SunChemical®

a member of the DIC group

Gas Barrier Coatings For Flexible Packaging

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working for you.

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Outline

- **Gas barrier Coatings**
  - Definition & Background
  - Market Information

- **Nanocomposite Gas Barrier Coatings**
  - Exfoliated Clay Composites
  - Analysis of Clay Composite Coatings

- **Performance in Packaging Applications**
  - Environmentally Friendlier Packaging
  - Coating Applications

- **Conclusions**

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Barrier Coatings: Definition

Prevent the penetration (or loss) of specific gases, light or aroma/odour which could compromise the integrity of the packaged product.

Typical Barrier Coatings:

- Oxygen Barrier
- Moisture Vapour Barrier
- CO_2 Barrier
- UV Barrier
- Aroma Barrier

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History/Evolution Of Gas Barriers in Packaging

Stage	Properties
Glass & Tin Al Foil	Excellent barriers but heavy
Plastics	Poor barriers, but light weight
First coatings on plastics	Reasonable barriers Especially PVdC and Al metallisation also lightweight
Extrusion Lamination	EVOH- Excellent O2 Barrier at medium %RH Thick laminates
SiOx & AlOx Ceramics	Excellent moisture vapour and O2 barriers, transparent but brittle
Emerging Technologies	Organic polymer structures and nanocomposites

All of these materials are in present use today

There is no one barrier technology that meets all requirements

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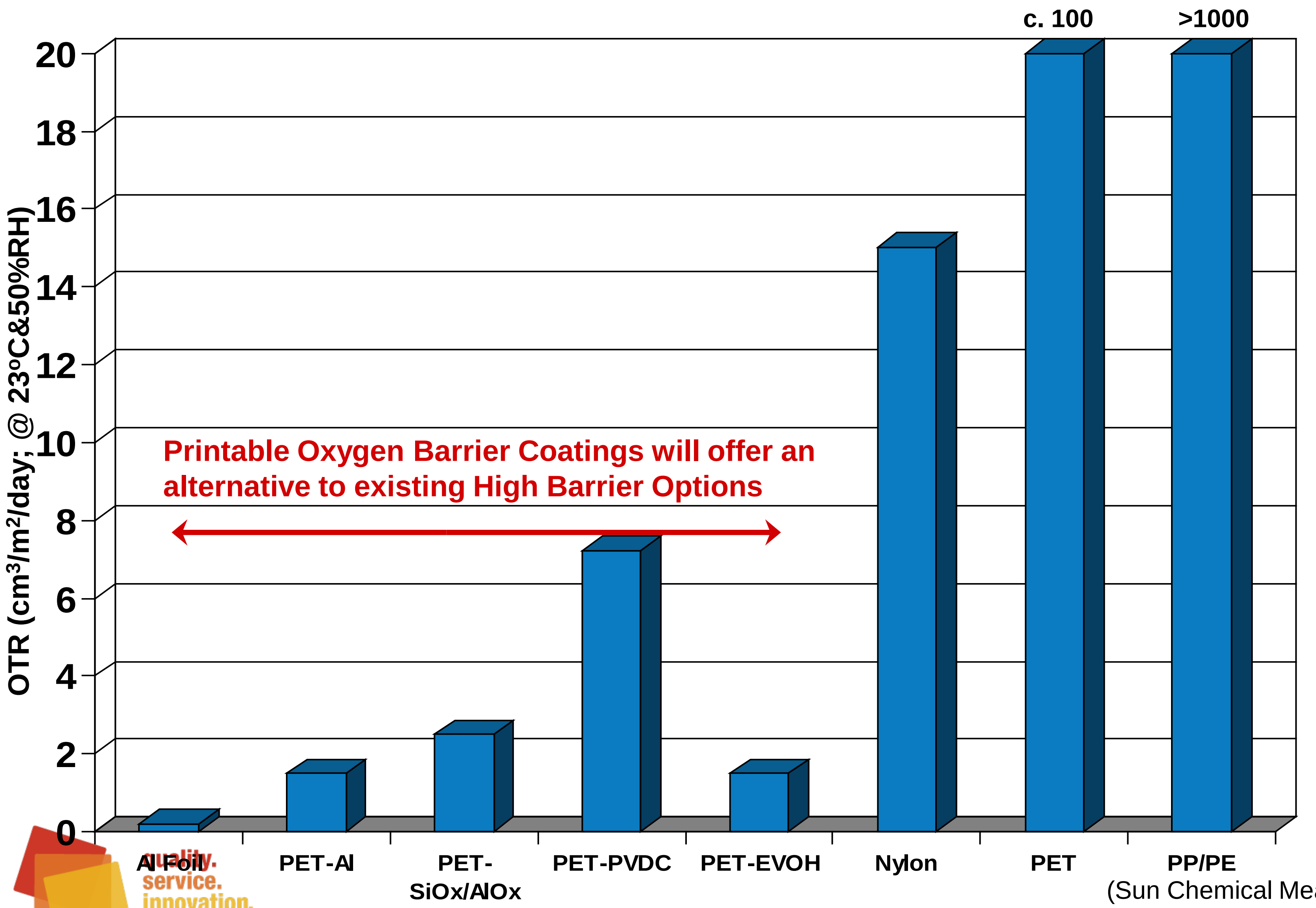
Oxygen Transmission Rates of Typical Flexible Packaging Materials



(Sun Chemical Measurements)

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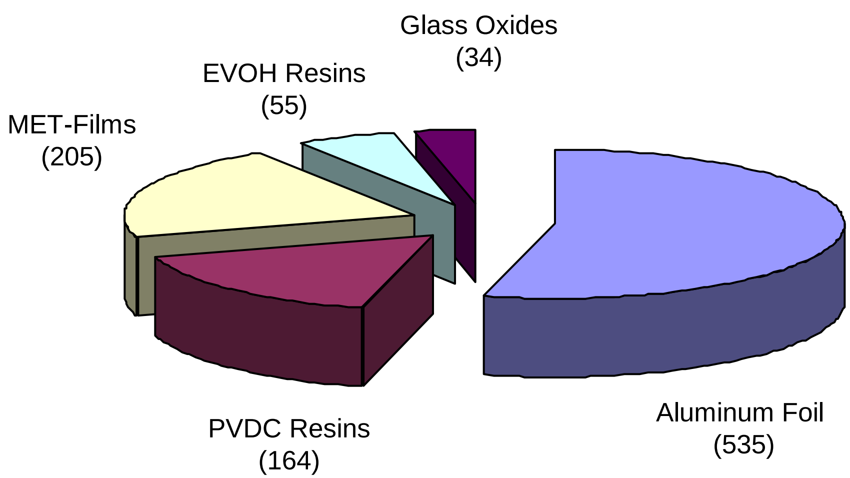
Gas Barrier Coatings:

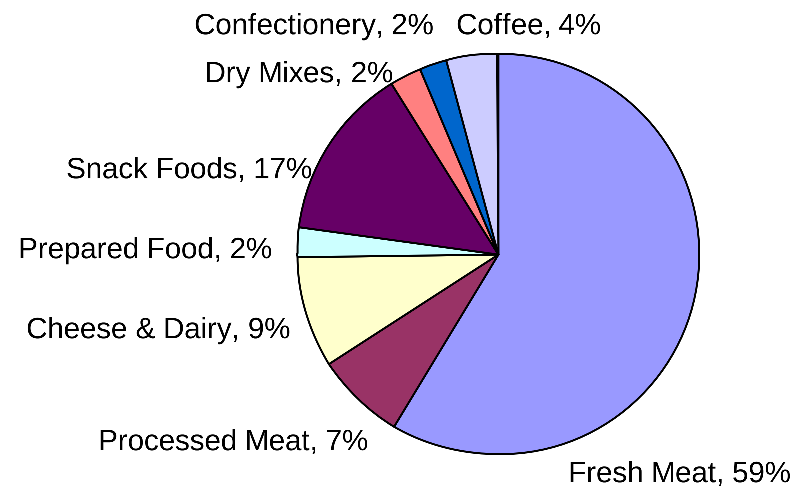
Market information

Market Overview - Barrier Materials for Food Packaging

Global Addressable (Printable) Market for Barrier Coatings potential –2,074,000tonnes 2008



Market Segmentation by Application



Conversion from current barrier technology/ film is a multi $ million coating opportunity

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Source: ADC/Kline

Packaging market overview (barriers)

Market / Applications

- Chilled Food
- Dry Food
- Liquid Packaging

Barrier technology

- PVdC
- EVOH
- Nylon
- Speciality Oxides
- Metallised
- Co-extrusions

Package structure

- Bags
- Lidding
- Stand Up Pouches
- Forming Webs
- Wraps

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Temperature & Relative Humidity are Important Considerations

Printable Oxygen Barrier Coatings

A gap exists in the market for transparent barrier coatings; free from halogenated compounds, converter applied, which afford high barrier performance.

