



Go Beyond Adhesion: the Dual Functionality of Tie-Layers

Yong Zheng, Brian Walther, Suzanne Guerra and Santosh Bawiskar

The Dow Chemical Company

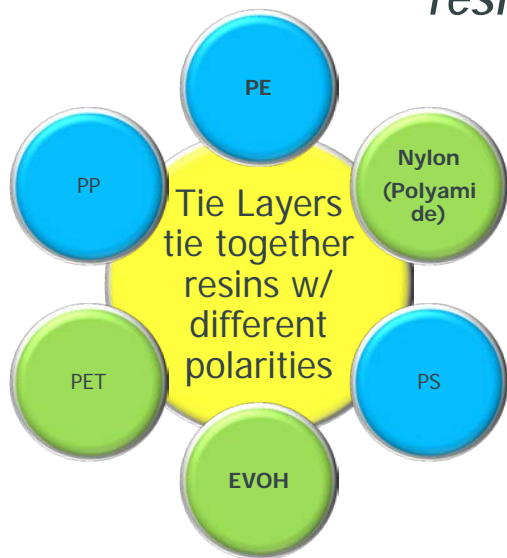
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Agenda

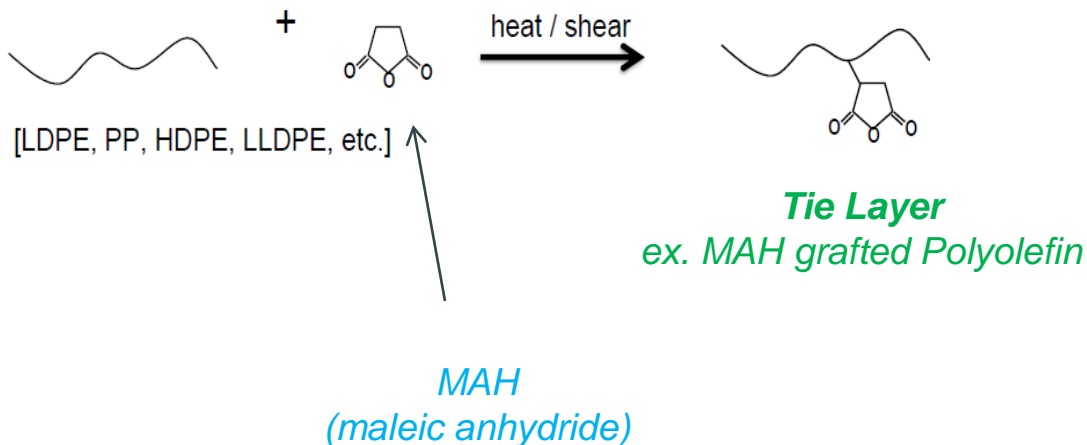
- Introduction
 - What to expect from a tie-layer
 - Multifunctional concept
- Ultra Tough tie-layer
 - Dart improvement
 - Nylon replacement
- Barrier tie-layer
 - Oxygen and water barrier improvement
 - Mechanical properties
 - Implementation
- Conclusions

What to Expect from a Tie Layer

Tie Layers help *adhere polar (EVOH, PA etc.) resins to non-polar (PE etc.) resins in single-step coextrusion process*



- Production: Polymer synthesis + reactive extrusion
 - Maleic anhydride is grafted to a polymer backbone
 - Free radical process



Polar resins (EVOH, PA (nylon)) are used for their **barrier** properties

Polyethylene Film – Multifaceted Approach

Tie layer selection

Current: 1. Fully Formulated Grades

“Bread and butter” products

2. Concentrates

Customer customization

Future: 3. Multifunctional Tie Resins

Adhesion + toughness

Adhesion + barrier



Value in Multifunctional

- Value in building two functions in a single film layer:
 - Streamlined process
 - Down-gauging potential
 - Better film property
 - Additional values to customers
- Adhesion + toughness
- Adhesion + barrier



Experimental

- Dual functional tie-layers vs. standard tie-layers
AMPLIFY TY 1352, AMPLIFY TY 1353
- 7-layer Alpine line in PackStudio, Freeport, TX
- Comparison with a model 5-layer and 7-layer film

