High Performance Barrier Films for Vacuum Insulation Panels

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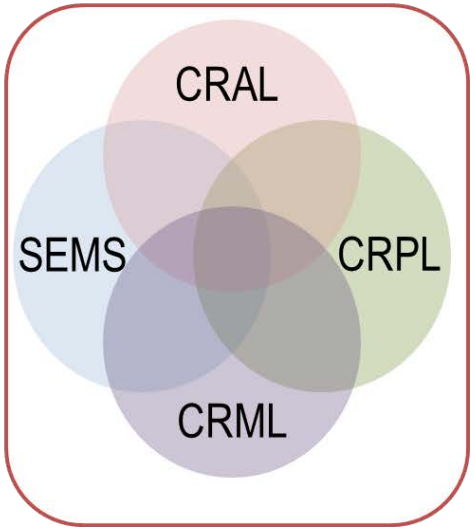
3M Technology to Product Commercialization Process

Fundamental Technology Development → Product Development → Product Commercialization

CRL



CRL – Corporate Research Lab
- CRPL: Corporate Research ***Process*** Lab
- CRML: Corporate Research ***Materials*** Lab
- CRAL: Corporate Research ***Analytical*** Lab
- SEMS: Software, Electronic, & Mechanical Systems Lab

CRL + Business Group: Multiple Divisions with Applied Development Engineering Teams

Industrial
From purification to aerospace – changing how industry works

Safety & Graphics
From protecting people & information to enhancing visual & design communication

Electronics & Energy
Enabling tomorrow's lifestyle today with power, communications and electronics

Consumer
From simplifying life at home to keeping you organized at work

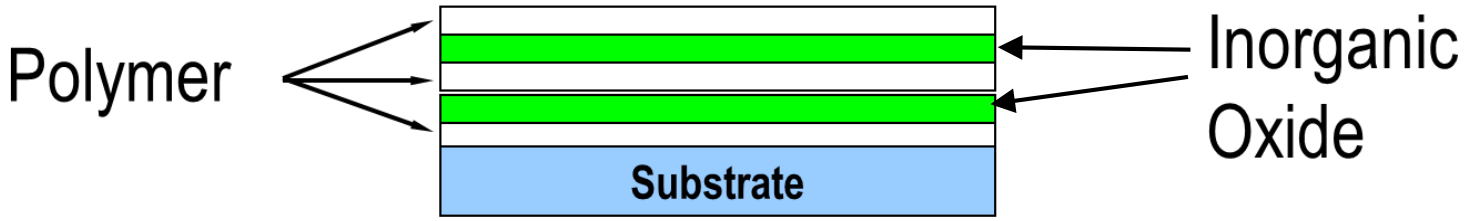
Health Care
From preventing infections to making smiles brighter

Outline

- Standard 3M barrier construction and performance
- Applications and WVTR specifications
- Vacuum Insulation Panels (VIP)
- Adaptions for barrier films for VIP application - Product Performance/Testing
- Summary

3M™ UltraBarrier Film (FTB3-50)

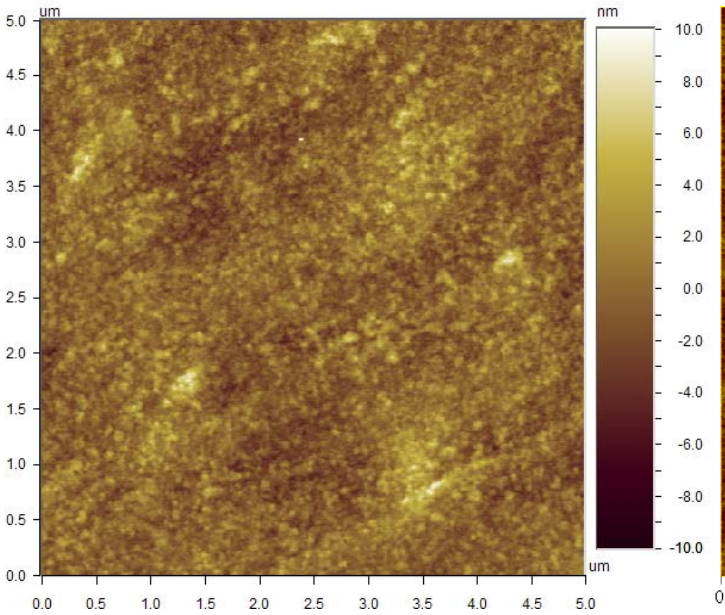
Polymer Multi-Layer (PML) constructions on flexible polymers - acrylate layers separated by inorganic oxides



