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Nanotechnology for Soldier Rations

Packaging for the Military

Jo Ann Ratto

June 26, 2008

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Outline

- Food Packaging - Background
- Introduction to Military Ration Packaging and Specifications
- Nanocomposites in Packaging
- Current Nanocomposite Research Efforts
- Results to Date
- Future of Multilayer Nanocomposites
- Questions

Food Packaging

Expectations for Packaged Food

- Taste (Appearance, Texture, Odor)
- Nutrition
- Convenience
- Storage Shelf Life
- Physical Structure
- Safety and Environmental Costs

*J.H. Hotchkiss, Cornell University

Shelf Life

The time it takes a food product to deteriorate to an unacceptable degree under specific storage, processing, and packaging conditions

Modes of Food Deterioration

Oxidation

Moisture Gain or Loss

Polymer Barrier Packaging

OXYGEN BARRIER – Traditional & New

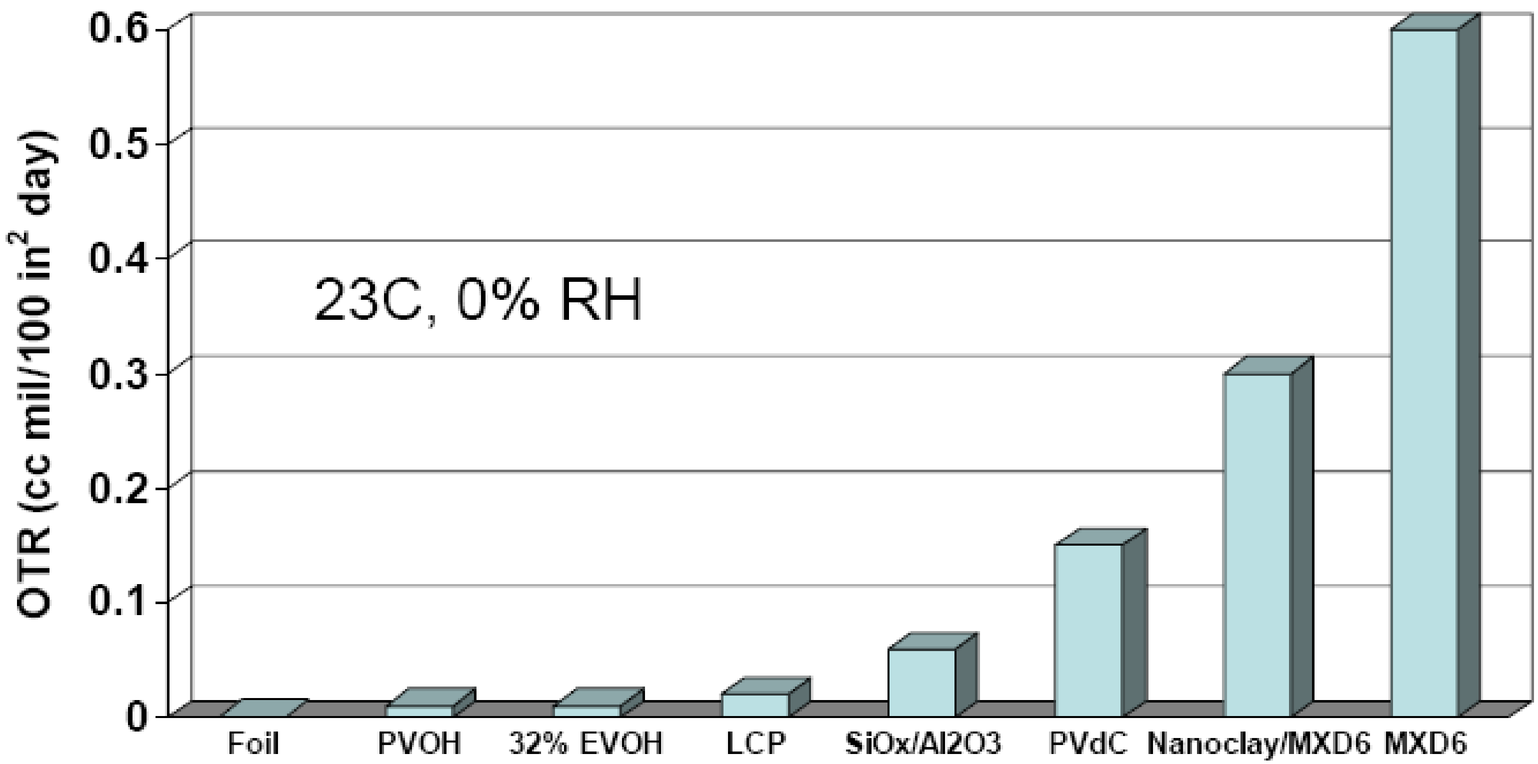
- EVOH
- PVDC
- Polyamides
- Polyester
- SAN, PAN
- $(SiO_2)_x$
- Metallized Polyester

*M.Stevens – MOCON Webinar Dec 12, 2007

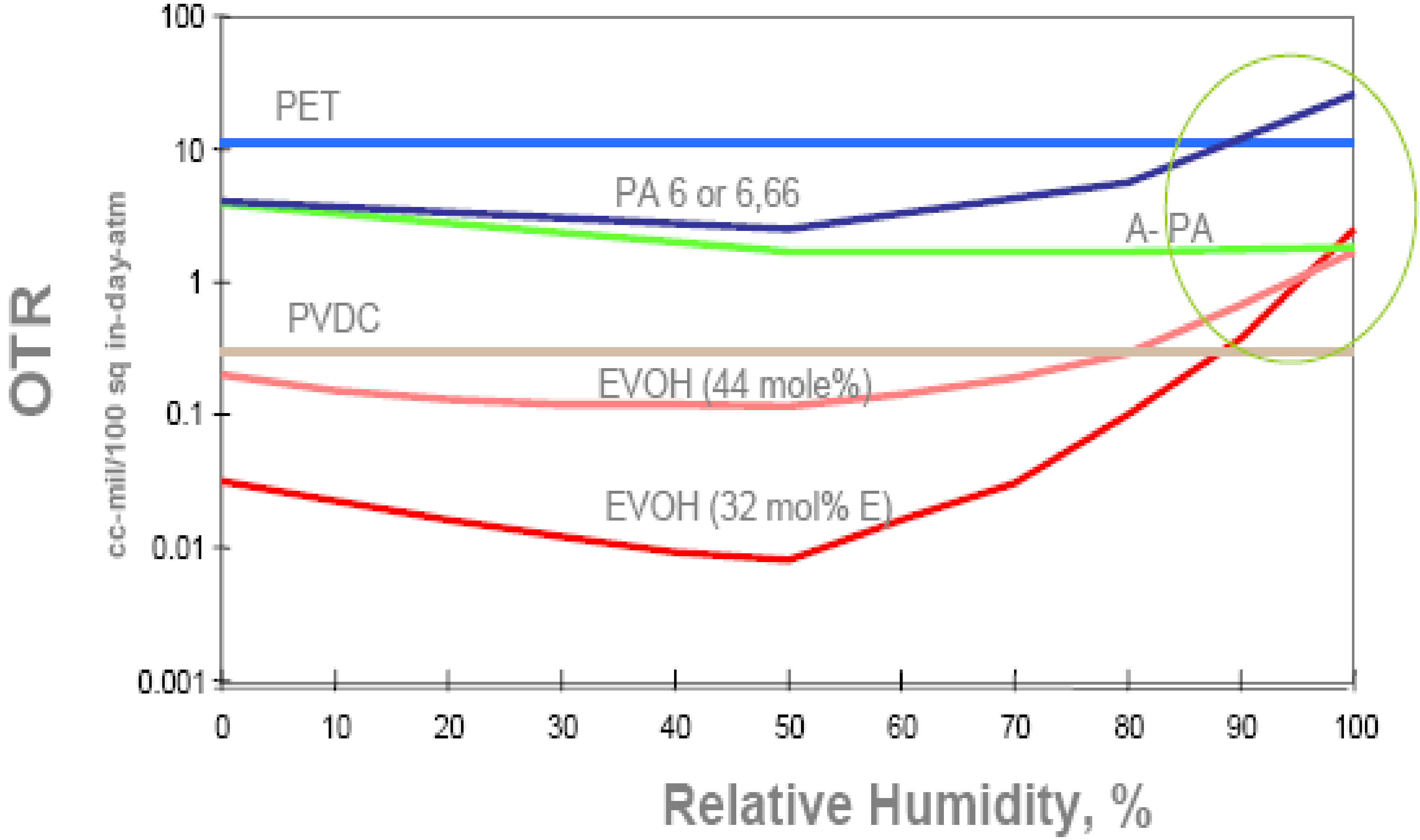
Water Barrier – Traditional & "New"