LLDPE (37.5%)/**ultra tough tie** (10%)/EVOH or Nylon (5%)/**ultra tough tie** (10%) /LLDPE (37.5%) 4 mil

LLDPE(24%)/**barrier tie**(18%)/EVOH(16%)/**barrier tie** (18%)/LLDPE(24%) 2.2 mil

LLDPE(17%)/**barrier tie**(15%)/nylon(7%)/EVOH(17%)/nylon(7%)/**barrier tie**(15%)/LLDPE(22%) 2.7mil

- Adhesion, dart, puncture, OTR and WVTR, modulus and tear.



Benefits of Ultra Tough Tie-Layer

Problem: Loss of toughness due to film downgauging or the presence of EVOH.

Incumbent solutions: Use additional discrete tough layers such as nylon or mPE resins.

Our solution: A multi-functional tie-layer,

- tie layer to adhere EVOH/polyamide to PE film structure;
- ultra tough layer to promote the toughness of the film.

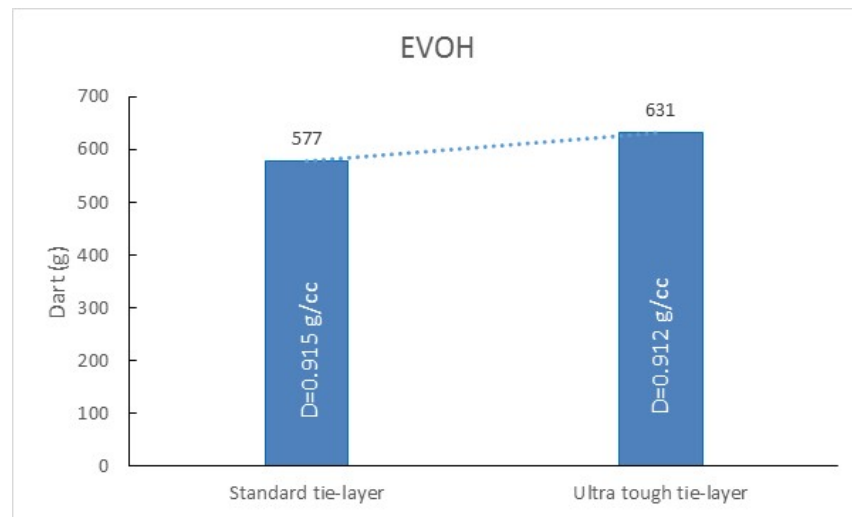
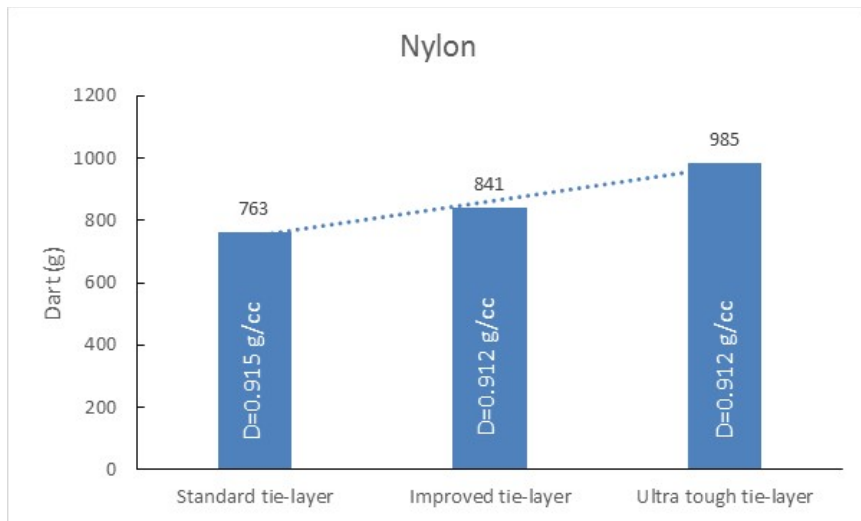
Competitive advantages: Toughness improvement for films containing EVOH or Nylon. Downgauging potential from improved film toughness.