Nanocomposite Gas Barrier Coatings

Description, Preparation, Function & Analysis

Emerging Technologies

- **Nanocomposites**
  - Highly dispersed/exfoliated silicates/clays

- **Sol-Gel Coatings**
  - Inorganic/Organic composites formed in-situ
  - e.g. $Si(EtOH)_4 \xrightarrow{\text{Condensation}} Si(OH)_4 \xrightarrow{\text{Hydrolysis}}$ 'SiOx'
  - Organically modified ceramic lacquers.
  - vapor and barrier layer strategy
- **Epoxy Based Coatings**

- **PAA & PGA-based coatings**

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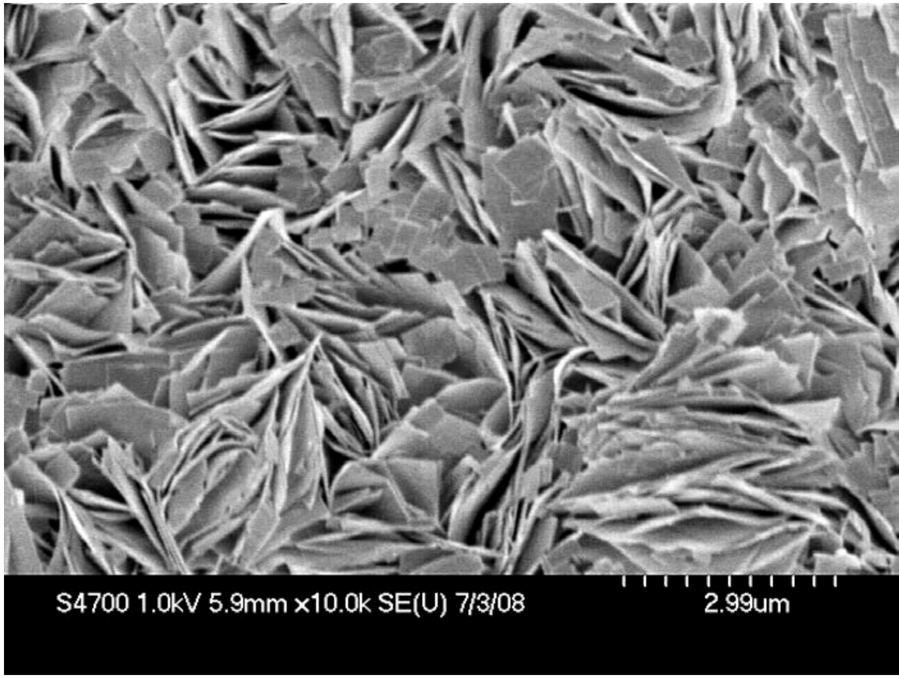
Sun Chemical's Nanocomposite Barrier Coatings

- Finely dispersed nanoparticulate (intercalated/ exfoliated) silicate mineral in a polymer solution/ dispersion
- The dispersion is applied using traditional printing and drying techniques
- The dried polymer coating on a film enhances the oxygen barrier performance of the substrate



Functional oxygen barrier of less than 1.0 $cm^3/m^2/24h$ at 23°C & 75%RH

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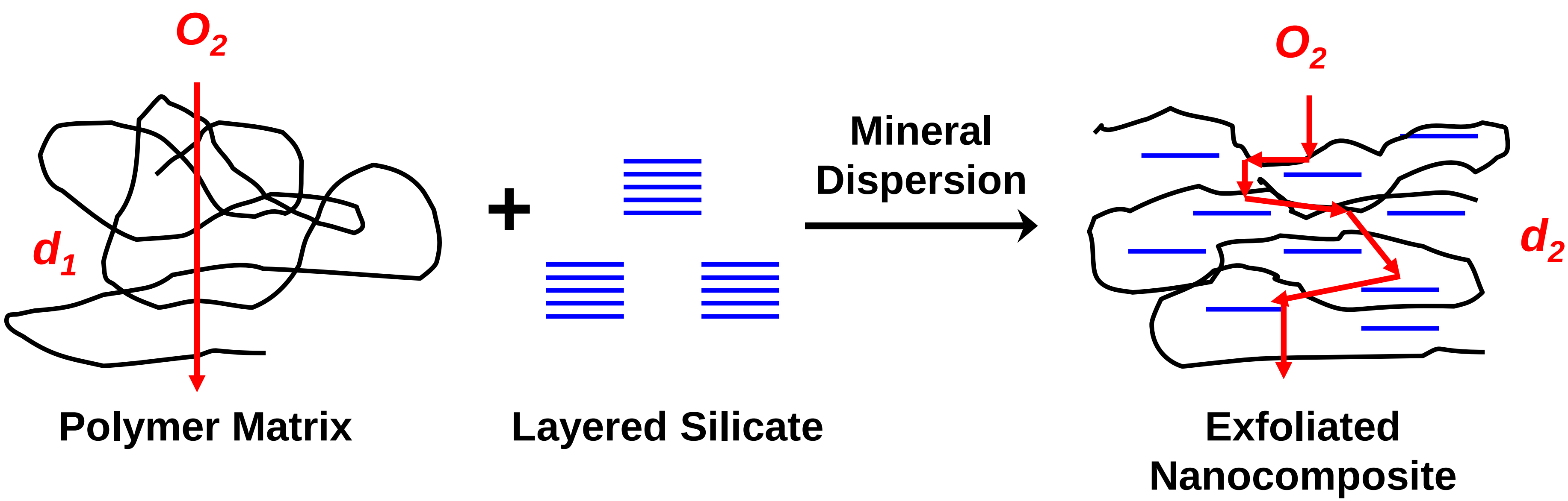
The influence of Exfoliated Minerals on Barrier Improvement

The generally accepted theory for barrier improvement is that dispersed/exfoliated ‘platy’ minerals increase the diffusion path length through a coating; ***‘TORTUOUS PATH’.***



$$d_2 > d_1$$

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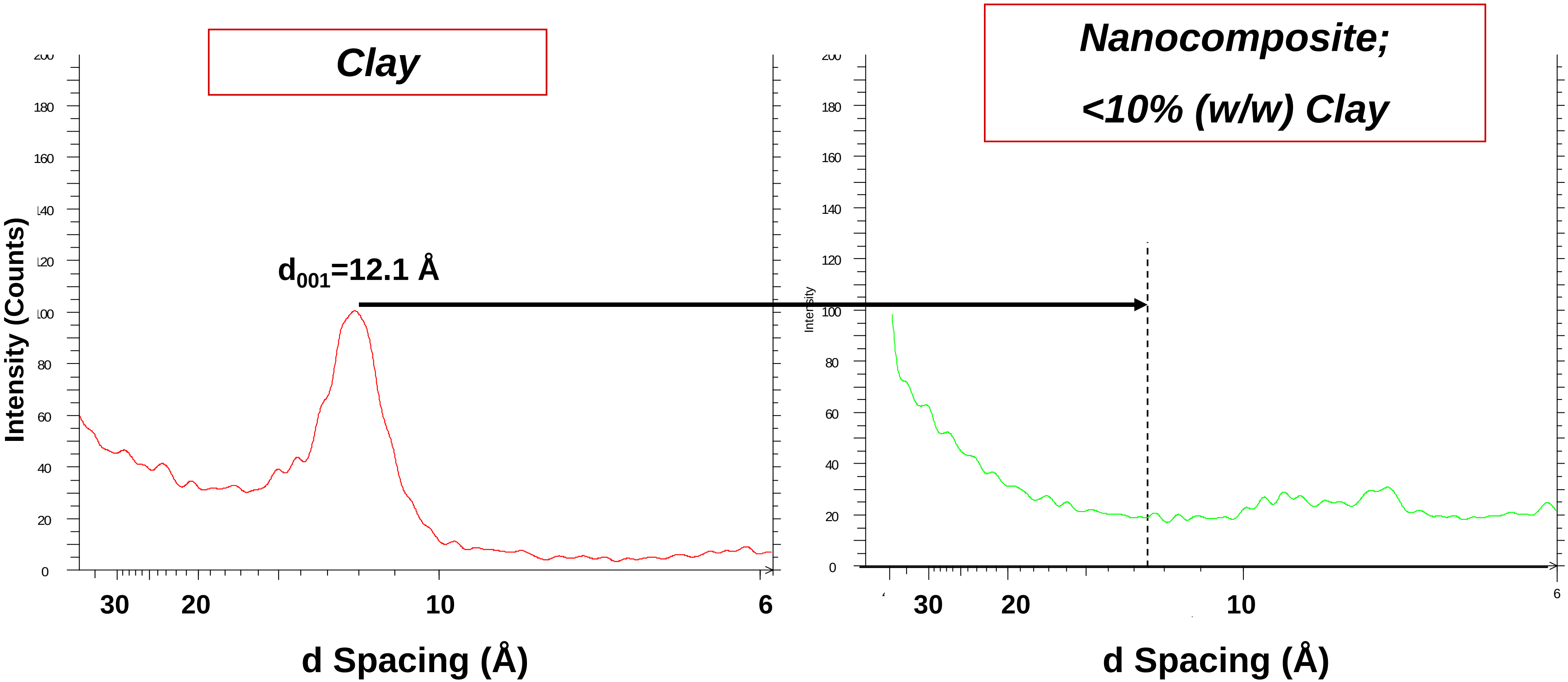
Analysis of Nanocomposites: XRD

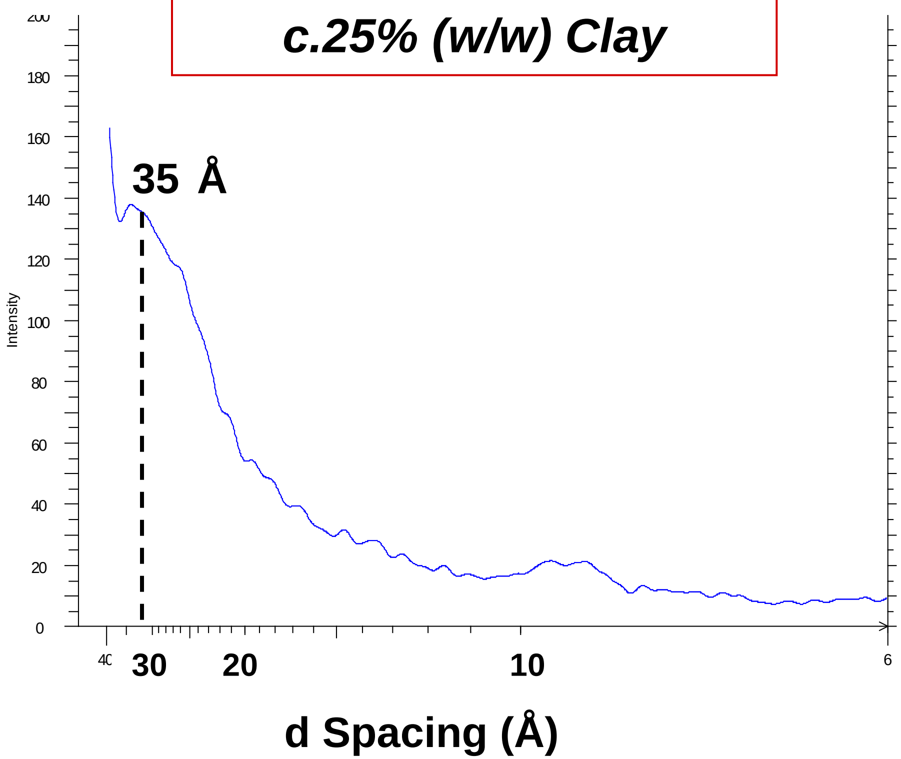
X-Ray Diffraction shows the increase in d-spacing (001) when the clay is successfully exfoliated.