- Polyethylene
- Ethylene Copolymers :
  - Ionomers, EVA, ACR
- Polypropylene
- PVdC
- COC's
- LCP's

OTR of high barrier materials



Permeability in Polymer Packaging



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Introduction to Military Ration Packaging and Specifications

Military Need

- Military needs an improved ration packaging system that:
  - Reduces logistical burden on Warfighter
  - Eliminates impact on environment
  - Perfoms comparable to existing packaging
- Need to address ration packaging at 3 levels
  - Primary packaging
    - Food preservation and containment
  - Secondary packaging
    - MRE containers, sleeves and shippers
  - Unit load
    - Pallet loads

Current Meal,Ready-To-Eat (MRE)

Layer	
Polyolefin	⇐ Inner Layer
Aluminum Foil	
Polyamide	
Polyester	⇐ Outer Layer

Retort Pouch (entrée)

Transmission Rates: O_2……….0.06 cc/m²/d
H_2O……...0.01 g/m²/d

Shelf Life: 3 years @ 80 ºF
6 month @ 100 ºF

Layer	
PE or ionomer	⇐ Inner Layer
Aluminum Foil	
Polyester	⇐ Outer Layer

Non-Retort Pouch (cookies, crackers, etc)

Layer
LLDPE

Meal Bag

Application to Military Rations

Unitized Group Ration (UGR)

Meal, Ready-to-Eat (MRE)

Remove Foil Based Packaging

Increase Compatibility with Advanced Food Processes

Eliminate Handling Problems

Improve Recyclability

Reduce Solid Waste

Military Food Packaging Application

Objectives:

- Reduce solid waste packaging
- Develop high barrier, non-foil material using nanotechnology
- Eliminate pinholes, flex cracking problems
- Improve barrier properties
- Enhance package survivability
- Enhance shelf life
- Enhance producibility

Limitations Caused by Foil Barrier Layer in Multilayer Structure

Processing Limitations

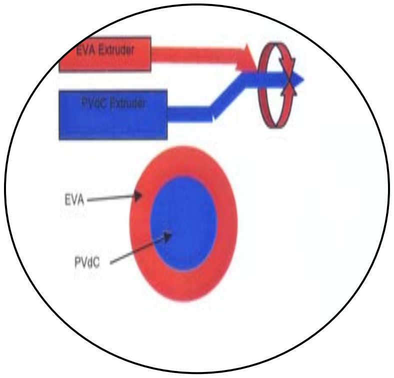
- **Limitations to Food Processing and Sterilization Techniques**
    - Microwave Processing
    - High Pressure Pasteurization (Delamination)
- **Multiple Lamination Steps Needed for Package**
- **Limited Pouch Forming Processes**

    (Horizontal Form Fill Seal)

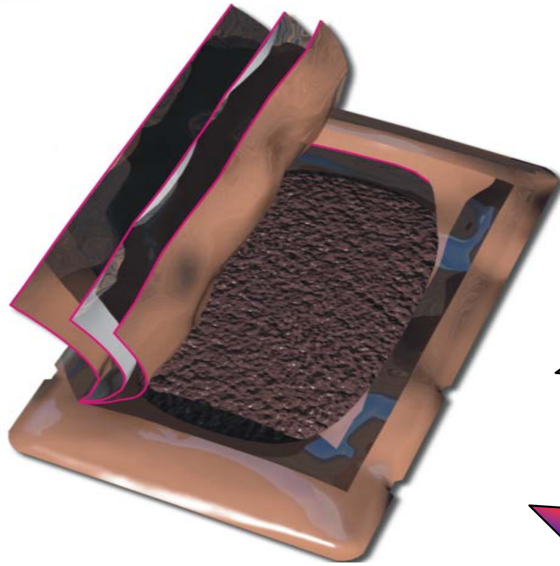
Performance Limitations

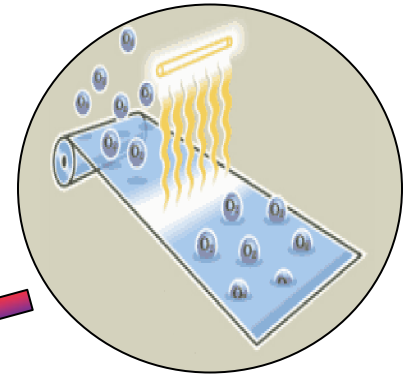
- **Susceptible to Pin-Holes and Stress Induced Fractures**

NSRDEC High Barrier Research



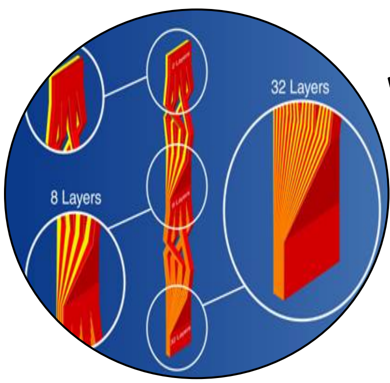
PVDC Encapsulation



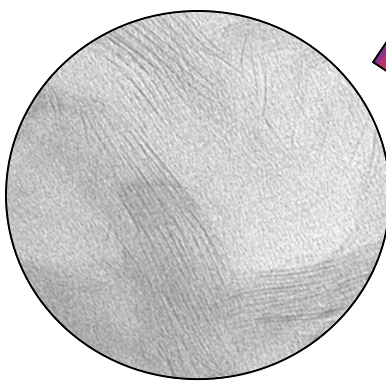


Oxygen Scavengers[1]

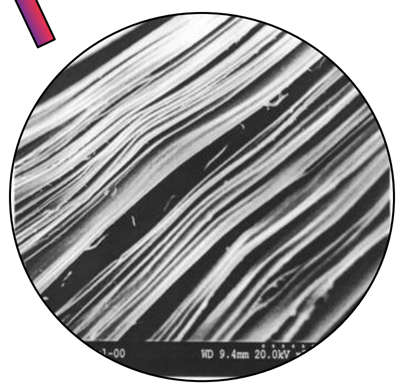
Multifunctional High Barrier Packaging



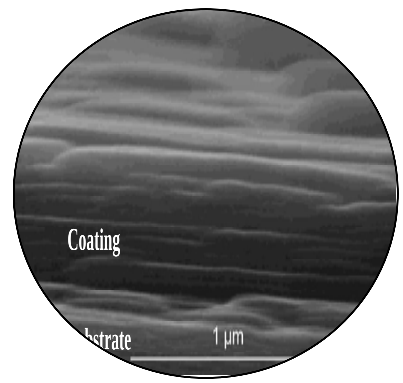
Layer Multiplying[3]