Ultra Tough Tie-Layer: Robust Dart Improvement

Film-1 DOWLEX 2045G/Tie/**Nylon**/Tie/DOWLEX 2045G (37.5/10/**5**/10/37.5) 4 mil

Film-2 DOWLEX 2045G/Tie/**EVOH**/Tie/DOWLEX 2045G (37.5/10/**5**/10/37.5) 4 mil

Tie-layers: Dow's standard tie-layer, improved tie-layer and ultra tough tie-layer



- Replacing the standard tie-layer with ultra tough tie-layer can deliver up to 30% improvement in dart in barrier films with tie-layers accounting for 20% of the total film.
- Robust with both nylon and EVOH films.
- Higher dart at a comparable density.
- Equivalent adhesion between the standard and ultra tough tie-layers.

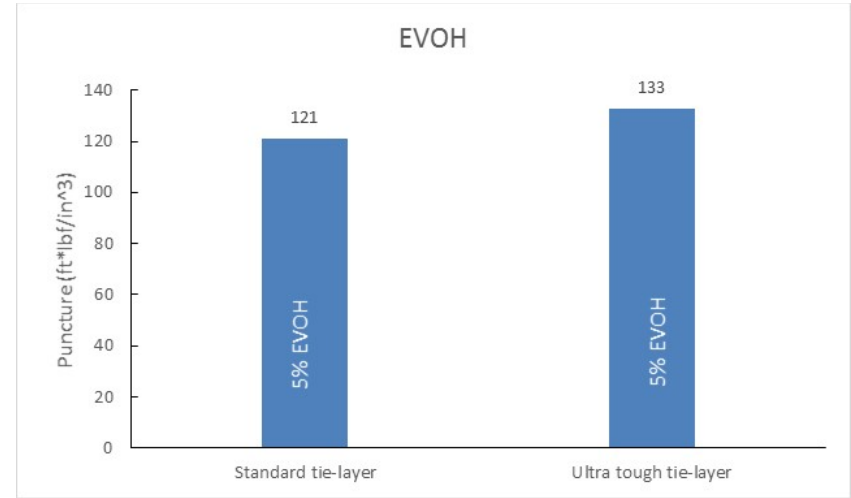
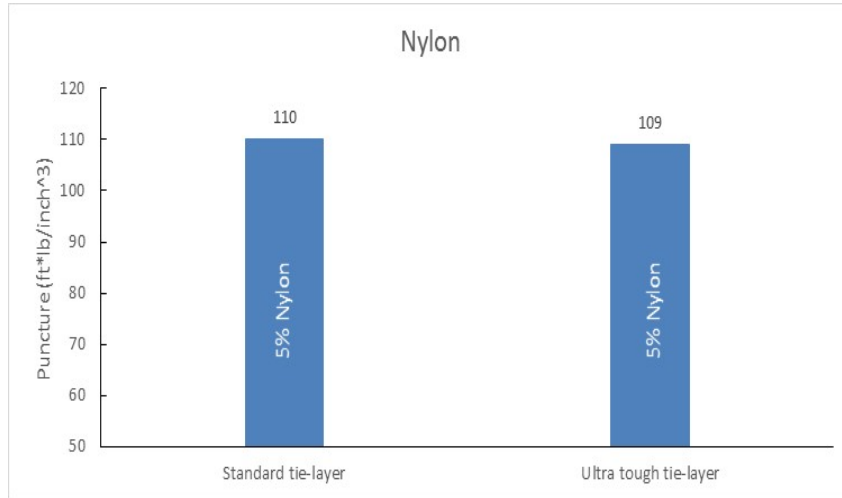