- Roll-to-Roll processing
- Polymer (acrylate): Organic Vapor Deposition
- Oxides: PVD (Sputtering, Evaporation)
- Required barrier performance dictates number of layers
- Ideal for flexible products (inorganic barrier layer thicknesses of 10’s of nm)

PML Smoothing Capability

PET ST-504, 5mil



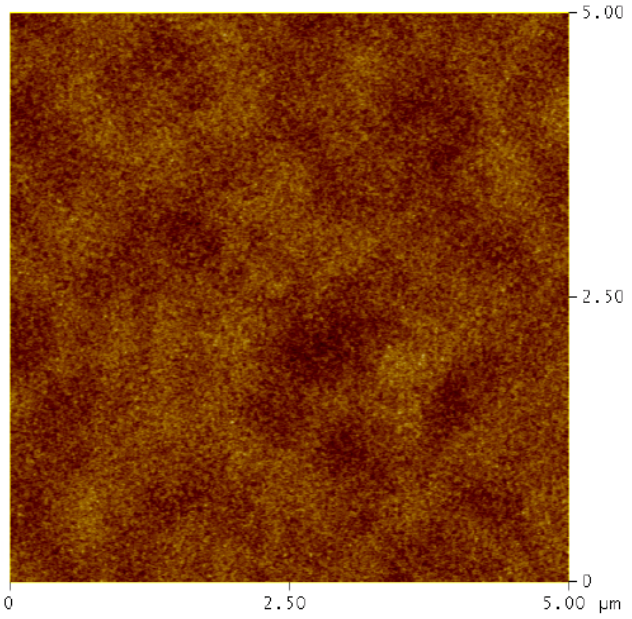
Ra = 1.36 nm

Rq = 1.75 nm

Rt = 19.84 nm

acrylate

PET ST-504, 5mil



Ra = 0.515 nm

Rq = 0.646 nm

Rt = 6.673 nm

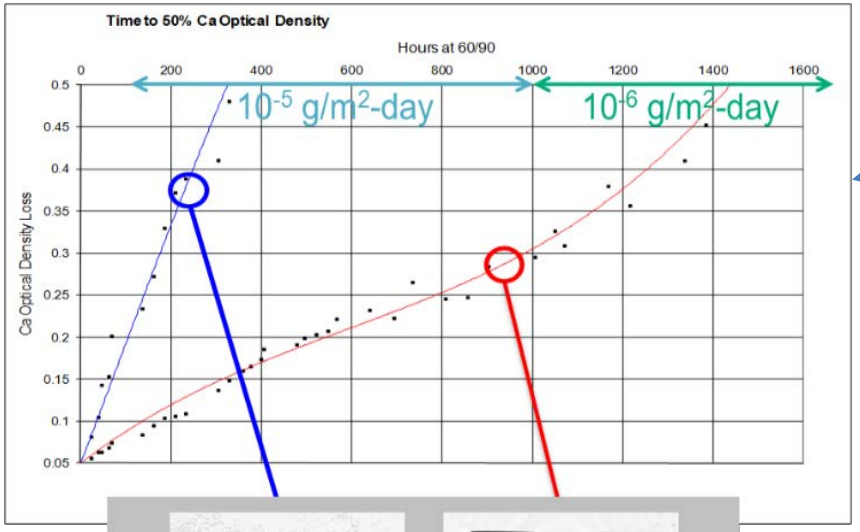
3M™ UltraBarrier (FTB3-50) Film Performance

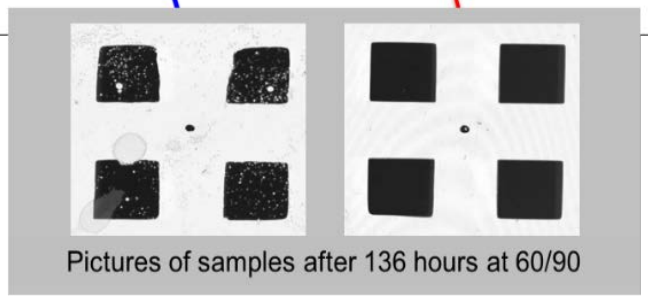
Typical WVTR values (50 °C, 100% Rh):

Mocon (Permatran 700) - <5 x 10^{-3} g/(m^2day) (below detection level)

Mocon (Aquatran I) - low-mid 10^{-4} g/(m^2day) (at or below detection level)

Ca Measurement Data (60 °C, 90% Rh)



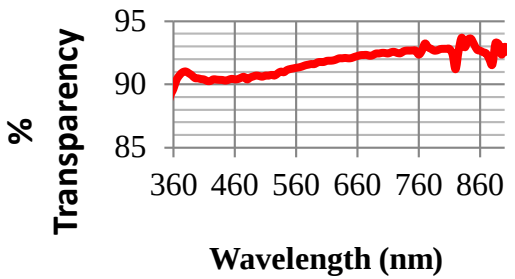


Values from stoichiometric modeling, Optical Trans. Data

Blue: standard FTB3-50 barrier film

Red: two-ply laminate barrier film (OLEDS)

high transmission (>90%)