Nanocomposites



Smart Blending[2]



Barrier Coatings

[1]http://www.cryovac.com/products/food/os1000/os_works.html
[2]http://www.ces.clemson.edu/mmpl/concepts/Tutorial/tutorial.html
[3]Micro-layer Coextrusion for High Barrier Performance Packaging Sheets, Draft Concept Paper, EDI, LLC

Nanocomposites for Military Food Packaging

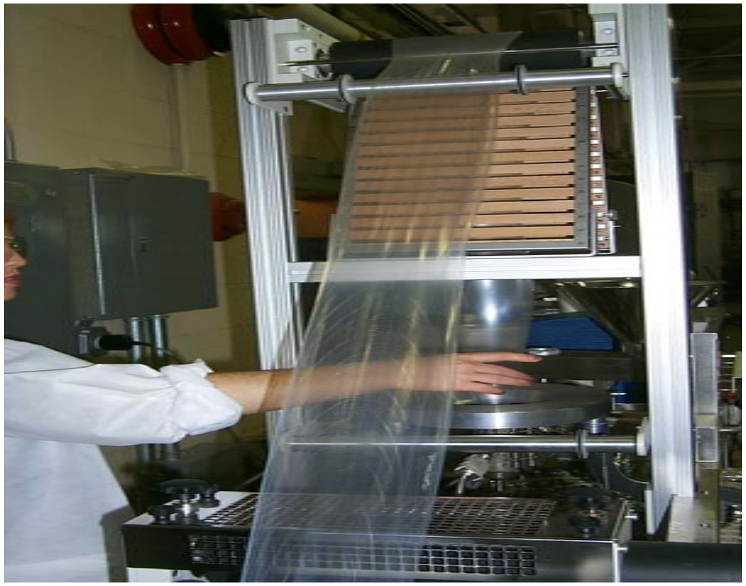
MRE **MRE Waste**

MRE Components

Nanocomposites in Packaging

Reduction of Solid Waste Associated with Military Rations and Packaging

- **Objective - Develop recyclable or biodegradable nanocomposite films with exceptional barrier properties to replace the Meals Ready to Eat (MRE) packaging components and reduce military ration waste.**
- **Approach - Utilize blown film/cast film extrusion processes to produce nanocomposite films and explore melt processing conditions (screw speed, residence time, feed rate, and temperature) that influence nanocomposite properties.**
- **Analysis - Characterize the samples for thermal, mechanical and barrier properties and compare to military specifications.**



This research supports Natick's mission to improve materials used by the soldier, with applications in the areas of packaging. This also supports the Strategic Environmental Research and Development Program (SERDP)

Polymers Studied

- Ethylene Co-vinyl Alcohol (EVOH)
- Low Density Polyethylene (LDPE)
- Polyethylene Terephthalate (PET)
- Nylon 6
- Polylactic Acid (PLA)
- Polyhydroxyalkanoates (PHA)
- LDPE/EVOH coextrusion

Why Nanocomposites?

Commodity Polymers **+** **2-8 wt % layered silicate reinforcements**

Melt Processing

NANOCOMPOSITES

Enhanced Mechanical Properties

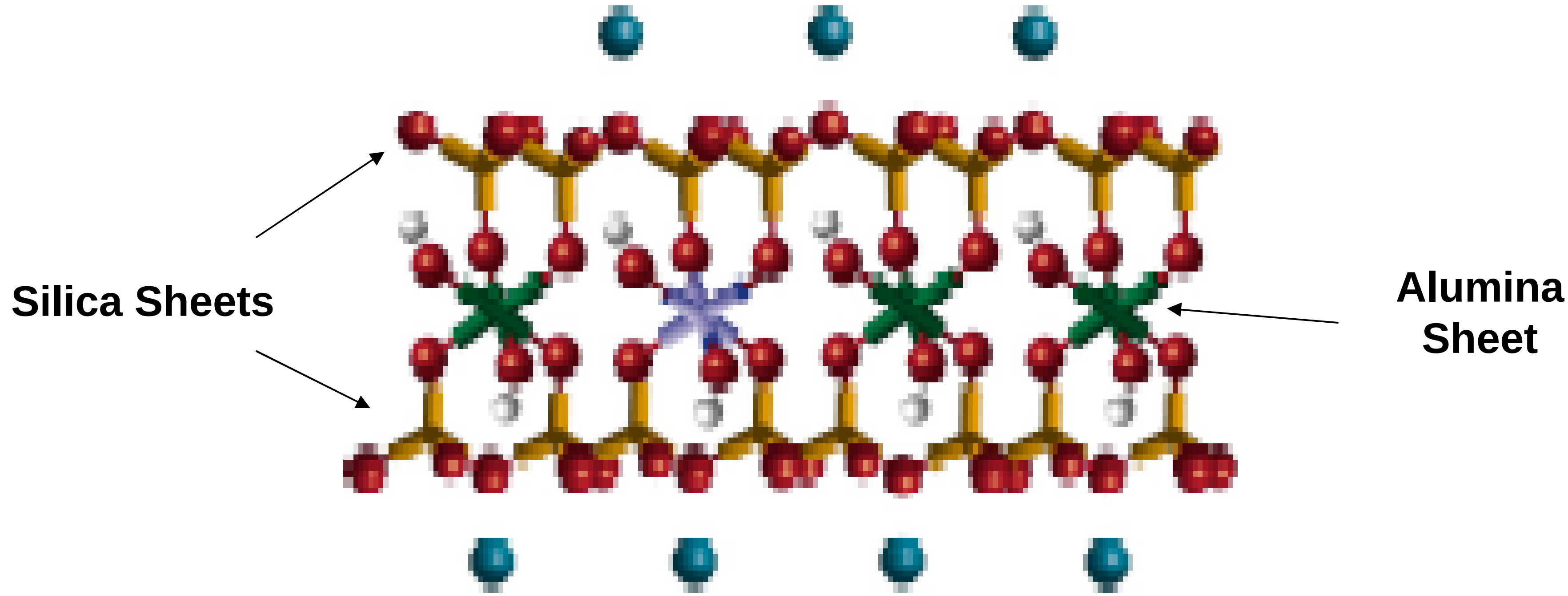
Enhanced Thermal Properties

Single-Step Processing

Enhanced Barrier Properties

Light-weight

Montmorillonite Layered Silicate (MLS)

