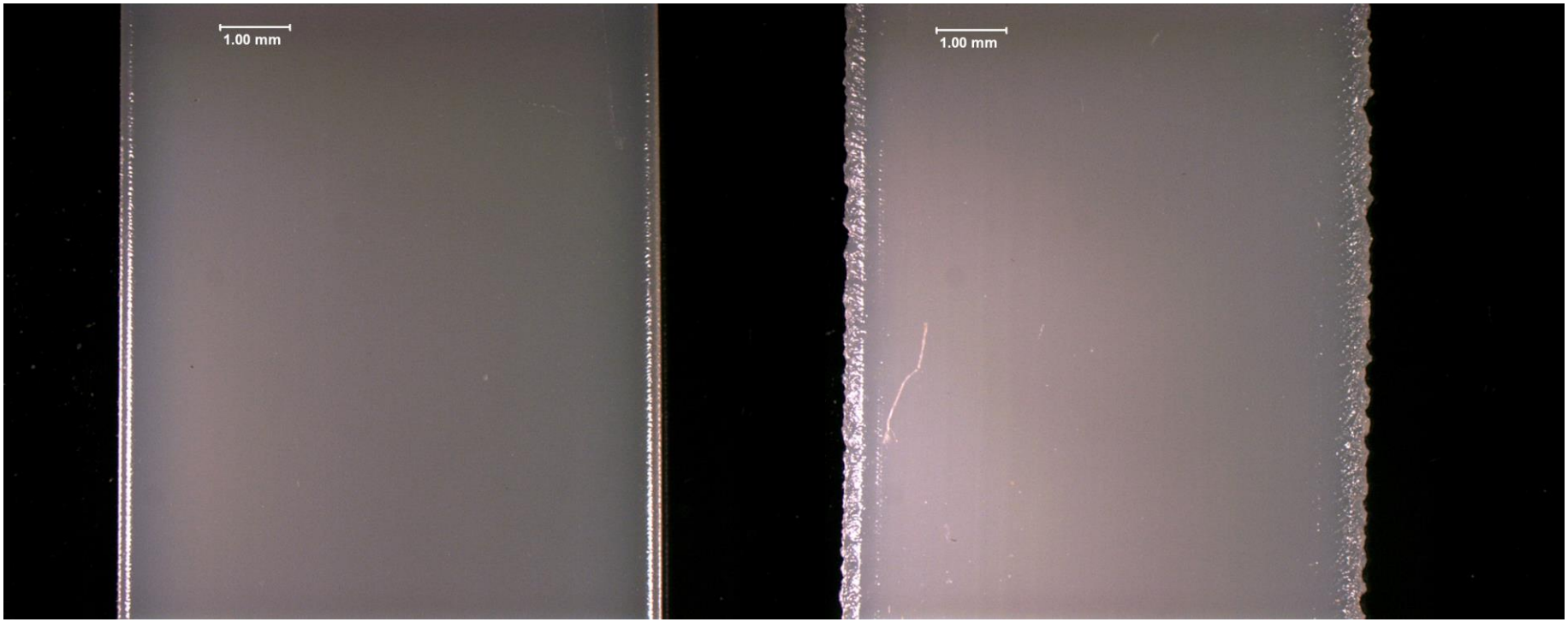
Film Appearance Comparison

- Use of barrier products in the outer layer of a multi-layer structure requires minimal dusting and low melt fracture
- Compare M6010X03 to competitive material
  - Lab scale testing due to limited sample

- Testing Method
  - Capillary Rheometer (ROSAND RH7 Flowmaster)
    - Shear rates between 50 to 800 s^{-1}
    - Temperature 190^{o}C
  - Slit Die
    - 34 mm in length with a cross sectional area of 6 mm x 0.5 mm

Melt Fracture Comparison

- Representative sample at 300 s^{-1}



M6010X03 Competitive Material

Smooth film edge indicates little melt fracture

Conclusions / Summary

- Location of barrier and HDPE toughness layers does not seem to have significant effect on WVTR or film toughness at these layer distributions
- Use of lower density toughness layers leads to poorer WVTR, but improved toughness
- Balanced structures show less curl
- Nucleated films curl more than non-nucleated films
- M6010X03 may be used in the skin layer due to low melt fracture

Performance optimization for these key properties may be achieved through modifications to layer distribution

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