Nanocomposites with Higher Clay Loadings

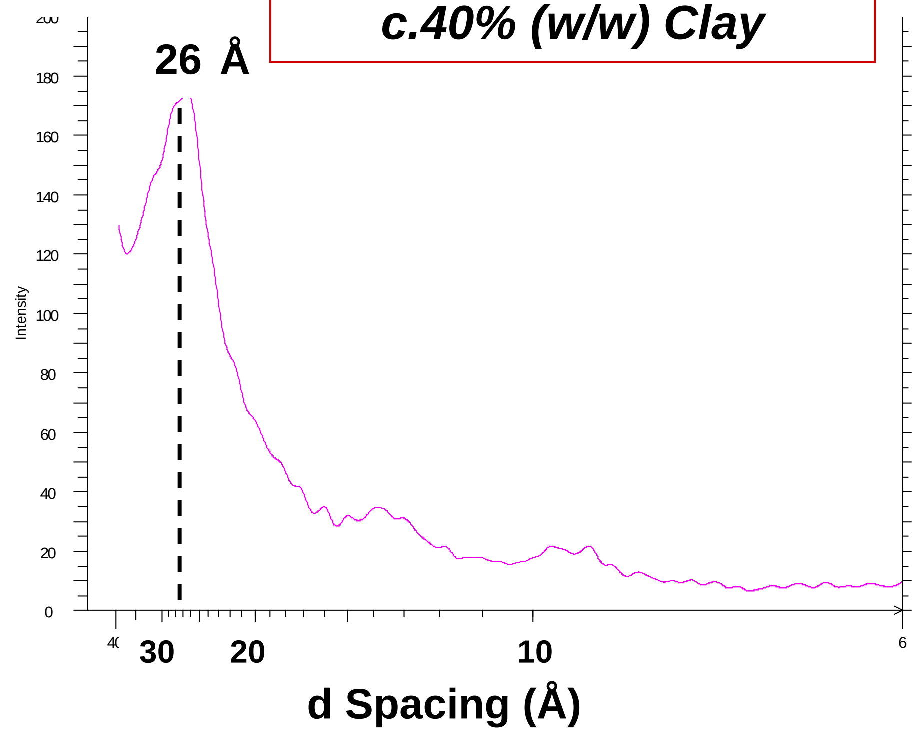
Nanocomposite;

c.25% (w/w) Clay



Nanocomposite;

c.40% (w/w) Clay



Intercalated composites or highly ordered exfoliated composites?

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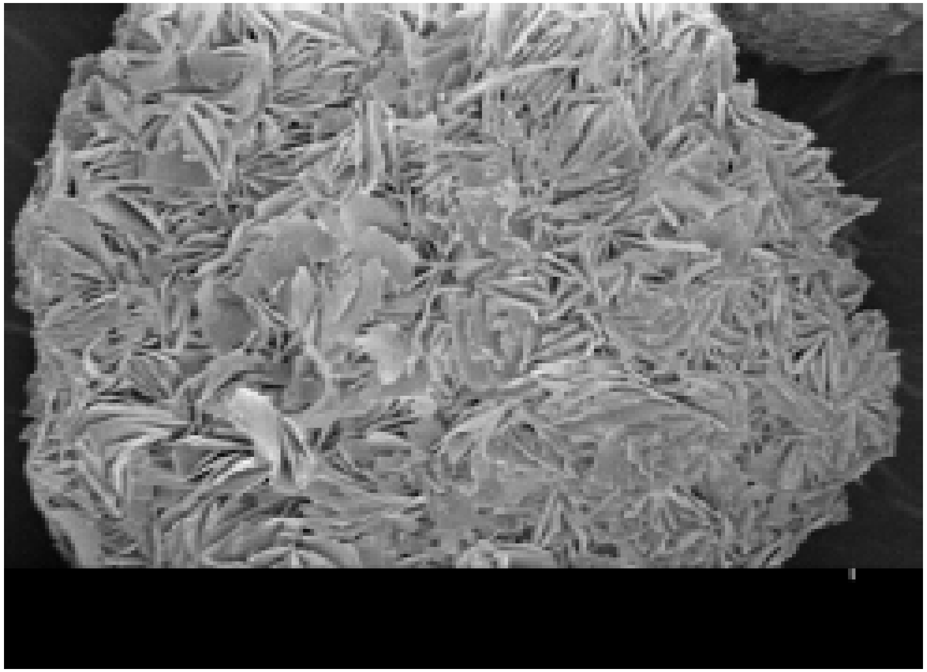
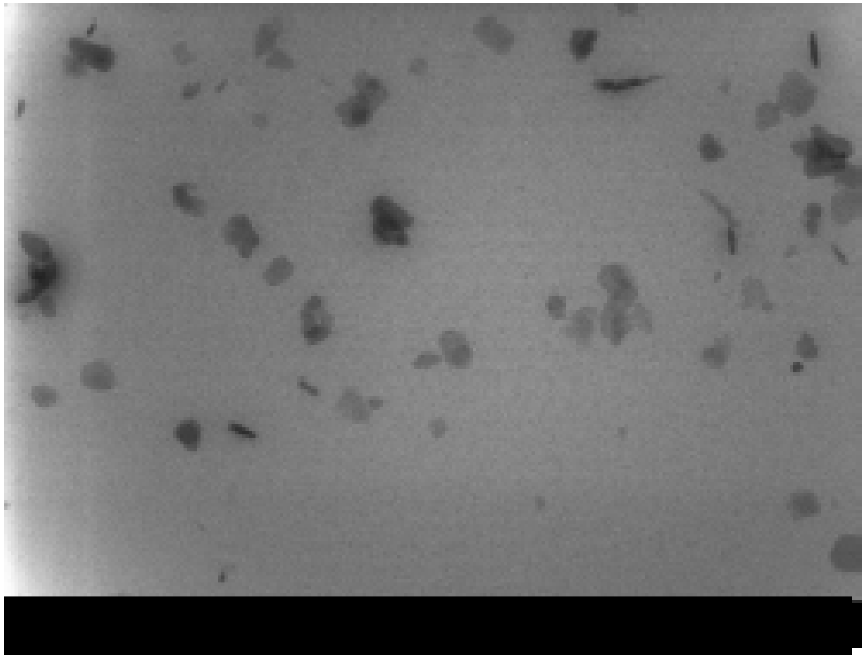
Analysis of Nanocomposites; Electron Microscopy

SEM: Agglomerated Clay



TEM: Nanocomposite Coating



Cast of Dilute Coating on Cu Grid (Sun Chemical)

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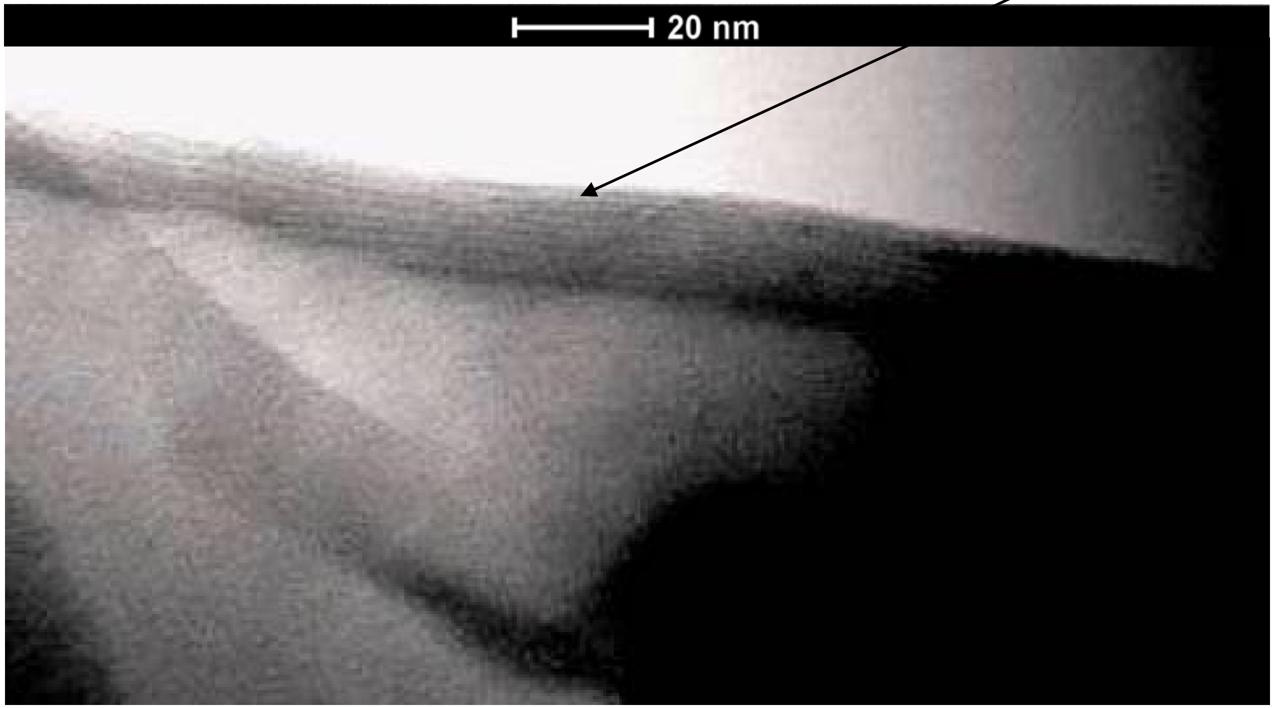
TEM of Cross Sectioned Coating on PET Film