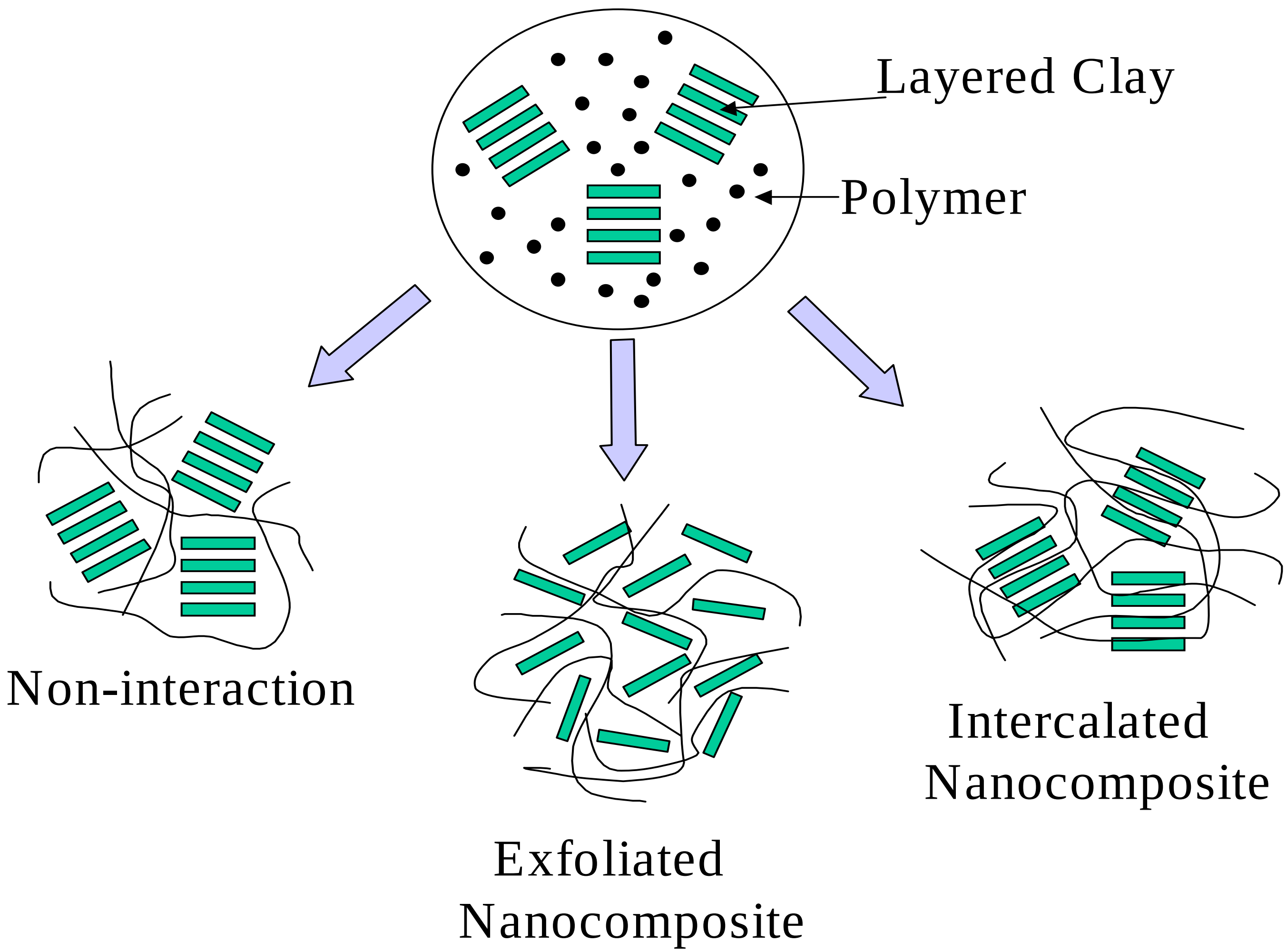


Thickness ~ 1nm

Length ~ 70 – 150nm

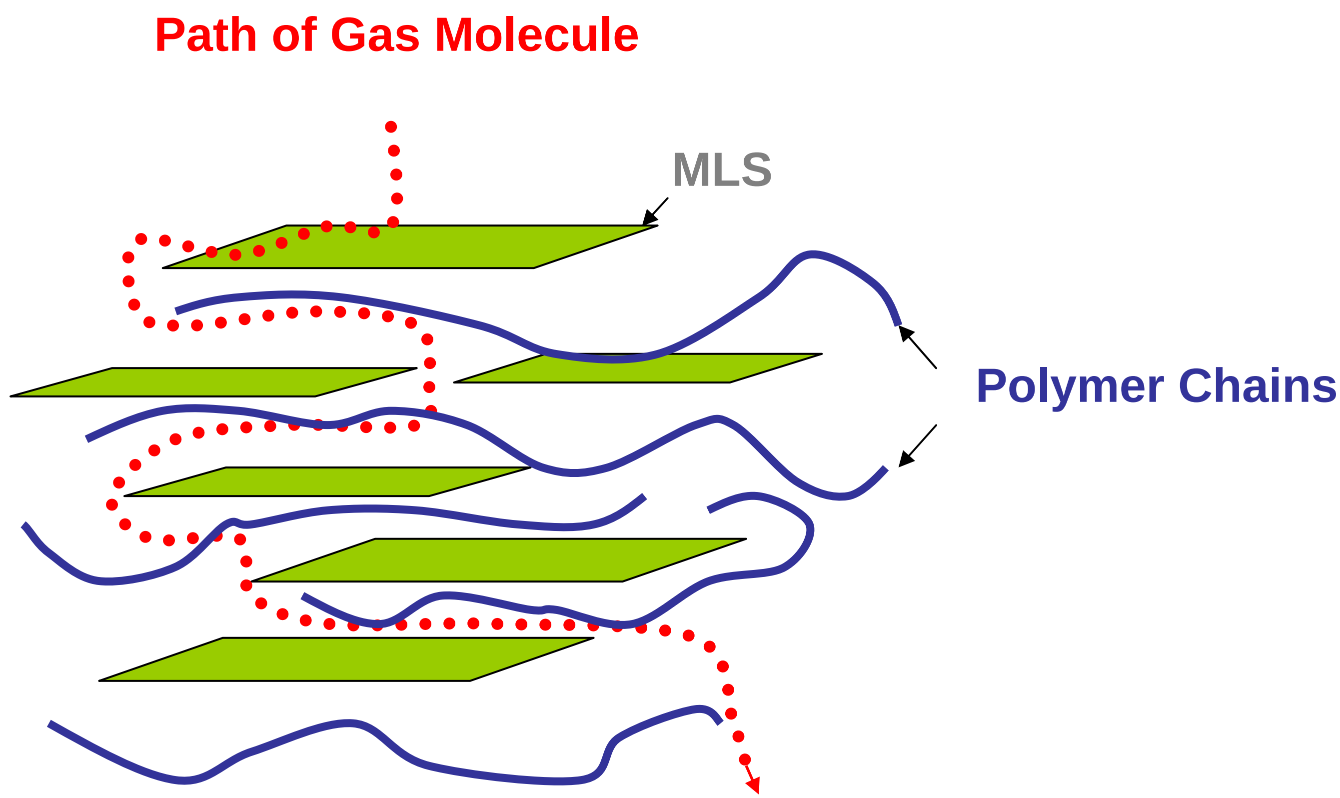
High Surface Area (750m²/g) and Aspect Ratio (>50)

Nanocomposite Morphology



How do Nanocomposites Improve Barrier Properties?