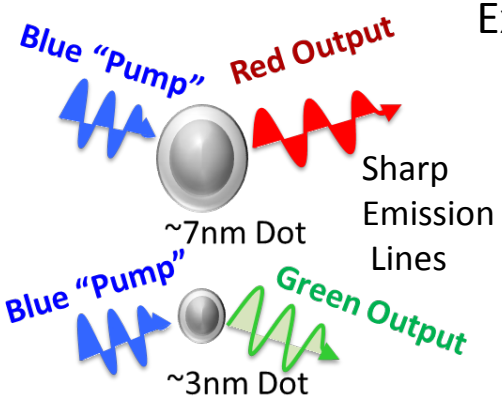


3M barrier flexible film for electronic applications

Displays

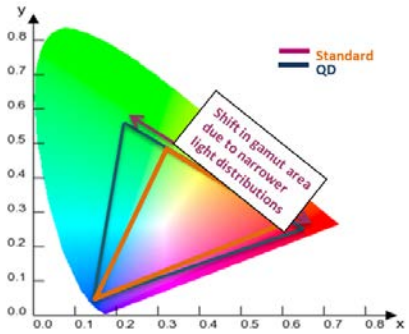
Quantum Dots (AIMCALS 2016)

Light Conversion

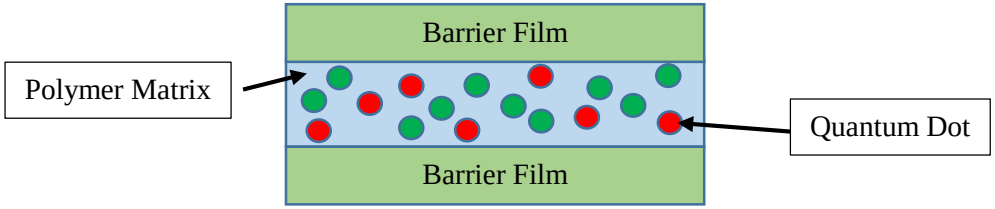


Sharp Emission Lines

Narrow emission lines= Expanded Gamut



Richer Reds, Deeper Greens



Barrier Requirements: WVTR of 10^{-2} to 10^{-4} g/(m^{2}day)

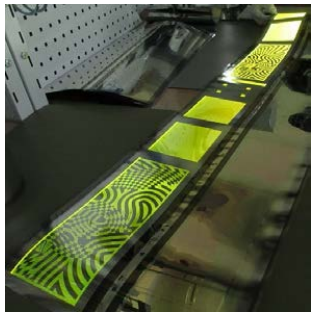
Organic Light Emitting Diodes OLEDS

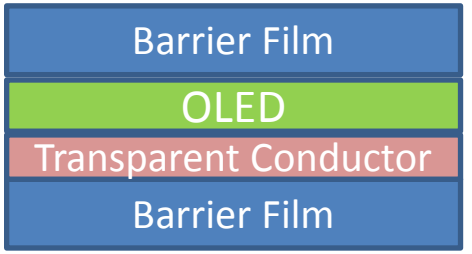
No backlight = deep black levels

Flexible Applications

Lighting Applications

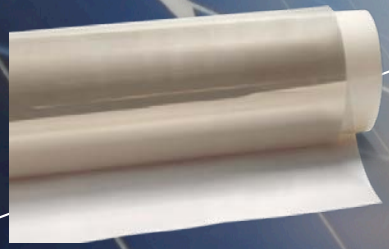
Roll-to-roll: 3M and Fraunhofer FEP





Barrier Requirements: WVTR of 10^{-6} g/(m^{2}day)

UBF 512 Solar Barrier Film

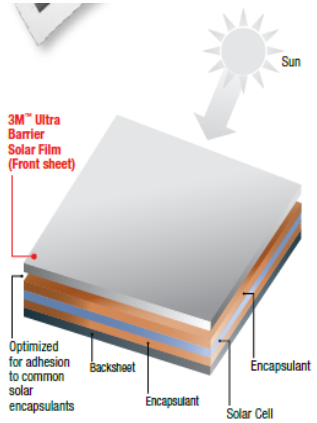


Delivering Efficient And Reliable Energy "EVERYWHERE"