Clay Particles



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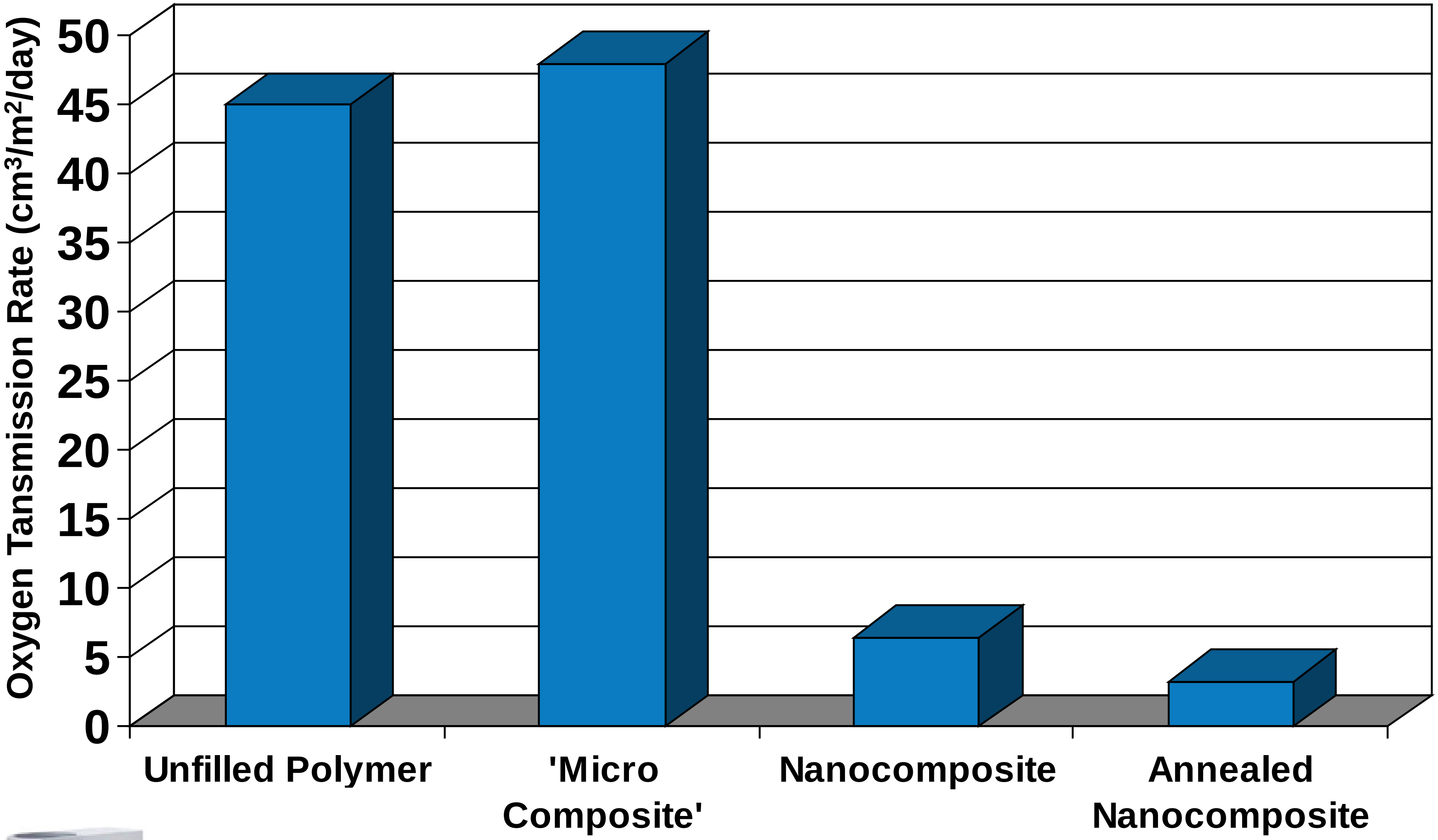
The Effect of Exfoliation on the Visual Appearance of NanoComposites

Unfilled Polymer

Non-Exfoliated Clay (Tactoid)

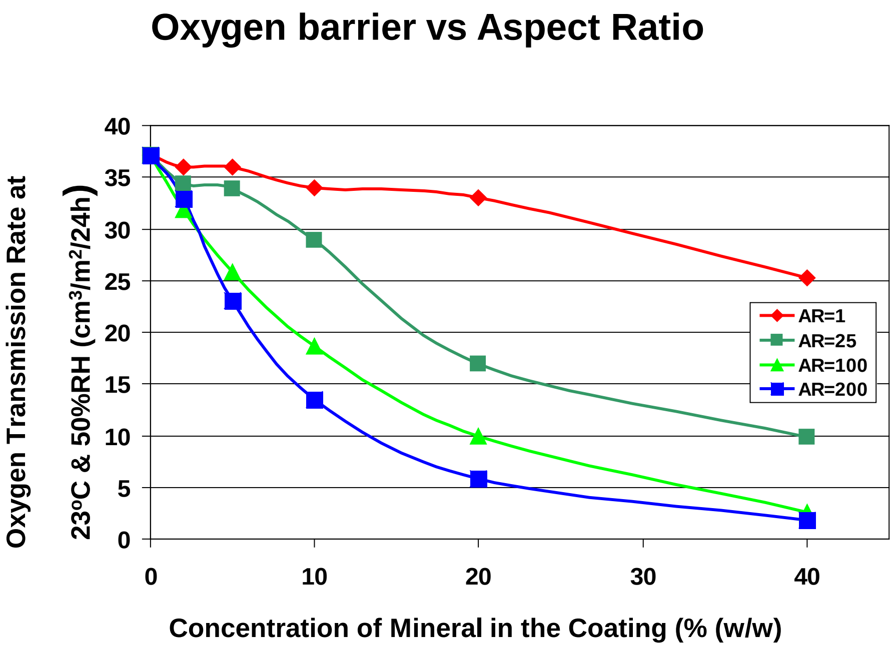
Exfoliated Clay Nanocomposite

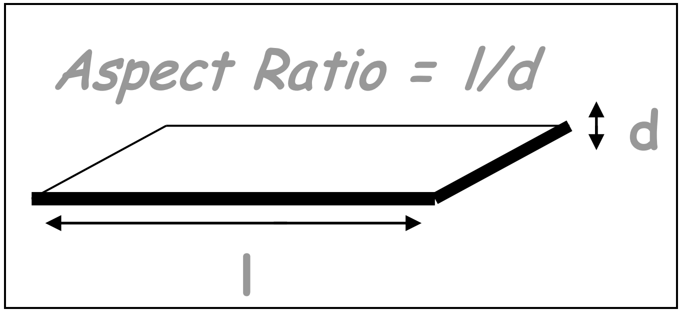
The Effect of Clay Exfoliation on the Oxygen Barrier

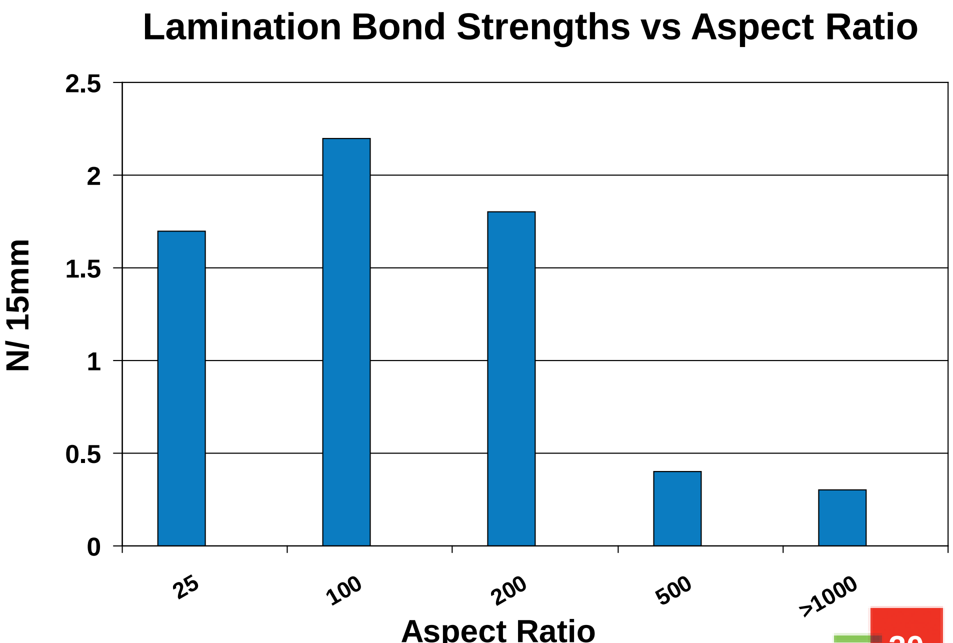


Oxygen Transmission Rates were measured with an Oxtran 2/21 at 23ºC&75%RH.