"Tortuous Pathway Model – Exfoliated Nanocomposite"



Permeation of gas molecule through nanocomposite structure

Current Research

Nanocomposite Meal Bag

	Current MRE Meal Bag	Neat Low-Density Polyethylene Film	Nanocomposite Low-Density Polyethylene Film
Film Thickness	11-mil	6-mil	6-mil
Oxygen Transmission Rate (cc-mil/m^2-day)	8264	9097	3703
Young's Modulus (MPa)	127	93	186
Onset of Thermal Degradation (°C)	351	370	450
Insect Infestation Test (Pass/Fail)	Pass	Fail	Pass

MRE Specification for Retort Pouch **Transmission Rates:** O_2 0.06 cc/m^2/d
H_2O 0.01 g/m^2/d

Possible Structure for Meal Bag:

LDPE-Tie layer- Nylon-Tie Layer-LDPE (11 mil) O_2 0.97 cc/m^2/d -60%RH

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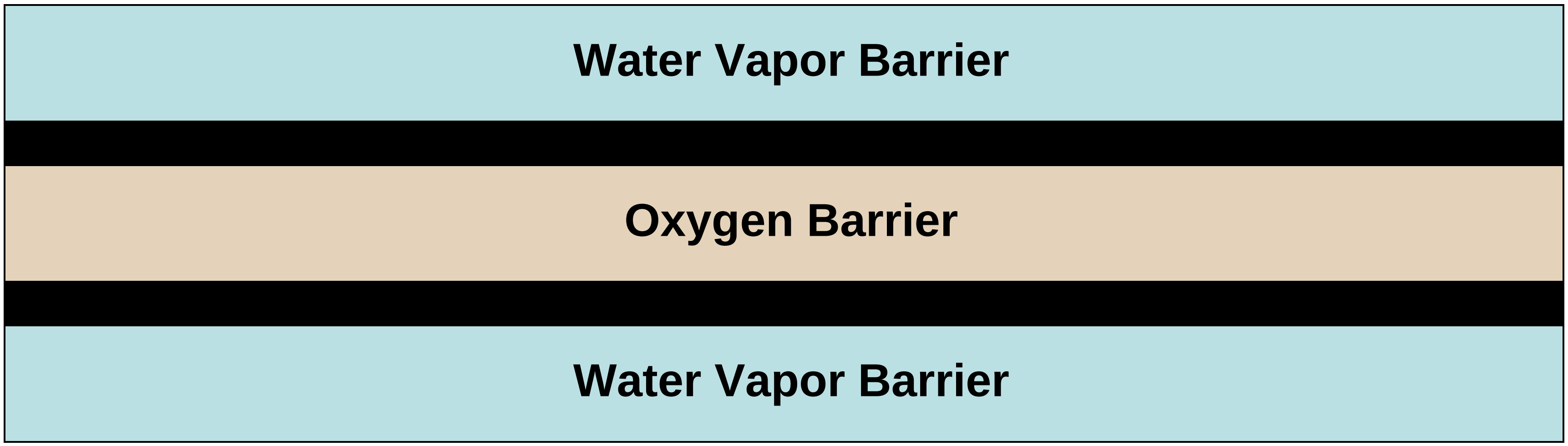
Multilayer Packaging Concept

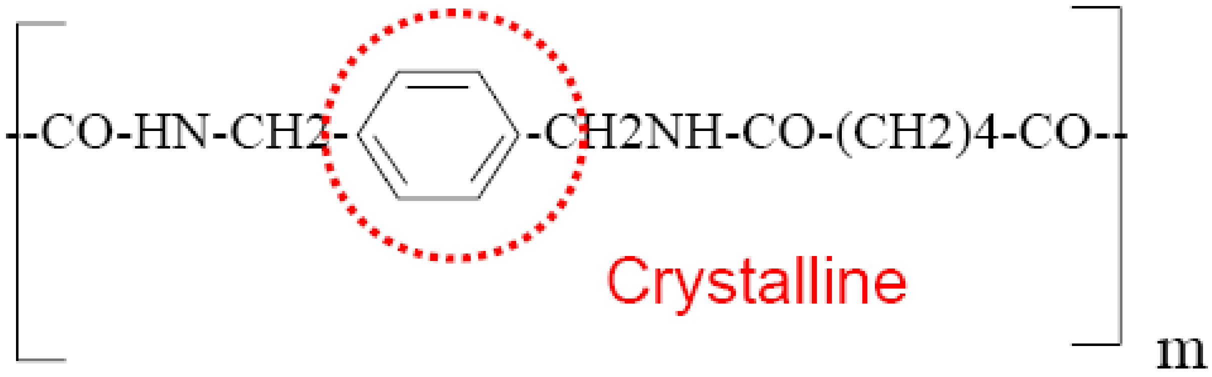


Water Vapor Barrier: Low Density Polyethylene (LDPE)

Tie Layers: Modic-AP (Modified Polyolefin – Mitsubishi)

Oxygen Barrier: Imperm (Nanocomposite MXD6)