Ultra Tough Tie-Layer: Good Puncture Resistance

Film-1 DOWLEX 2045G/Tie/**Nylon**/Tie/DOWLEX 2045G (37.5/10/**5**/10/37.5) 4 mil

Film-2 DOWLEX 2045G/Tie/**EVOH**/Tie/DOWLEX 2045G (37.5/10/**5**/10/37.5) 4 mil

Tie-layers: Dow's standard tie-layer and ultra tough tie-layer



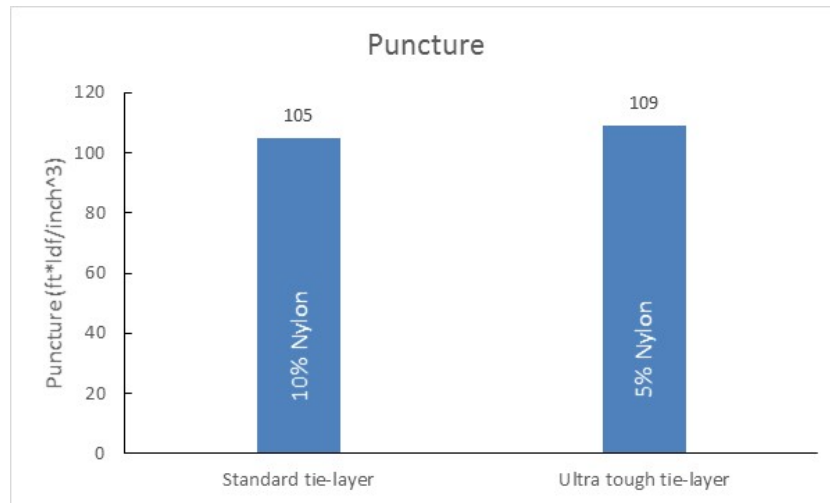
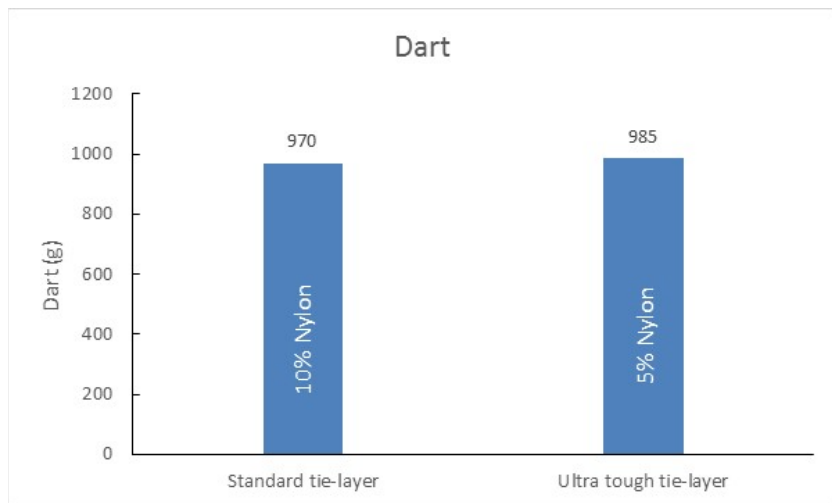
- Ultra tough tie-layer has equal or better puncture resistance than the standard tie-layer.



Ultra Tough Tie-Layer: Nylon Replacement

Film-3 DOWLEX 2045G/Standard tie/Nylon/Standard tie/DOWLEX 2045G (35/10/10/10/35) 4 mil

Film-4 DOWLEX 2045G/UT tie/Nylon/UT tie/DOWLEX 2045G (37.5/10/5/10/37.5) 4 mil



- The dart and puncture shown by a structure with a 5% nylon layer and ultra tough (UT) tie-layer are equivalent to a structure with a 10% nylon layer and a standard tie-layer.

Benefits of Barrier Tie-Layer

Problem: The O₂ barrier properties of EVOH and polyamide deteriorate when being exposed to high moisture or relative humidity.

Incumbent solutions: Use extra amount of LDPE or LLDPE, blend HDPE, position HDPE around EVOH and polyamide, or use an extra amount of EVOH or polyamide.

Our solution: A multi-functional tie-layer,

- tie-layer to adhere EVOH/polyamide to PE film structure;
- barrier-layer to protect the EVOH/polyamide layer.

Competitive advantages: Longer shelf life for the same packaging structure; streamlined process; down-gauging potential from improvements of both OTR and WVTR.