Nanocomposite Coatings- Influence of Aspect Ratio







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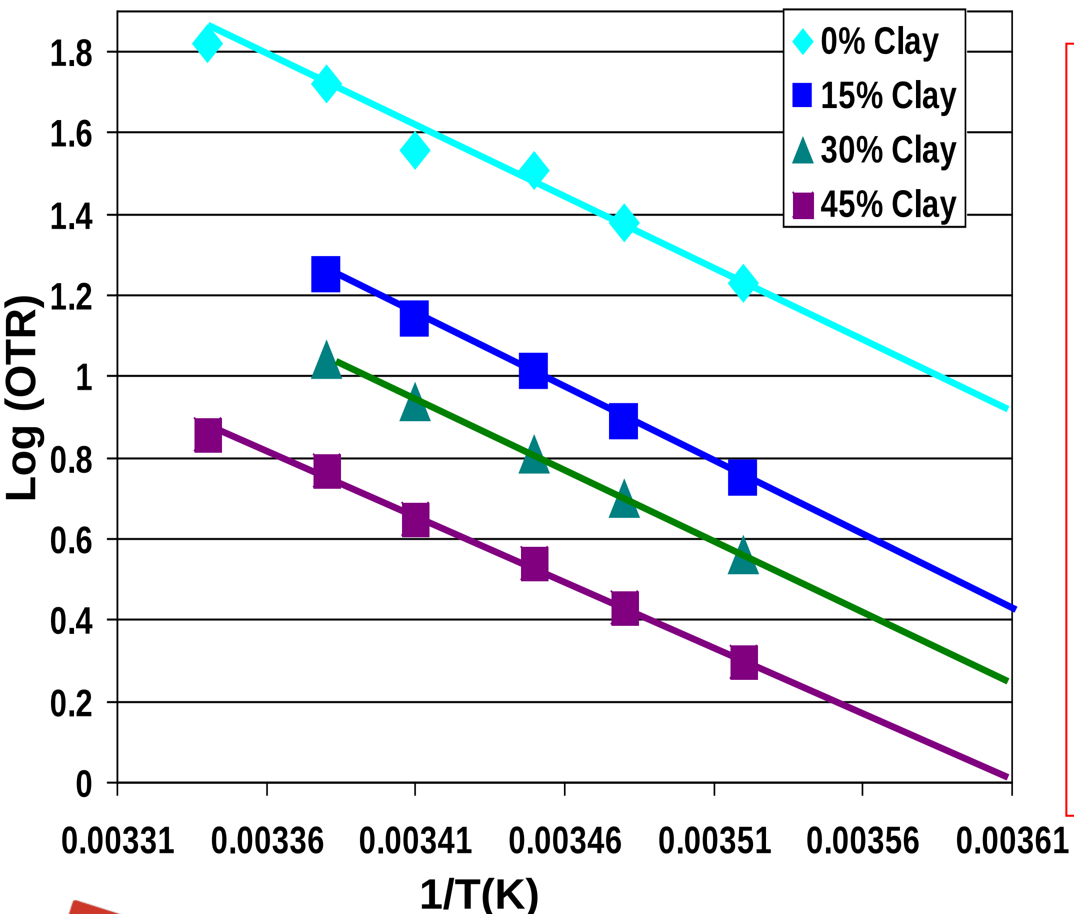
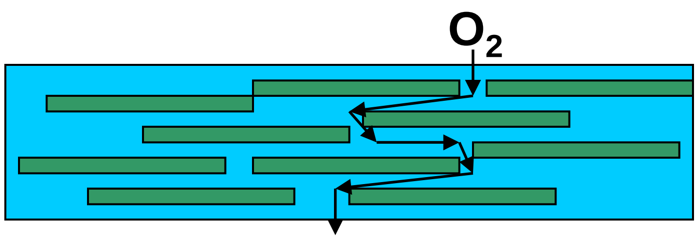
Understanding the Role of Clay on Oxygen Barrier Performance; a Mechanistic Study

Arrhenius Plots used to determine the effect of changing clay concentration on Oxygen Permeability



- Slope α – E_a (Activation Energy)
  - Therefore; no change in E_a
  - Polymer Matrix character does not change
  - Increase in diffusion path length the likely mechanism



(% Clay = wt. % in the dry coating applied to PET)

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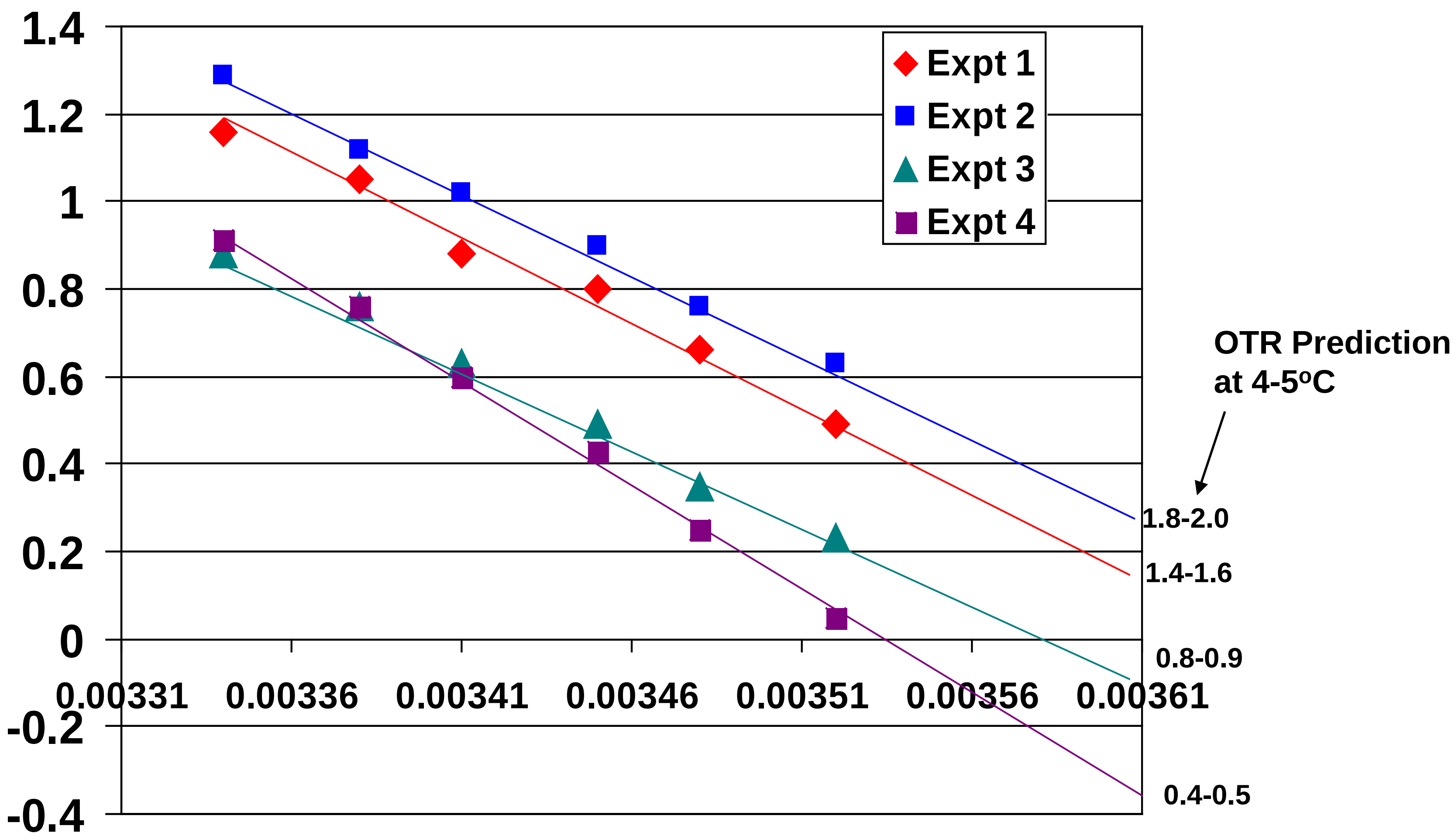
Using Arrhenius Plots; Log OTR v. 1/T to Extrapolate Performance