Nylon MXD6 Oxygen Barrier

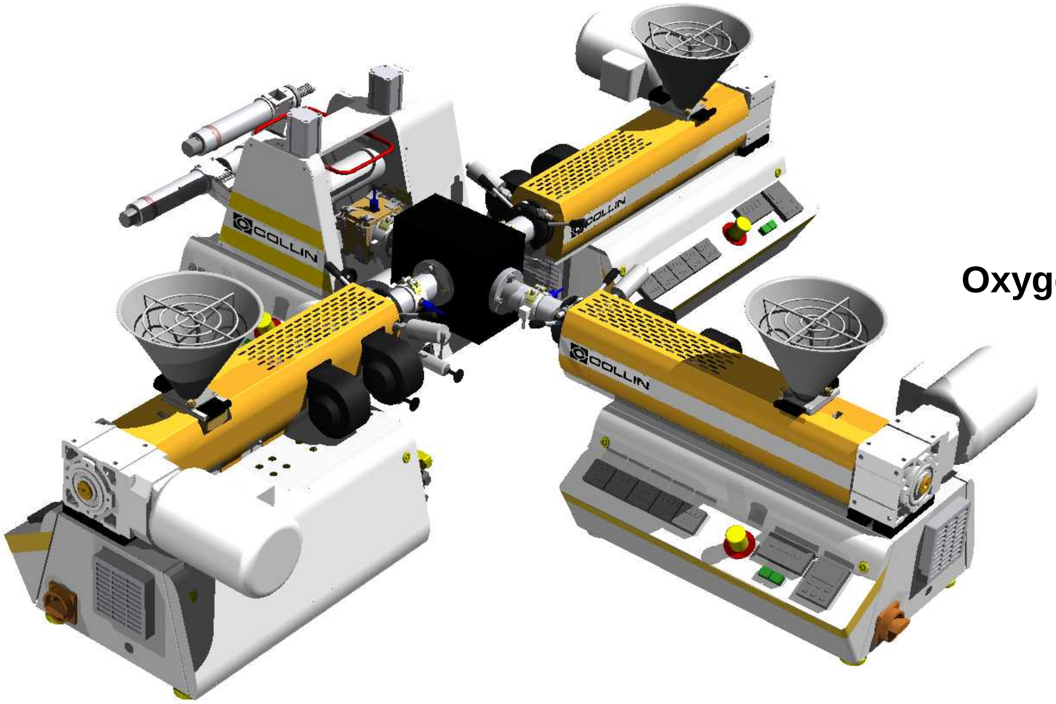


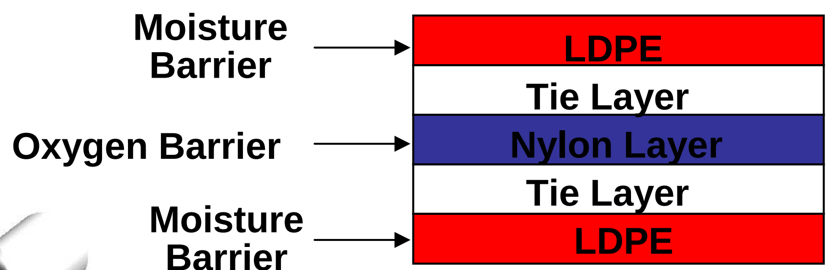
MXD6
Mitsubishi

Barrier related to aromatic groups

IMPERM™ - MXD6/Clay Nanocomposite from Nanocor/Mitsubishi

Co-extrusion of Multilayer Nylon Films Laboratory Scale Processing

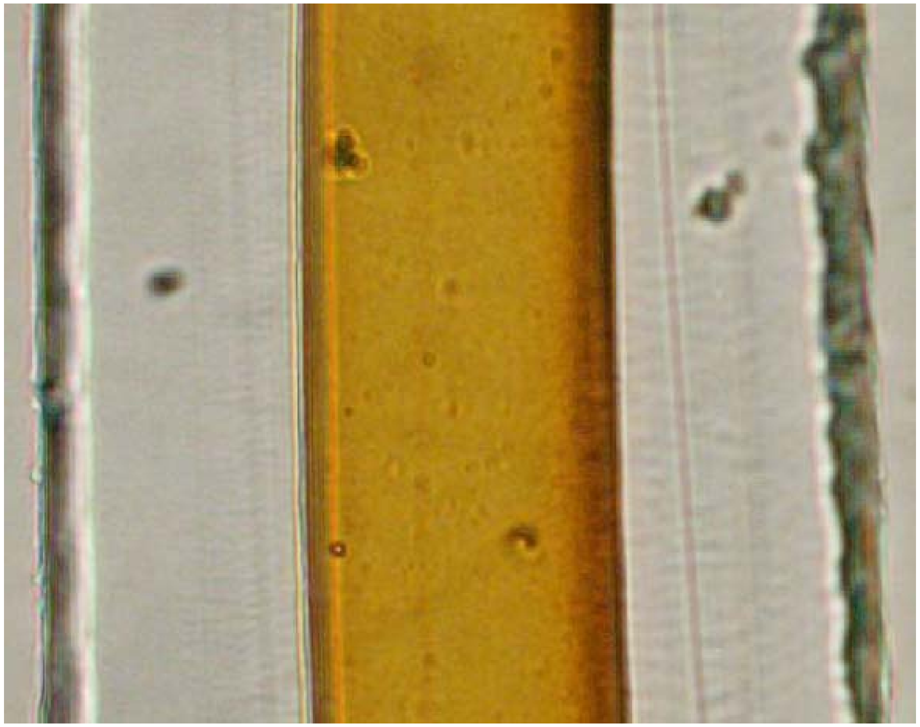




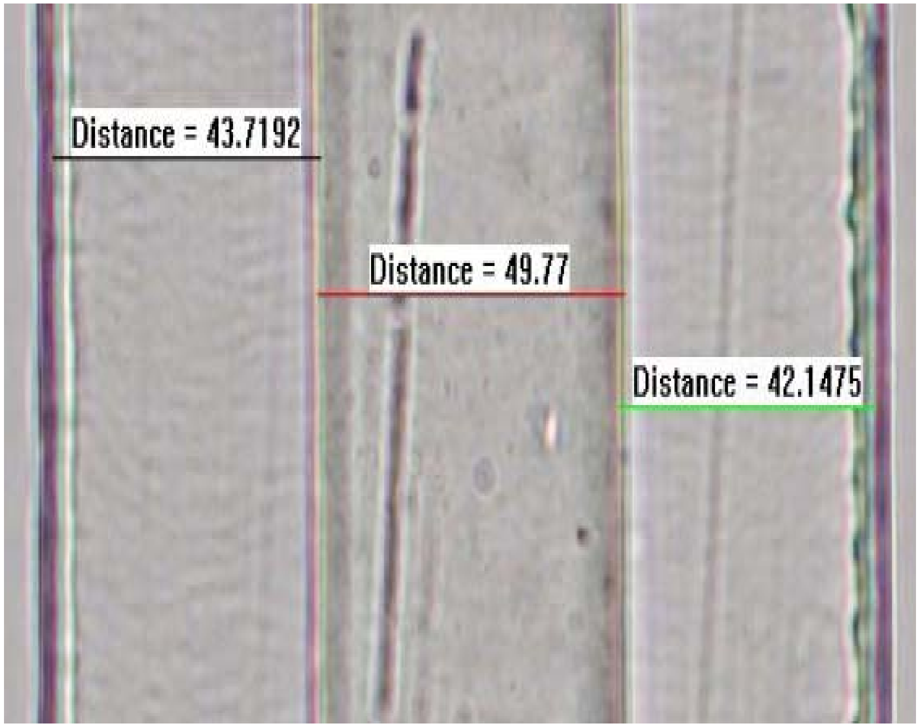
5-Layer Film

- Collin Teach-Line Multi-Layer Extrusion System Using Feed-block Design
- 5 Layer Capability: 3 Materials

Microspcopy Images of Co-Extruded 5-Layer Imperm Films



Imperm Layer Stained with Iodine



Thickness Measurements in Microns

Pilot-Scale Processing

Pliant Corporation – Chippewa Falls Wisconsin

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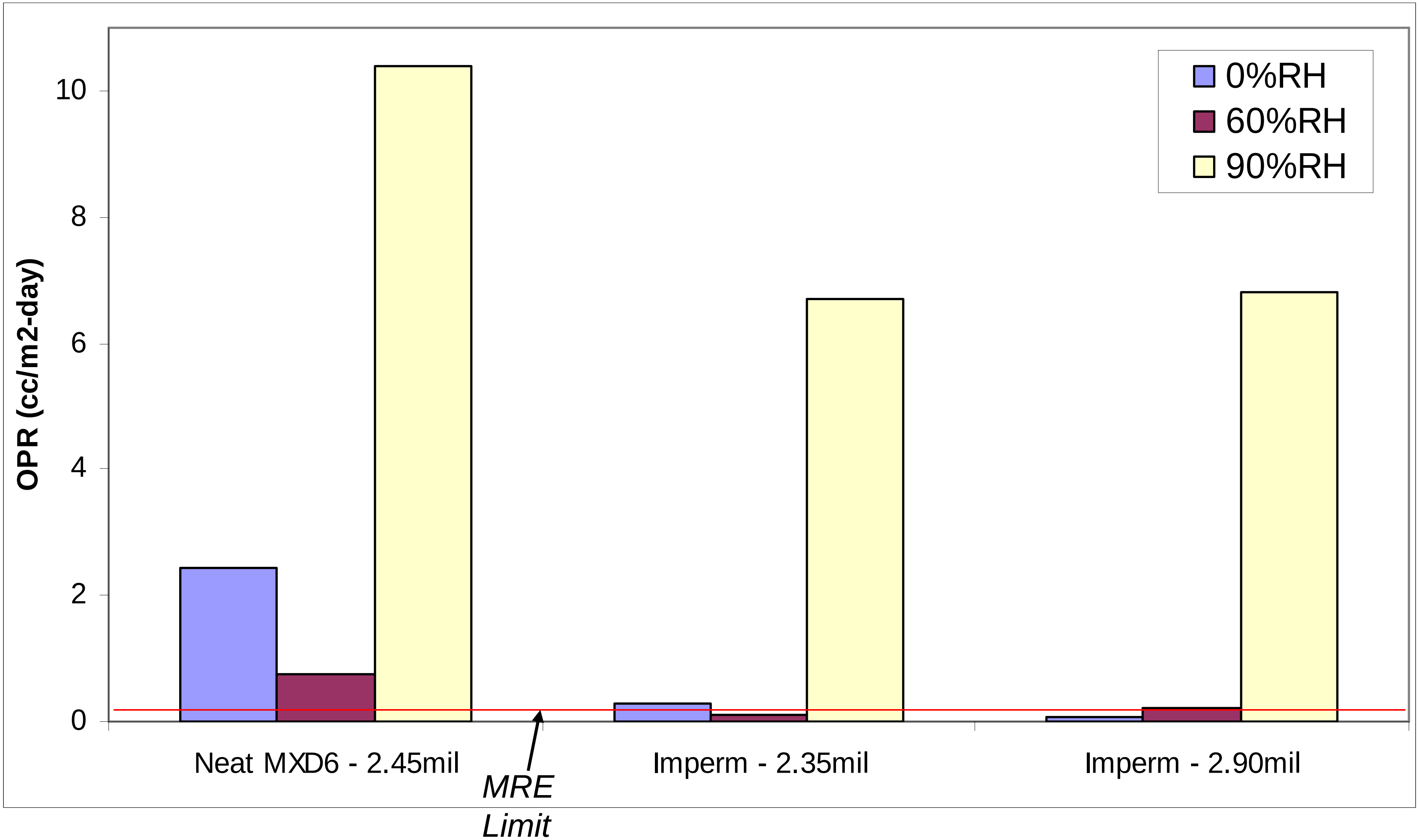
Oxygen Barrier of Pilot-Scale Multilayer Films