3M Electrical Markets Division
Renewable Solutions

Why Flexible Modules?
– 3M UBF 512 enabling new markets for PV

- **Lightweight** (1/5 the weight of silicon modules)
- **Large Area** (not limited by glass size)
- **New Form Factors**
- **Portable Power Generation**
- No roof penetrations
- No racking needed
- Potential for roof integration
- Ability to adapt to curved roof
- Flush integration with standing seam metal roofs
- High durability and low profile
- Good for high wind zones



Barrier requirements: WVTR of 10^{-4} g/(m^2day)

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Going beyond electronic applications for 3M barrier

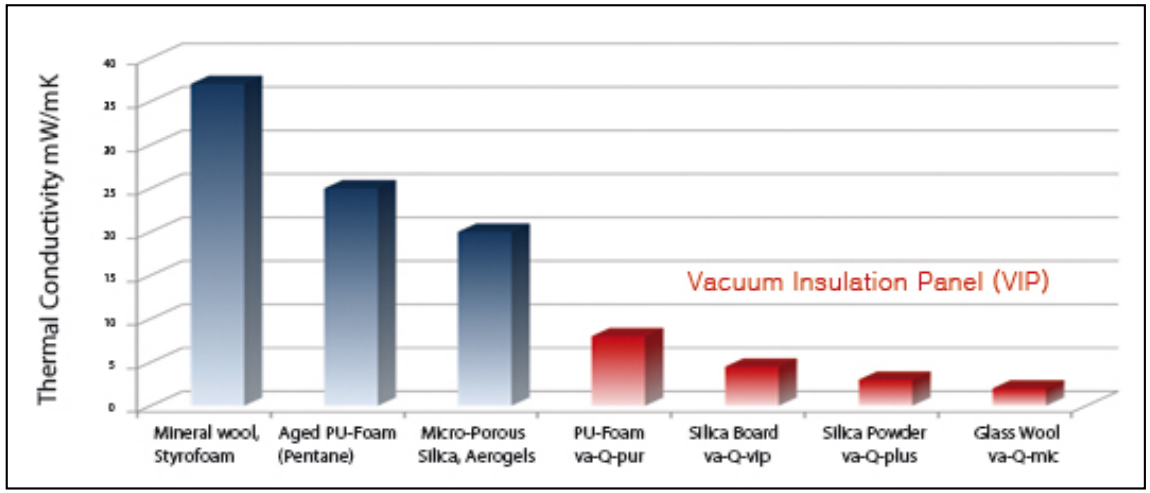
Vacuum Insulation Panels (VIP)

Thermal insulation consisting of a gas-tight enclosure surrounding a core material

- Building insulation
- Refrigeration

Advantages over standard insulation:

- Eliminates **convection** - (Vacuum)
- Lower **conductance** (no atom collisions)
- Higher thermal resistance per thickness
- **10 times greater efficiency than glass fiber, PU foam & other standard materials**



R values: VIP ~30-50/inch depending on type of core
(typical value for fiberglass board, spray cellulose ~3-4/inch)

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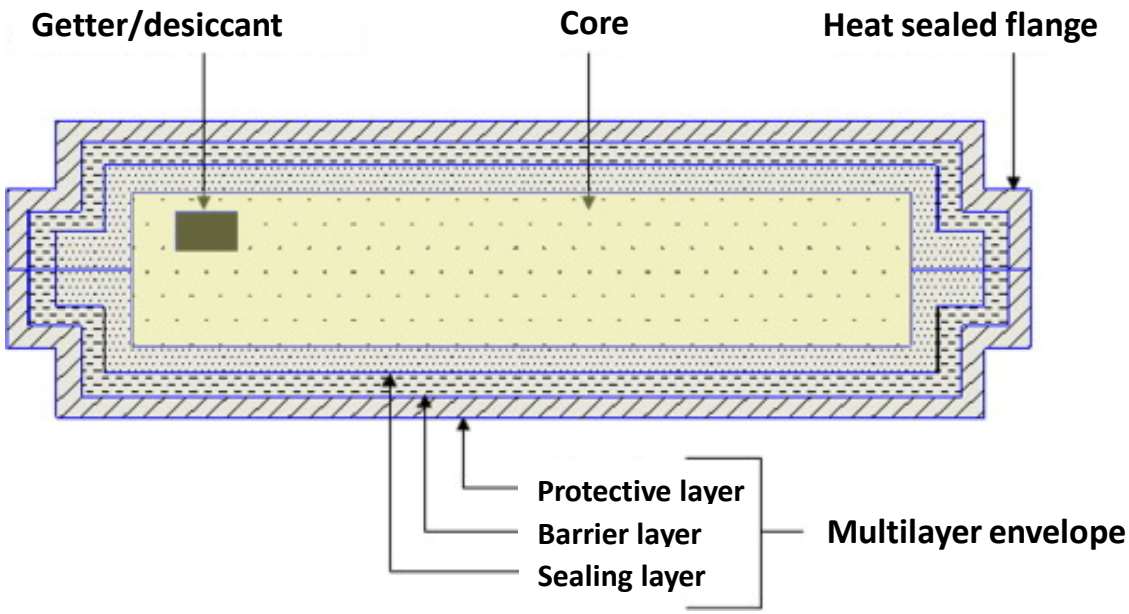
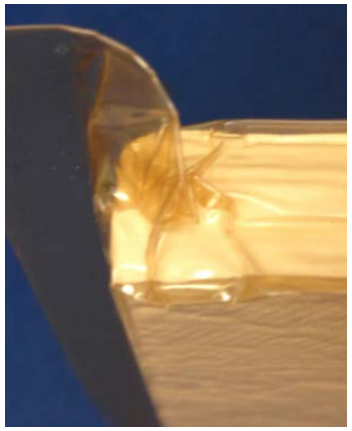
Vacuum Insulation Panel