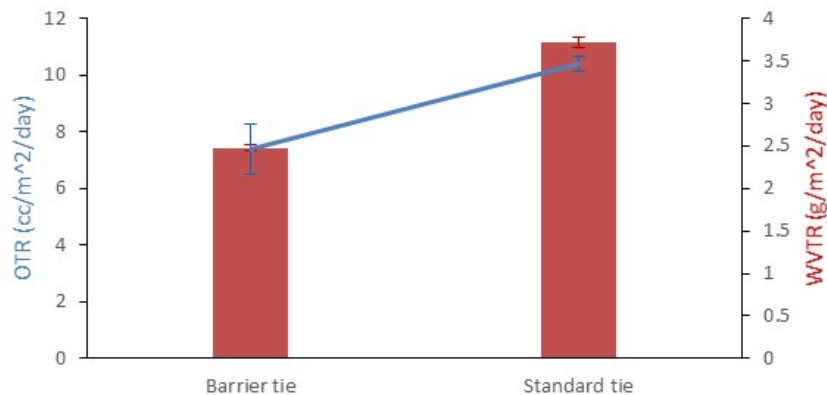
Barrier Tie-layer: Robust Barrier Improvement

Film-5 Dowlex 2045G /Tie /EVOH /Tie/Dowlex 2045G (24/18/16/18/24) 2.2 mil

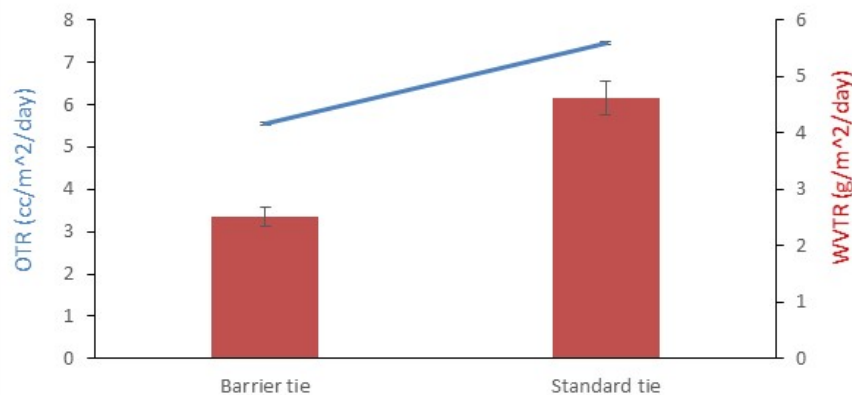
Film-6 Dowlex 2045G/Tie/Nylon/EVOH/Nylon/Tie/Dowlex 2045G (17/15/7/17/7/15/22) 2.7 mil

Tie-layers: AMPLIFY™ TY 1353 and barrier tie

5-layer film with EVOH (2.2 mil)
RH=90%, T=23°C(OTR), 37.8°C (WVTR)



7-layer film with Nylon/EVOH (2.7 mil)
RH=90%, T=23°C (OTR), 37.8°C (WVTR)