Mocon Oxtran 2/21 Min Temp =11° C

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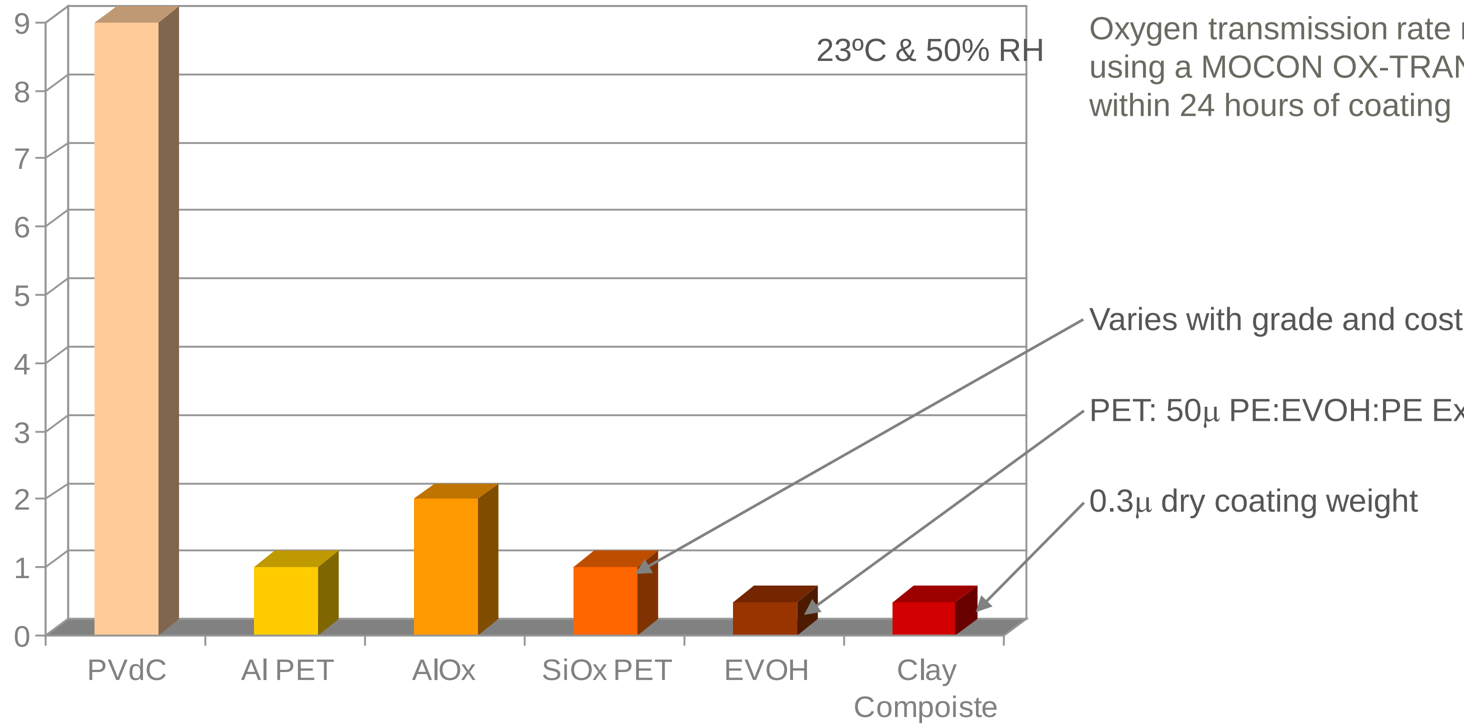
Performance Clay Composite Coatings in Packaging Applications

Comparison of Functional Barriers on PET

Untreated polyester film OTR 100-110 cm^3 / cm^2



Oxygen transmission rate measured using a MOCON OX-TRAN® 221 within 24 hours of coating

- PVDC major disadvantage – contains chlorine & higher OTR
- AlOx / SiOx major disadvantage – brittle & higher OTR
- EVOH deteriorates over time in humid storage conditions

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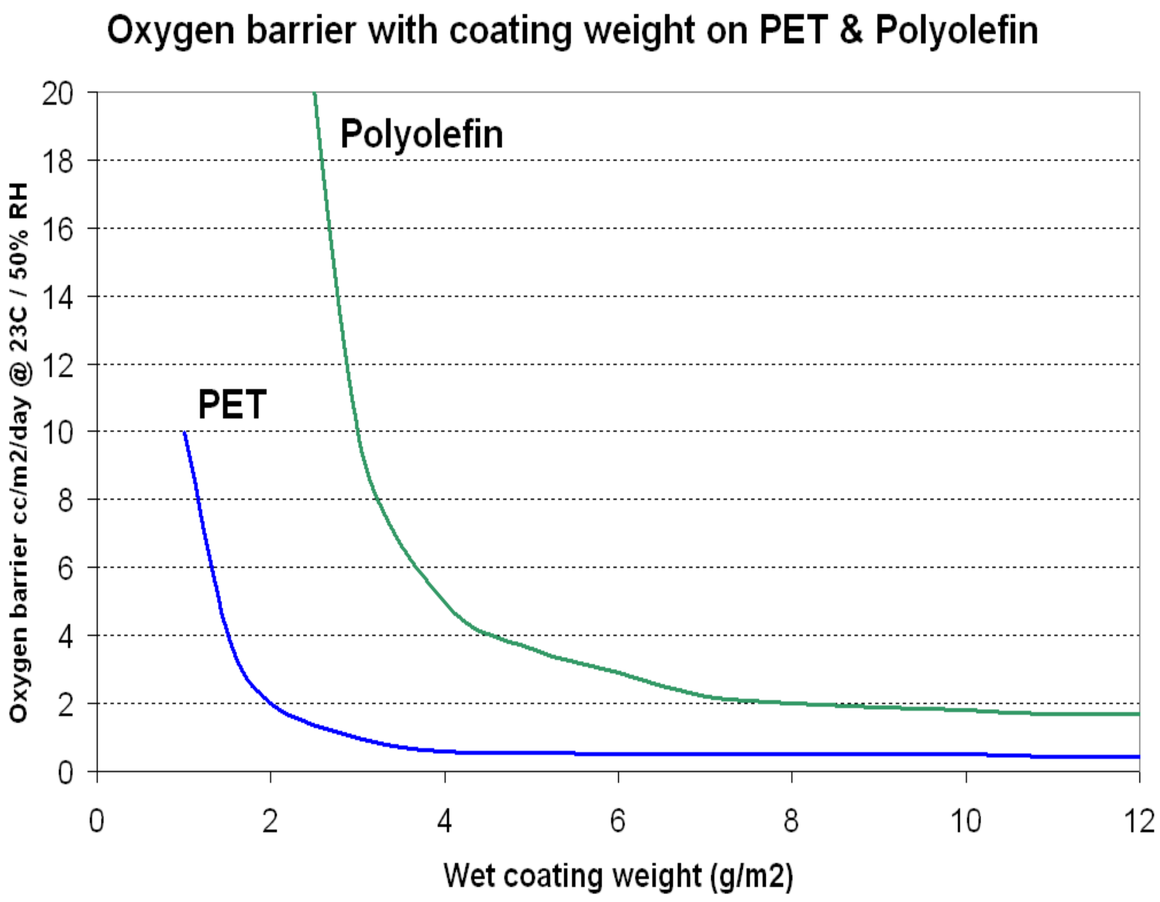
Influence of Coatings Thickness on Barrier performance



The clay composite coatings provide excellent barrier performance on both PET and OPP with dry film weights as low as 0.2 g/sm (dry).

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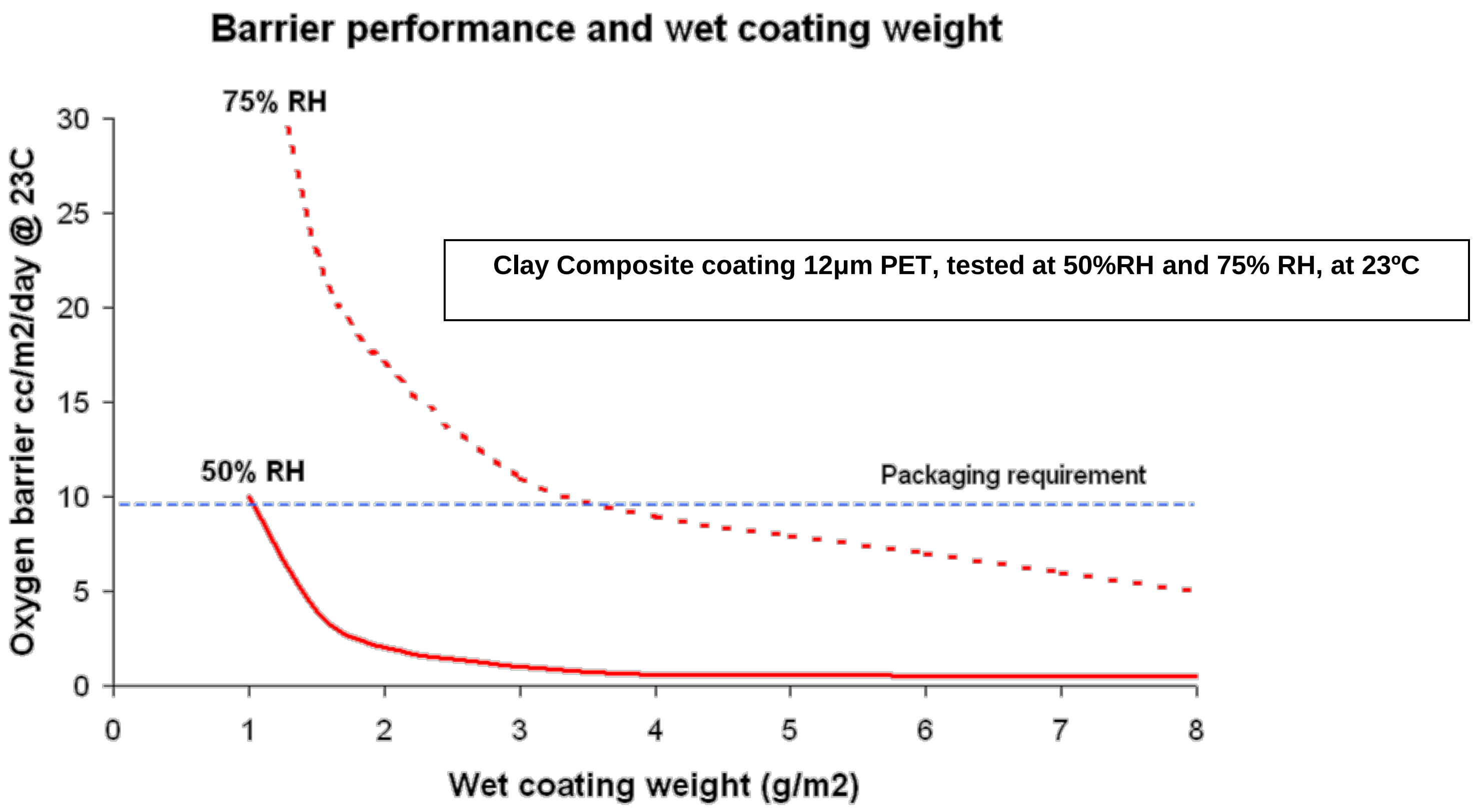
Influence of Relative Humidity & Coat Weight