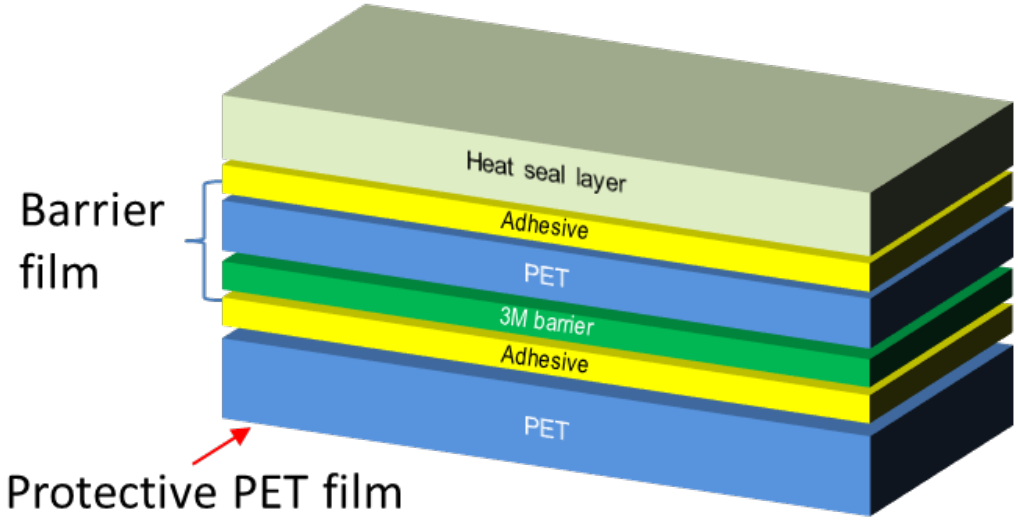
- **Core Material**
  - Fumed Silica
  - Aerogels
  - Polyurethane Foam
  - Glass Fiber
- **Barrier Envelope**
  - Aluminum Foil
  - Metalized PET films
- **Barriers to greater adoption**
  - **Cost**
  - **Longer service life**
  - **Durability and puncture risk**
  - Lack of customization



Barrier requirements: O_2 of 10^{-2} to 10^{-6} cc/(m^2day)
Wide range for different product lifetimes



3M VIP barrier film construction



Construction Details:

1) Heat seal layer for making VIP envelope
2) Protective PET – Puncture resistance, protects barrier component
3) Optimized construction (PET and heat seal thicknesses) – neutral stress plane located at barrier film

Specifications:

Application of 3M barrier film to VIP

- Longer service lifetimes → excellent barrier performance:

  High end design: OTR $\sim 10^{-4}$ cc/(m^2*day) (23C, 50%Rh)

  WVTR $\sim 10^{-4}$ g/(m^2*day) (50°C, 100% Rh)