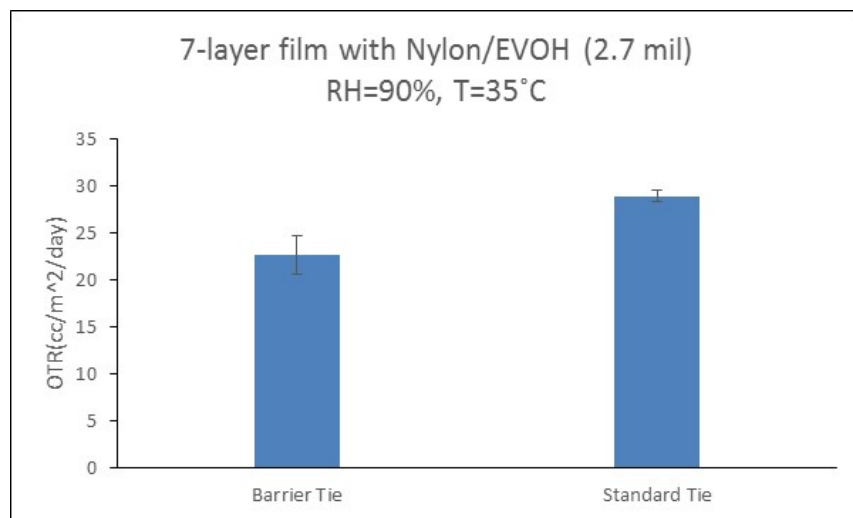
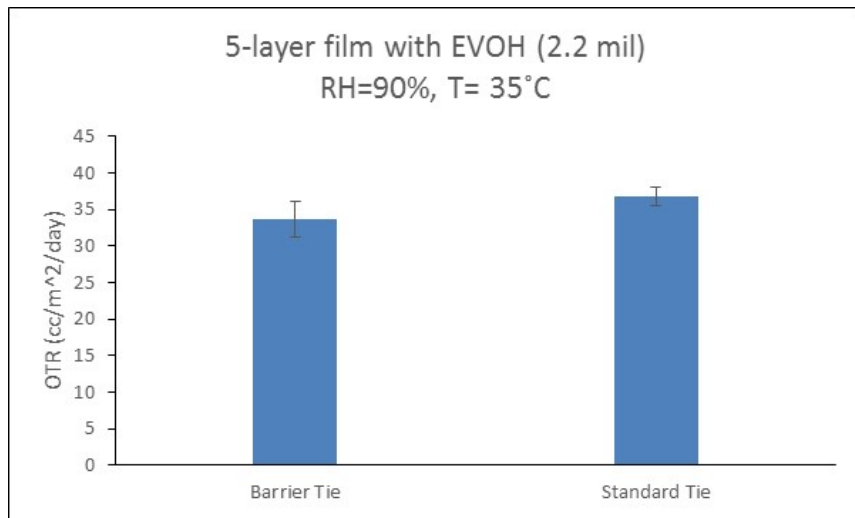
- OTR is lower by ~30% with barrier tie-layer.
- WVTR is lower by ~ 40% with barrier tie-layer.

O₂ Barrier Improvement at 35°C

Film-5 Dowlex 2045G /Tie /EVOH /Tie/Dowlex 2045G (24/18/16/18/24) 2.2 mil

Film-6 Dowlex 2045G/Tie/Nylon/EVOH/Nylon/Tie/Dowlex 2045G (17/15/7/17/7/15/22) 2.7 mil

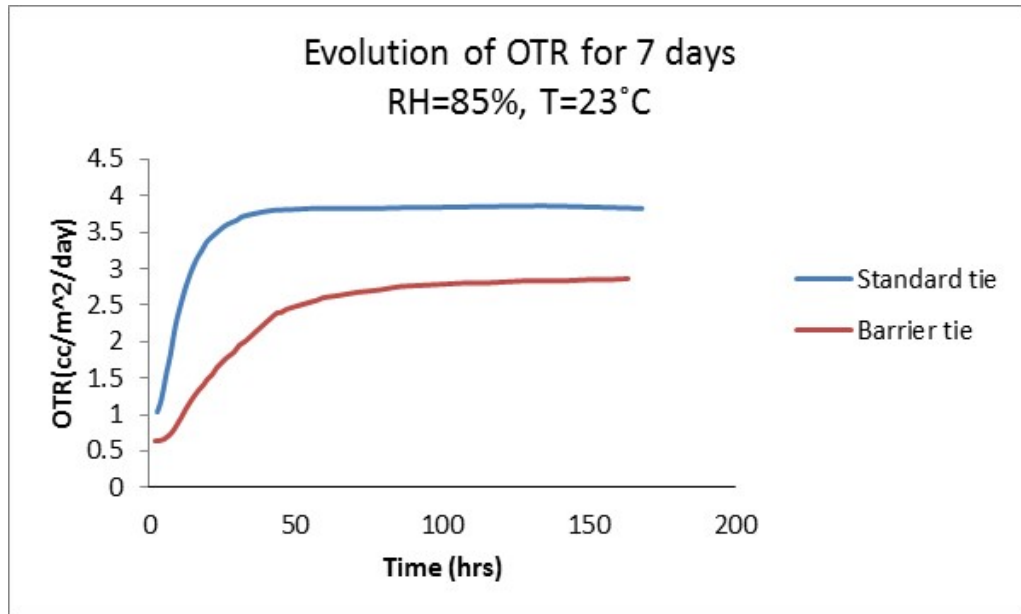
Tie-layers: AMPLIFY™ TY 1353 and barrier tie



- OTR is lower with barrier tie-layer even at 35°C, the extreme condition.