Higher Coat Weights are Generally needed at Elevated %RH

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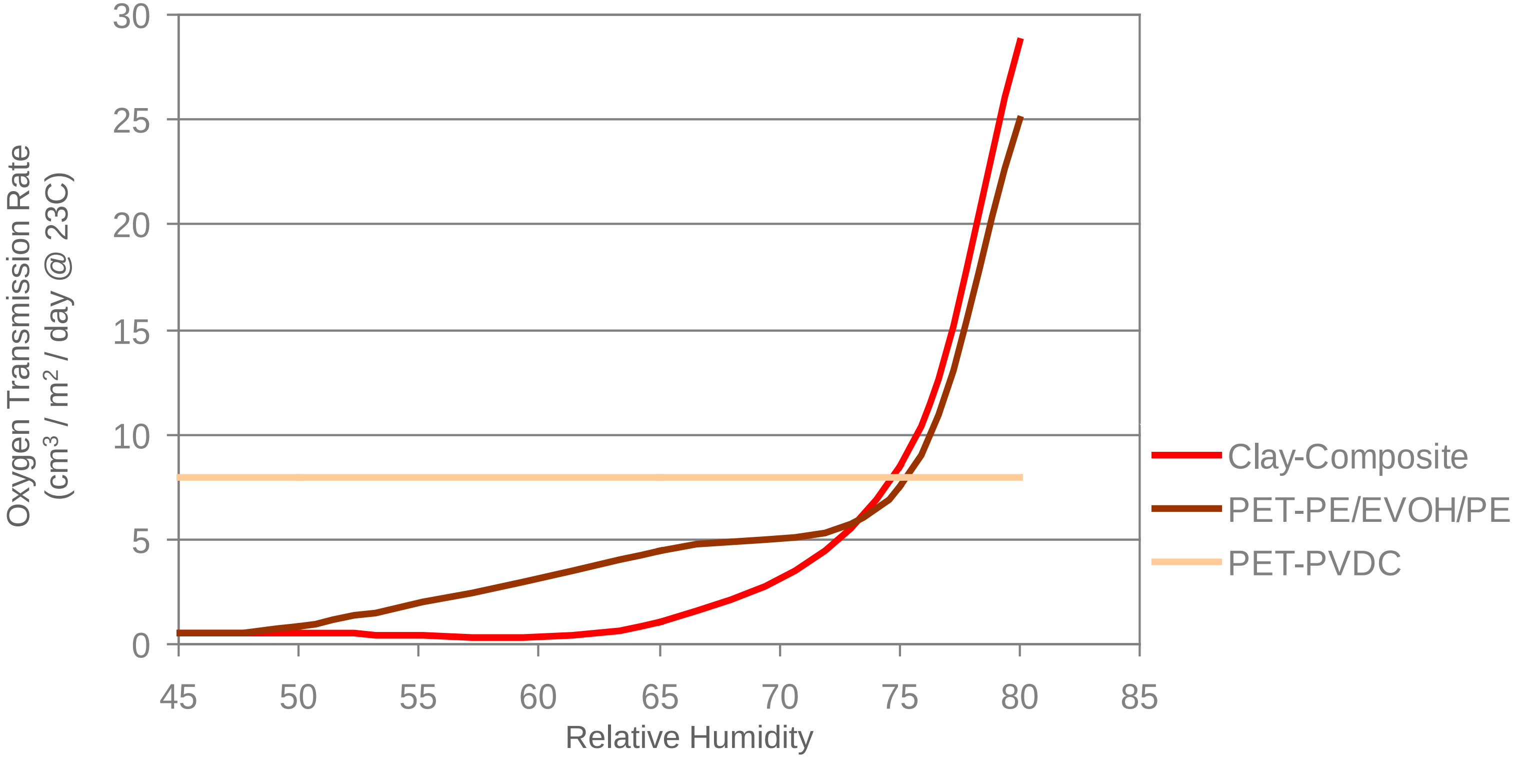
Performance Benchmark – Effect of Humidity



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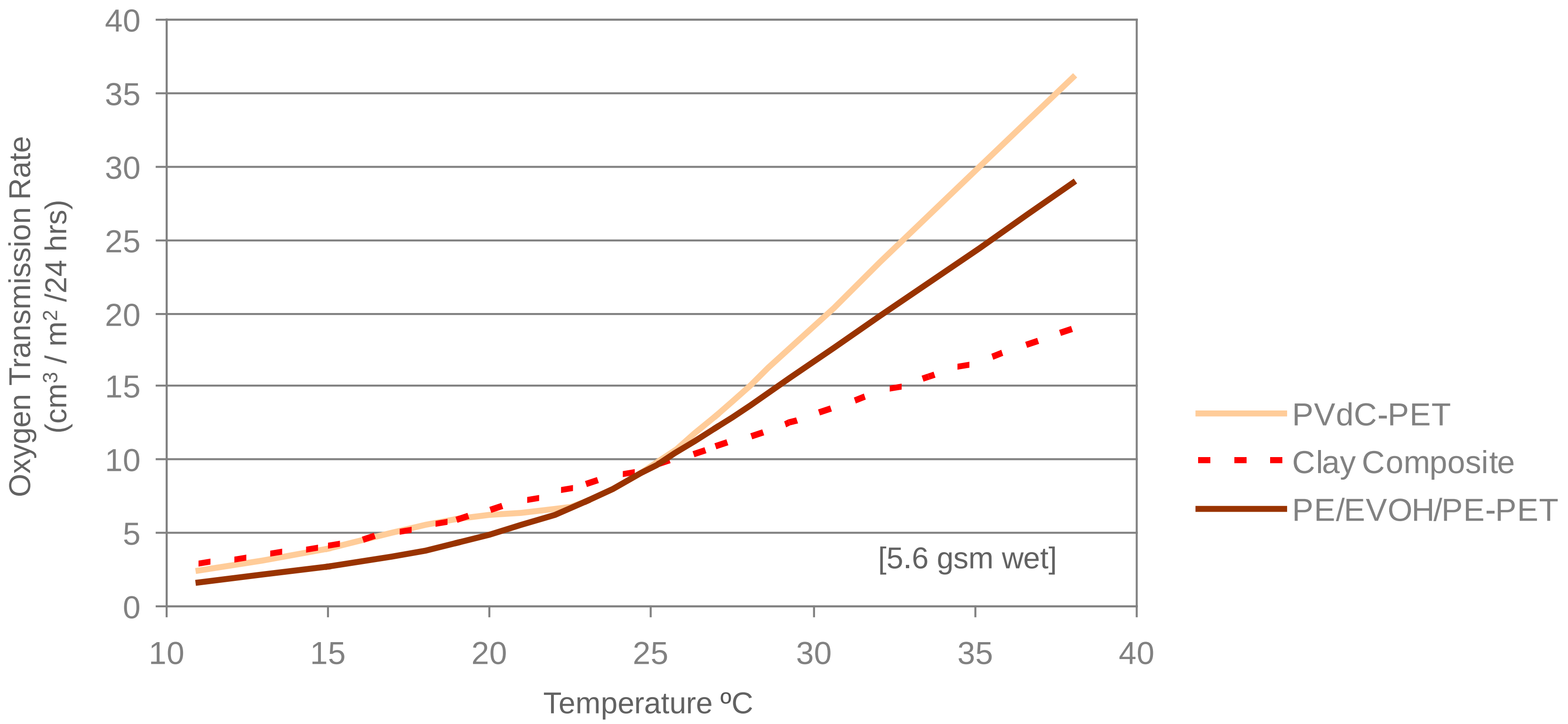
Performance Benchmark – Effect of Temperature at 75% RH