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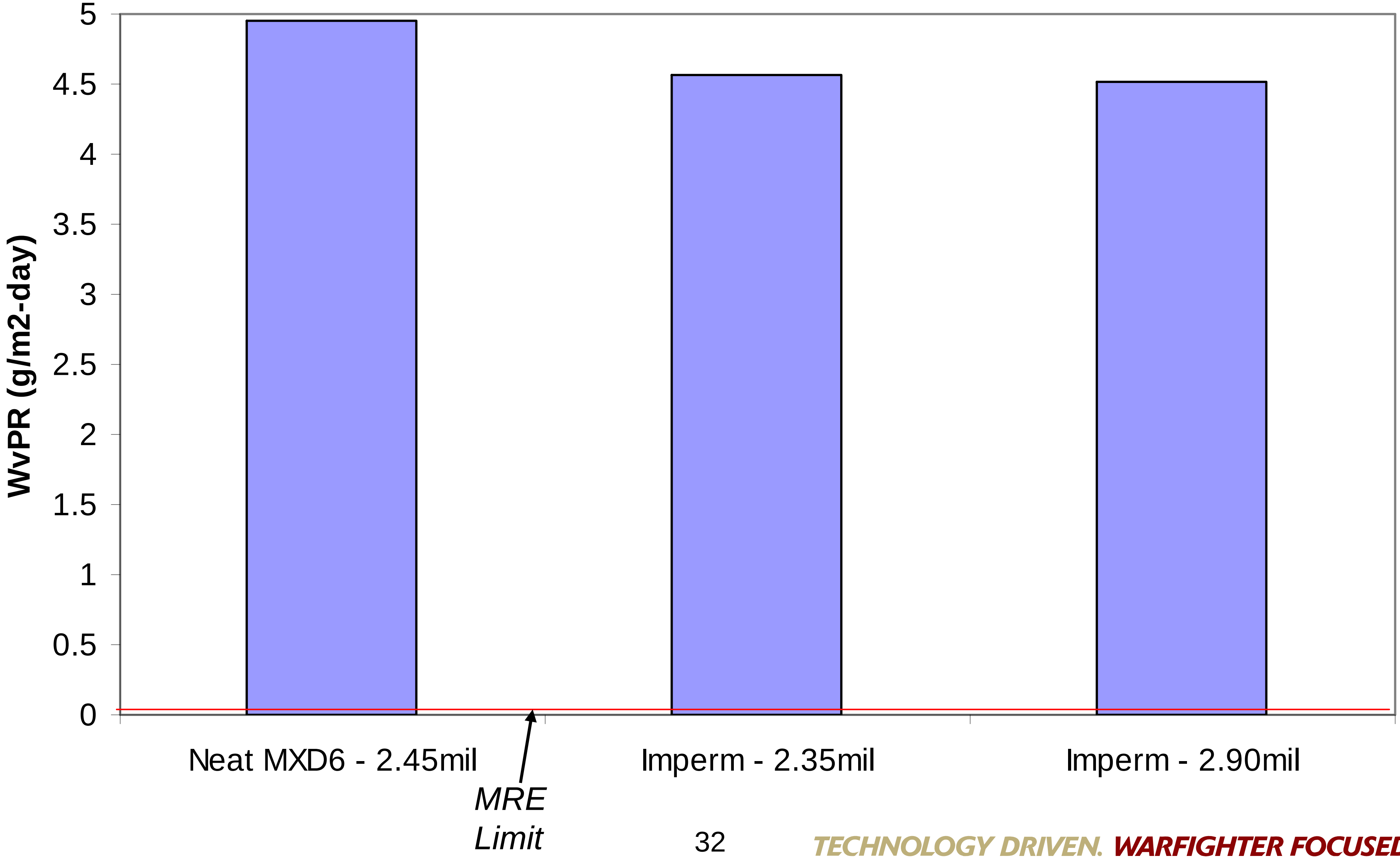
Water Vapor Barrier of Pilot-Scale Multilayer Films



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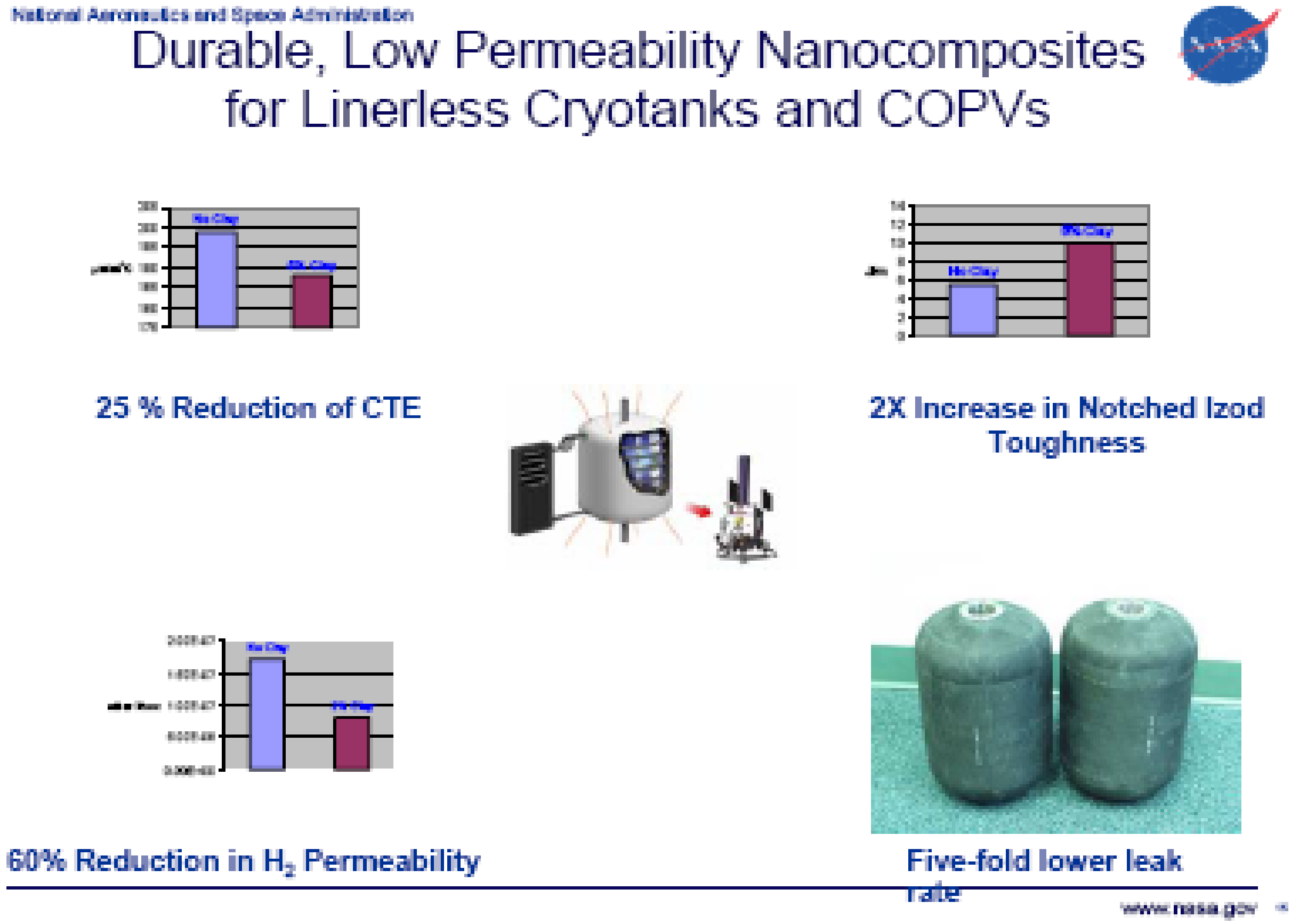
Current and Future Applications for Multilayer Nanocomposites