- Durability

  Good Forming Performance – edges of panel

  Optimal bend performance

  Optimized construction – Neutral stress plane in region of barrier film

  Puncture resistant

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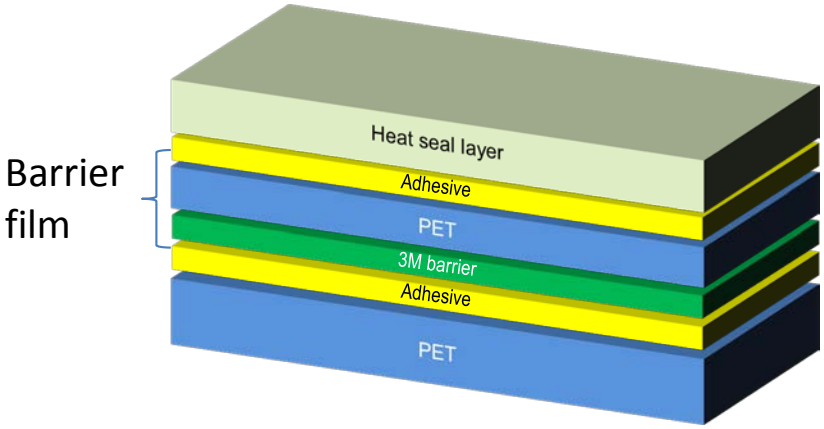
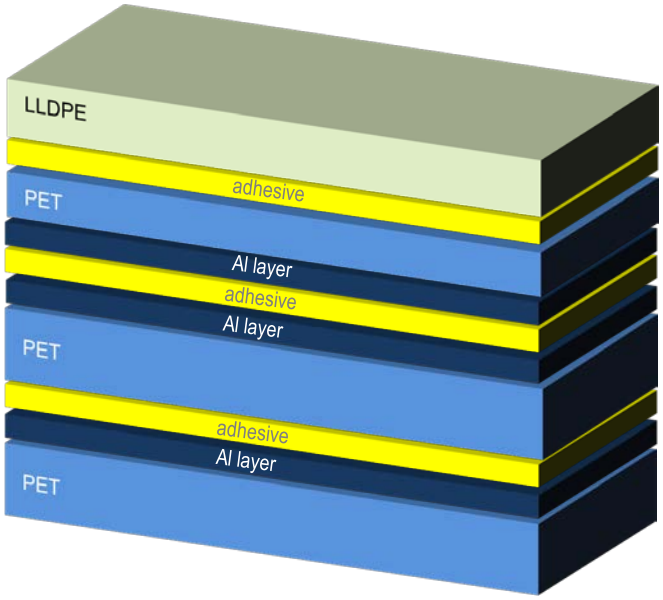
3M vs Standard VIP films