Clay-composite coating improved performance at elevated temperature

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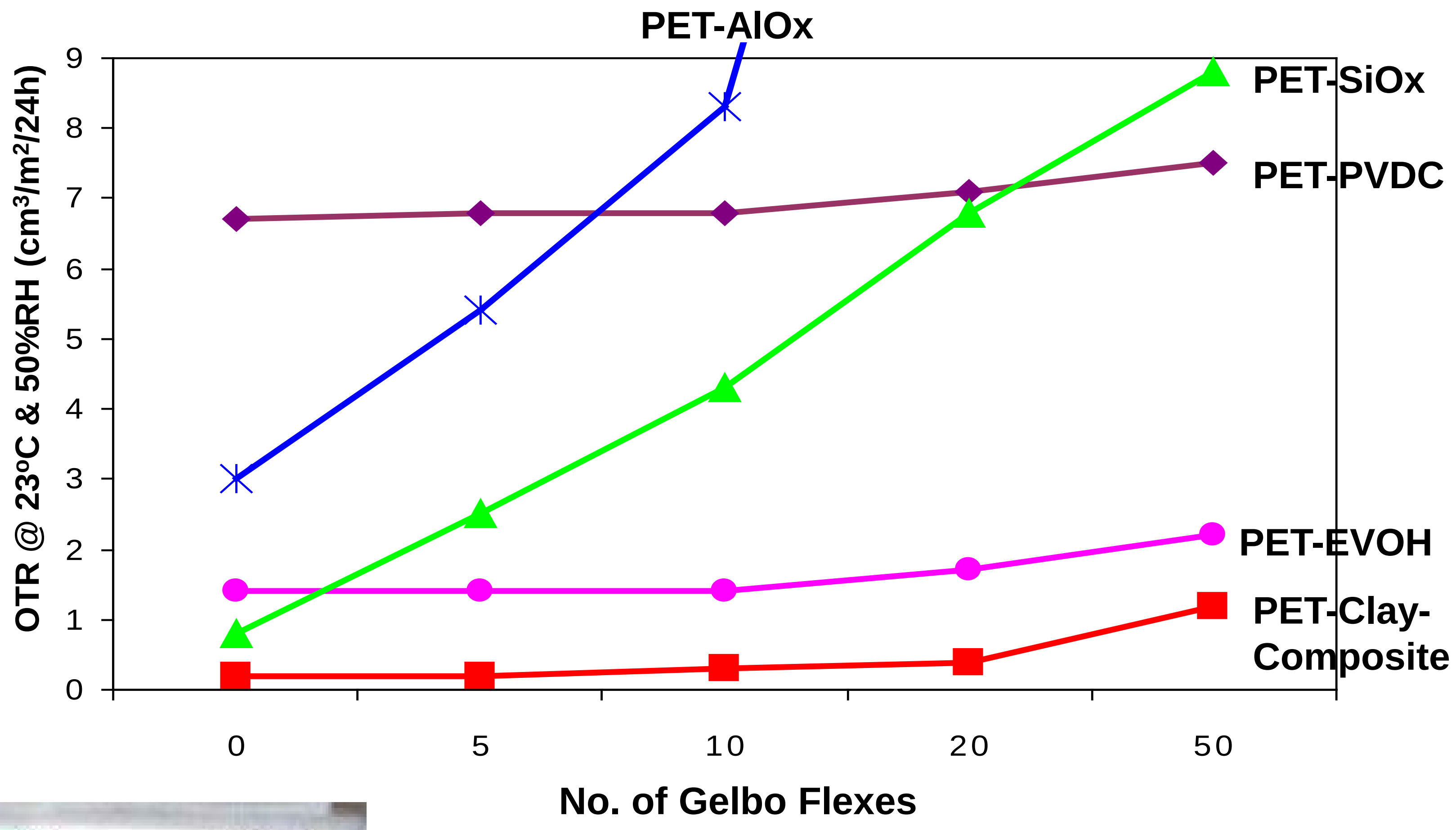
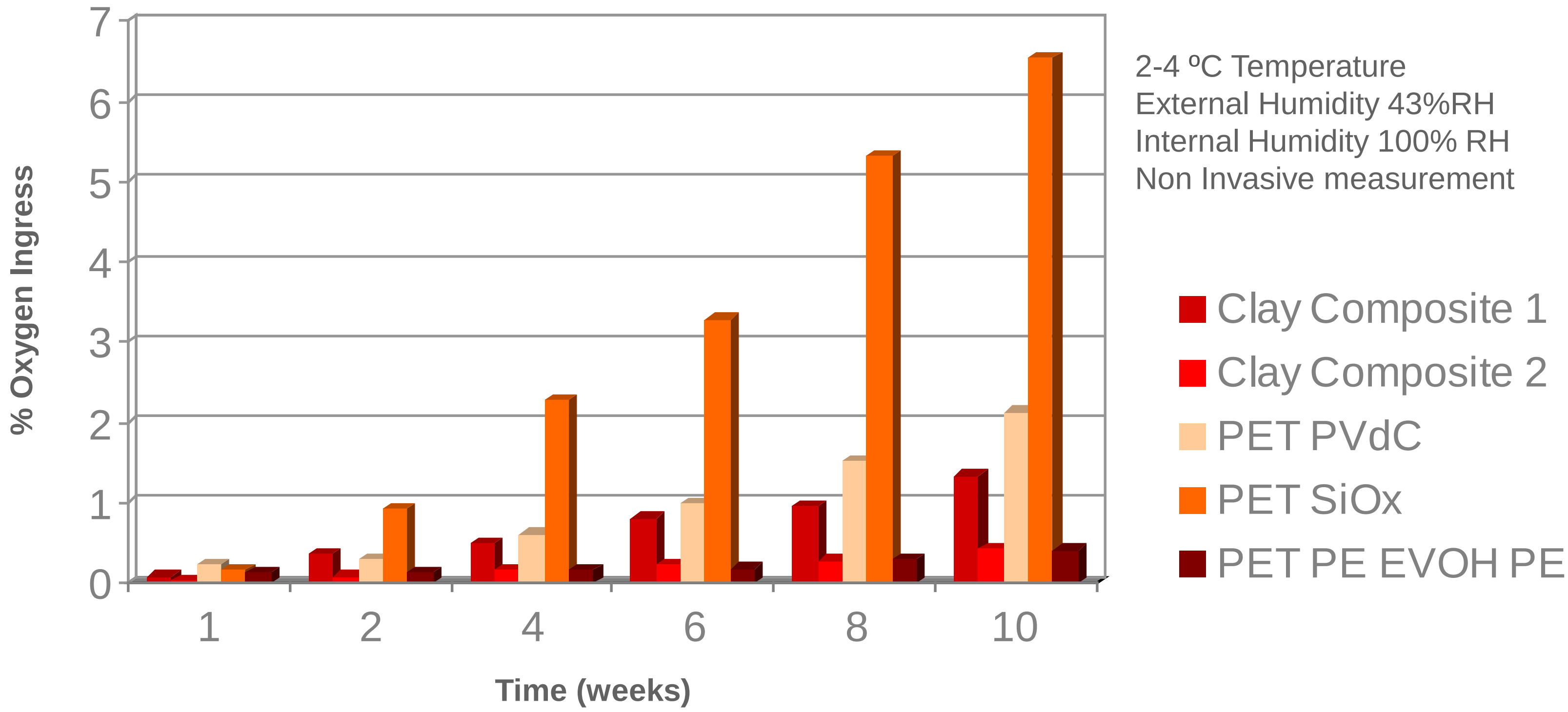
Flexibility of Barrier Coatings



Oxide-coated films have poor flex resistance

(Performance improves when laminated and coated)

Chilled Foods-Real Time Packaging Performance



Clay composite coatings perform as well as EVOH Structures

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Coating Applications

Key Packaging Trends

1. Rigid to flexible
2. Visible product contents
3. Light weighting
4. Single piece packs

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Trend #2: Visible product contents

Longer shelf life. Visible content packs with high oxygen barrier

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Trend #4: Single piece packs

Excellent oxygen and aroma / odor barrier for base substrates.

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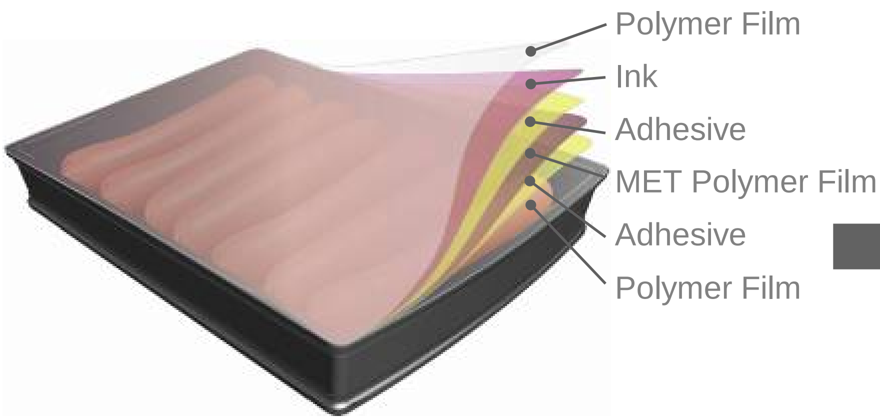
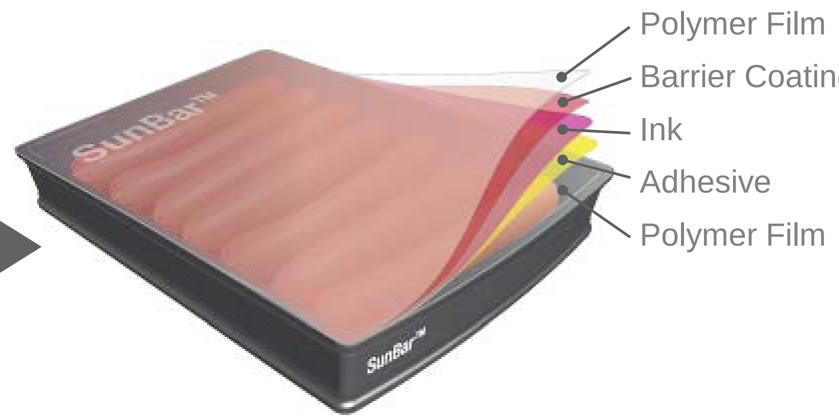
Light weighting

Commercial 3-Ply Laminate



2-Ply Laminate plus printable barrier coating



- Removal of barrier film or foil and one layer of adhesive
- Lighter weight packaging (up to 30% reduction)
- Improved laminate integrity (post flexing O_2 barrier improvement)
- Lower material and / or operational costs
- Improved recycling
- Improved shelf life

Conclusions

- **SunBar™** Clay composite oxygen barrier coatings
  - enable (transparent) barrier packaging having exceptional barrier properties.
  - Oxygen Barrier Performance equivalent/superior to existing technologies
  - Can be applied by conventional printing methods
  - can reduce the environmental impact of plastic packaging.(lightweighting, improved recycling, Cl free, replace metal, more flexible)

- Increasing the mineral aspect ratio provides improved barrier performance.
- Improvements in oxygen barrier shown to result from an increase in diffusional path length ('Tortuousity').

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Acknowledgements

- Thank you for your attention
- The Functional Coatings Research team at St. Mary Cray (UK)
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