Sustained Barrier Improvement

Film-6 Dowlex 2045G/**Tie/Nylon/EVOH/Nylon/Tie**/Dowlex 2045G (17/15/7/17/7/15/22) 2.7 mil
Tie-layers: AMPLIFY™ TY 1353 and barrier tie



- Long lasting barrier improvement with barrier tie-layer.

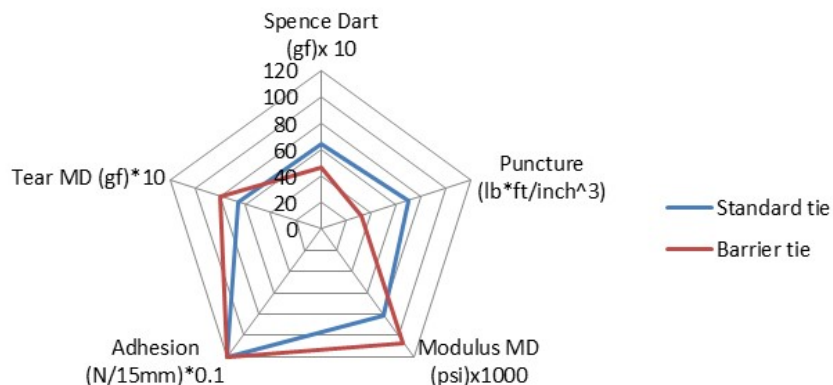
Mechanical Properties

Film-5 Dowlex 2045G /Tie /EVOH /Tie/Dowlex 2045G (24/18/16/18/24) 2.2 mil

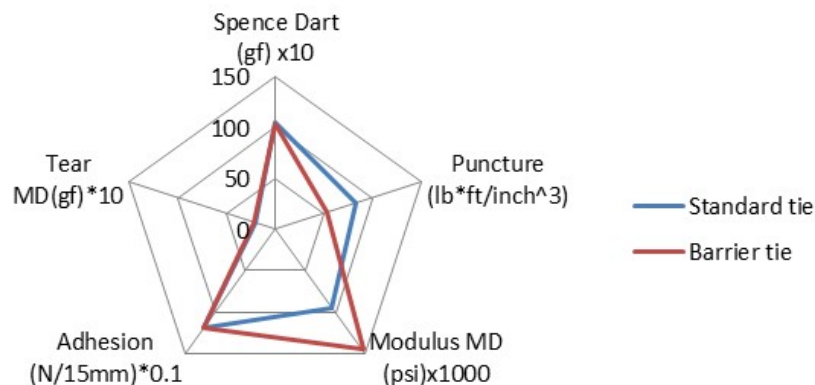
Film-6 Dowlex 2045G/Tie/Nylon/EVOH/Nylon/Tie/Dowlex 2045G (17/15/7/17/7/15/22) 2.7 mil

Tie-layers: AMPLIFY™ TY 1353 and barrier tie.

5-layer Film with EVOH (2.2 mil)

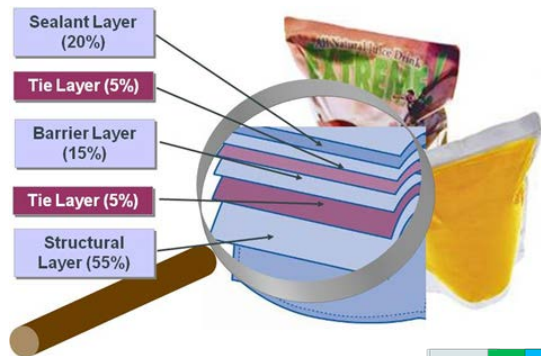


7-layer film with Nylon/EVOH (2.7 mil)



- Great adhesion achieved with barrier tie-layer. (Patent pending technology)
- Higher modulus but lower toughness with barrier tie-layer.
- Moderate increase in tear with barrier tie-layer.