3M VIP barrier film construction



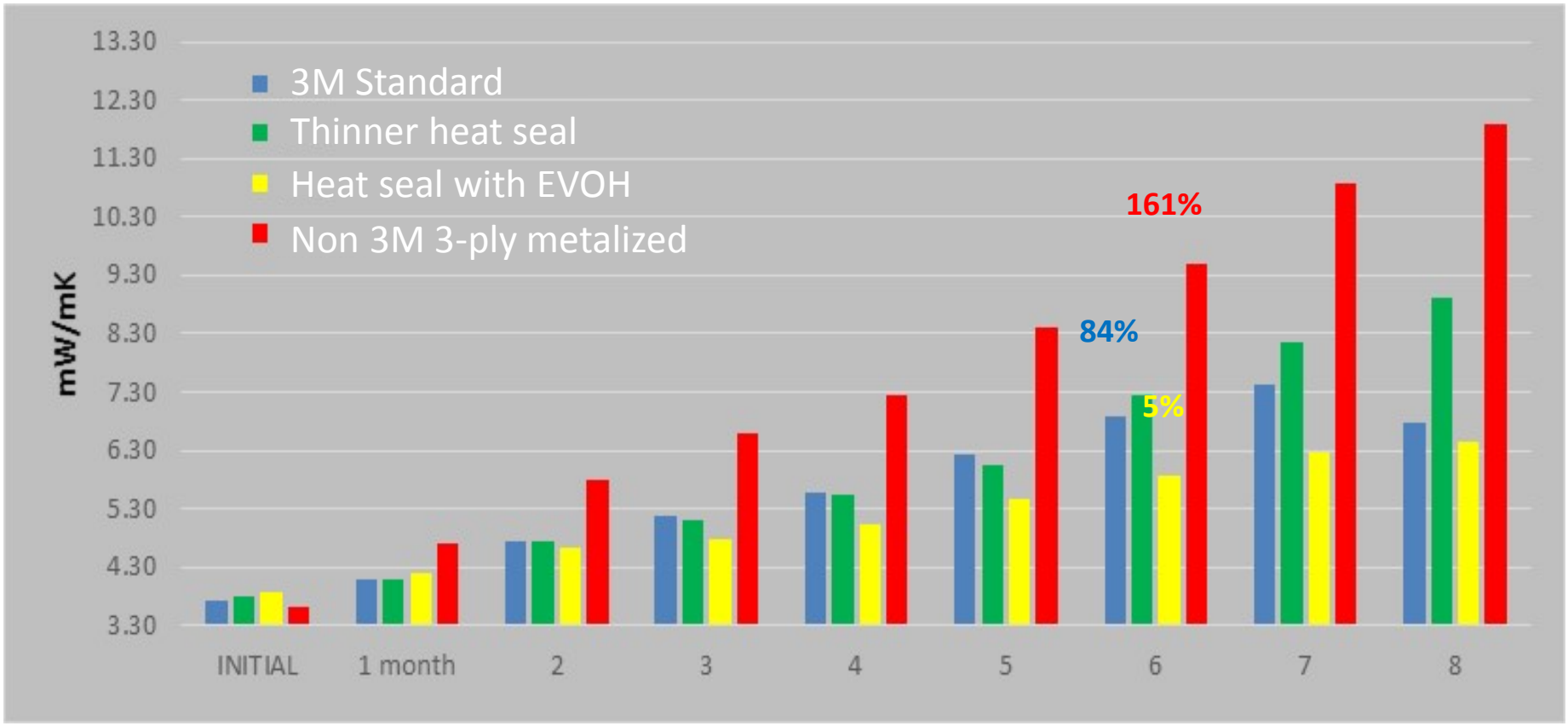
3 –ply metalized competitors option



Tested Options:

1) Std.
2) Thinner heat seal layer – lower costs
3) Heat seal film with Ethylene vinyl alcohol (EVOH) layer – for O_2 gettering

VIP Accelerated Aging
50°C + 70% RH



- After 6 months of accelerated aging exposure , 3M degradation 3X less than 3 ply metalized film
- Thinner heat seal layer– increased degradation due to unoptimized construction – Neutral plane not at barrier film
- Heat seal EVOH – best performance (but added cost)

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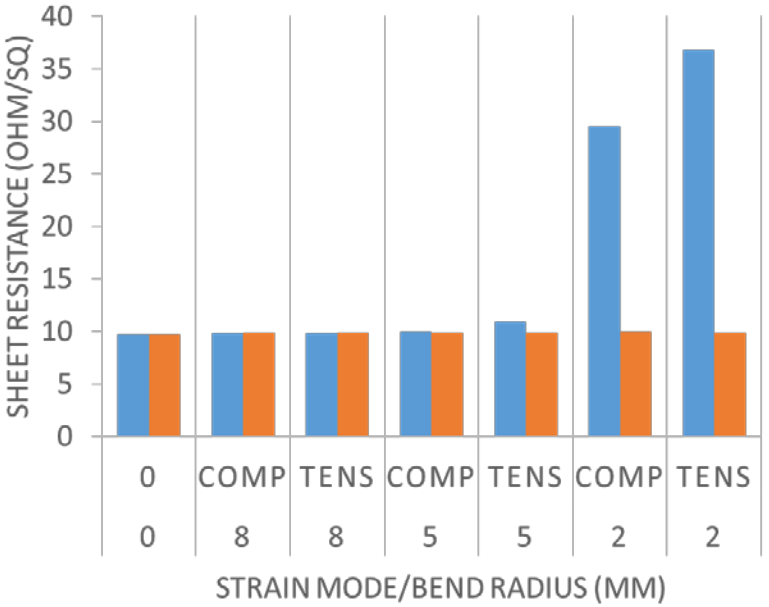
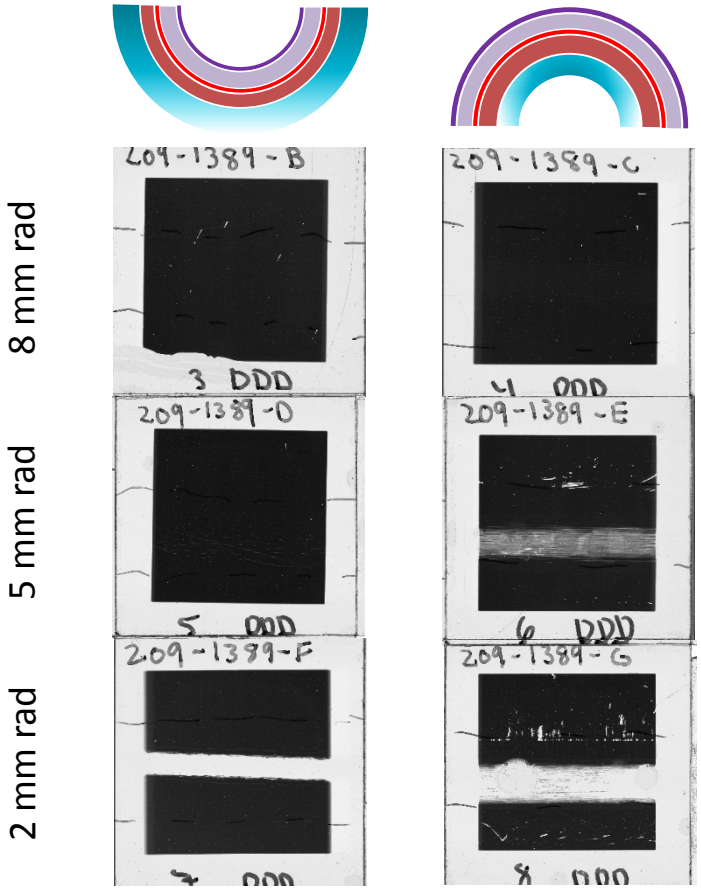
Barrier Performance with bend testing