Future of Multi-layer Nanocomposites



COPV: Containerized Over-wrapped Pressure Vehicles

M.Meador – NASA Glenn Research Center

Future of Multi-layer Nanocomposites

Nanocor

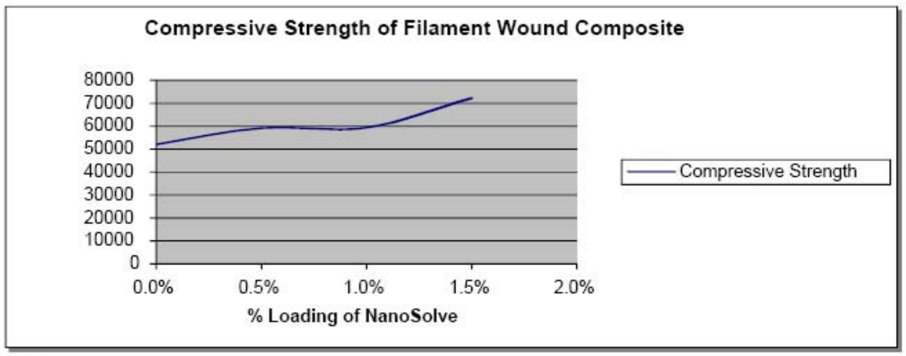
Oxygen Sensitive Products

INTERTECH pira Nanomaterials, June 25-27, 2007

Current Uses of Nanocomposites

Case Example

APPLICATION	:	YACHT MASTS
CUSTOMER	:	SYNERGY YACHTS
PROBLEM	:	Looking for stronger material for mast
BENEFIT	:	Lighter, stronger sailing mast
OUTPUT	:	37% increase in compressive strength
TIME	:	6 Months



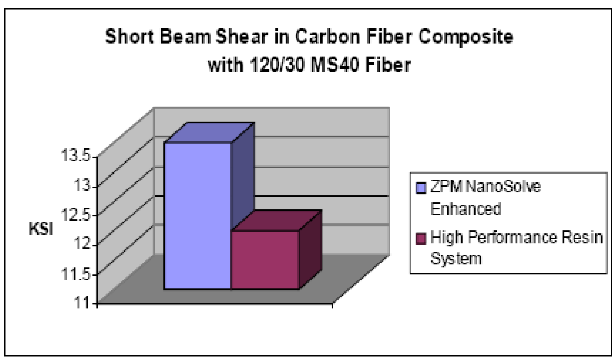
ZYVEX PERFORMANCE™ MATERIALS

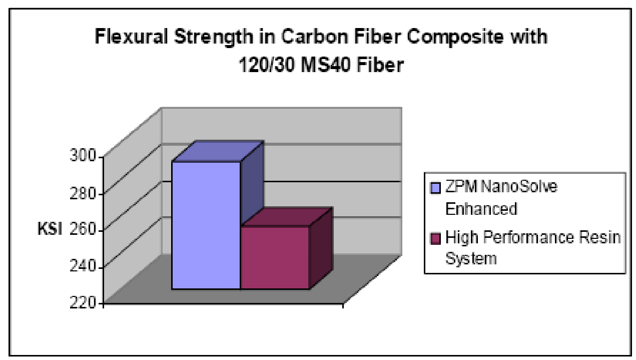
Current Uses of Nanocomposites

Case Example

ALDILA

APPLICATION	:	GOLF CLUB SHAFT (GS)
CUSTOMER	:	ALDILA
PROBLEM	:	Looking for lighter weight golf shaft with stiffer performance.
BENEFIT	:	Stiffer shaft, improved durability, better swing flex
OTHER	:	Shaft won 2006 US Open, other pro events
TIME	:	12 Months
Production Volume	**:**	**500,000 shafts per year**



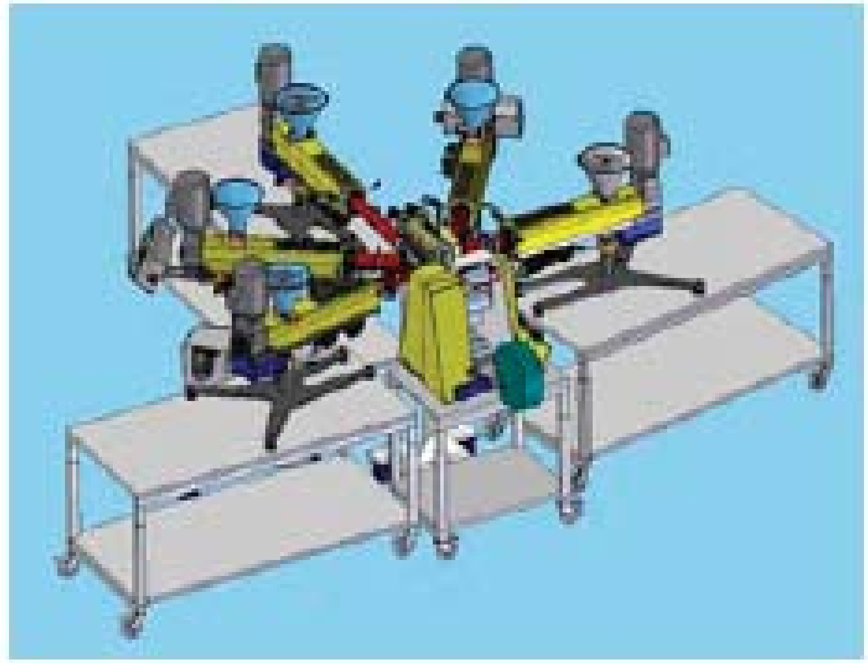


ZYVEX PERFORMANCE™ MATERIALS

NSRDEC's Facility

NSRDEC Polymer Film Center of Excellence

5-Layer Blown Film Co-Extrusion



9-Layer Cast Film Co-Extrusion

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Acknowledgements

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- MOCON – Michelle Stevens
- Air Products – Charles Hegedus
- EVALCA – Gary Woodall, Edgar Chow, Gene Medlock
- Nanocor – Tie Lan
- NASA – Micheal Meador
- ZYVEX – Lance Criscuolo