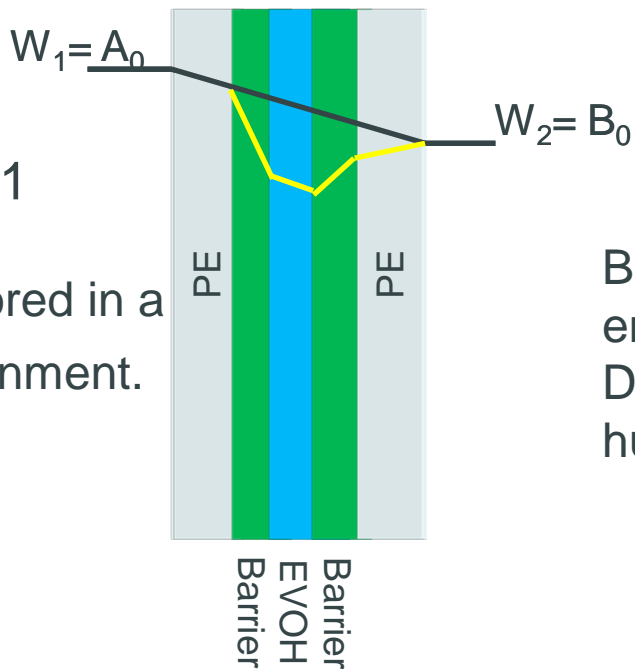
Film Design Considerations



1. High moisture on both sides
2. High moisture on one side

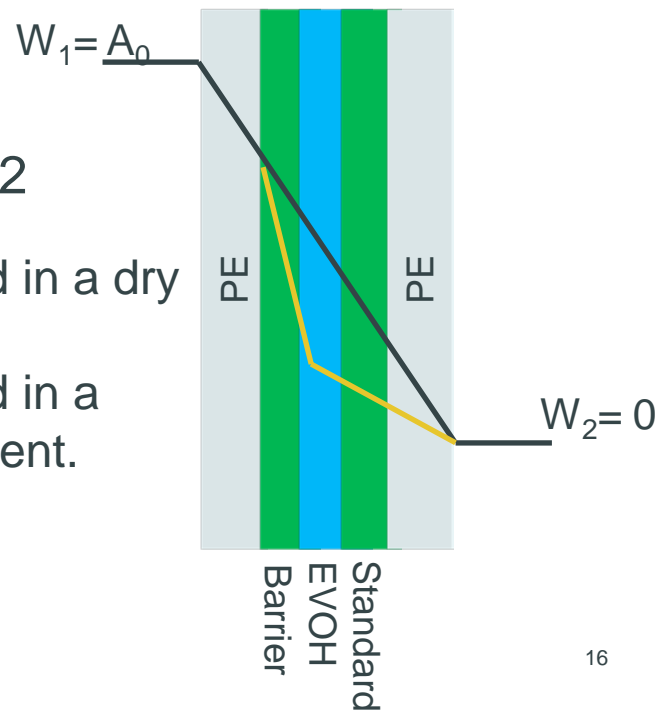
Scenario-1

Beverage stored in a humid environment.



Scenario-2

Beverage stored in a dry environment.
Dry foods stored in a humid environment.



Conclusions

- Dual functional tie-layers can help converters improve film properties while maintaining a streamlined process.
- Tough tie-layer can deliver up to 30% improvement in film dart with tie-layers accounting for 20% of the total film.
- Tough tie-layer can potentially reduce the use of nylon in selected film structures.
- Barrier tie-layer can reduce OTR and WVTR by ~30% with tie-layers accounting for 30% of the total film.
- The use of barrier tie-layer can improve the tear and stiffness, but incur some toughness loss in the film.
- Both dual functional tie-layers have excellent adhesion.



THANK YOU!