- Barrier film with transparent conductor
- Transparent conductor to monitor sheet resistance
- Good Performance up to 5 mm bend radius
- Significant (3-4x) increase in R_{sheet} only at 2mm





2 hrs at 60C/90%RH

Application of 3M barrier film to VIP

- Longer service lifetimes → excellent barrier performance:

  High end design: OTR $\sim 10^{-4}$ cc/(m^2*day) (Tests conditions)

  WVTR $\sim 10^{-4}$ g/(m^2*day) (50°C, 100% Rh)

- Durability

  Good Forming Performance – edges of panel

  Optimal bend performance

  Optimized construction – Neutral stress plain in region of barrier film

- Cost

  Barrier previously optimized for Electronic Applications: Higher price points

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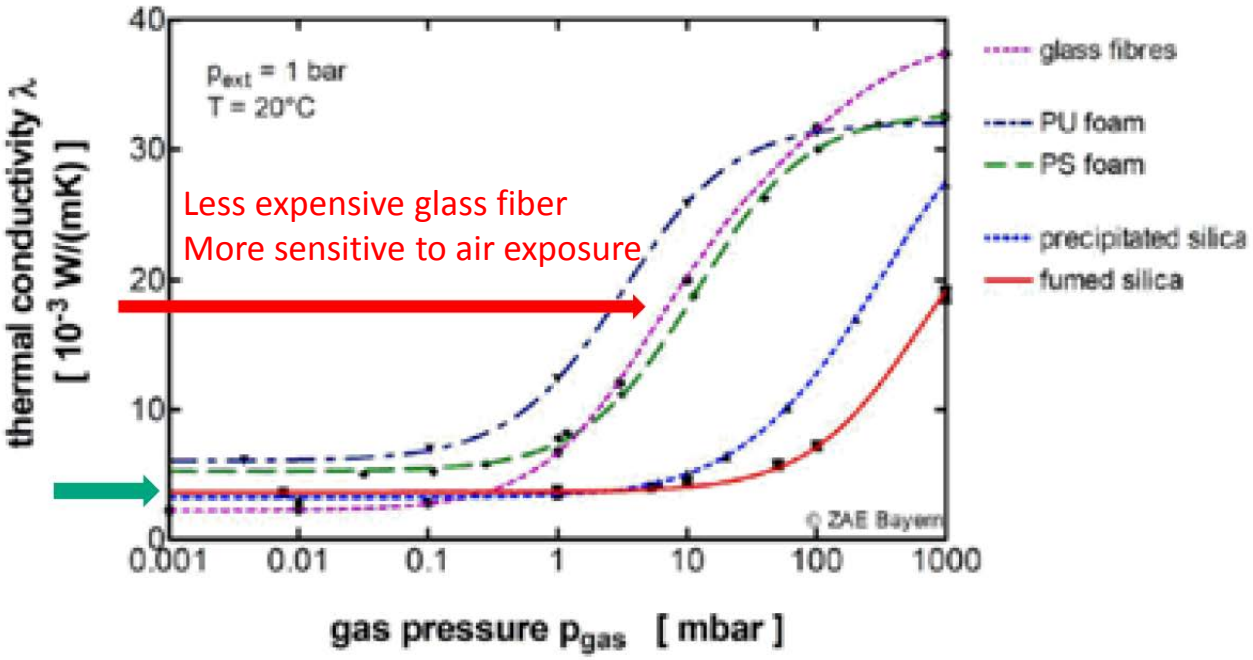
Cost reductions

- Why a high performance barrier film → Allows for use of glass fiber over more expensive fumed silica



- Minimizing PET thickness – Optimized for lower cost while maintaining neutral axis on barrier film
- Higher Operation Speeds – alterations to barrier film fabrication conditions

With these changes, 3M barrier films cost competitive for VIP applications

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Summary

- High Performance, high transparency 3M barrier films – optimized for high opto-electronic applications
- Further optimization of the process and barrier film construction → 3M degradation is 3X less than 3 ply metalized film
- Cost effective option for Vacuum Insulating Panels :
  - Low WVTR and OTR values
  - Good durability with bending (seal formation)
  - Good durability with optimal construction- optimal placement of the neutral stress plane
  - Competitive costs
    - thinner PET
    - Lower cost core material
    - Higher web speeds

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