Polytechnique
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Material Reduction and Biobased Materials Use For More Sustainable Polymer Packaging

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3S pack

SPE Polyolefins & Flex pack conference, Houston, TX, Feb 24 - 26, 2018

Sustainability in Packaging

Packaging Performance is Paramount/Priority requirement

- Must have performance to protect the economic and environmental investment in the product as well as the package.

Reduce, Replace, Recycle, Reuse, …

- May still be room for further performance and cost optimization,
- New opportunity to further optimize with sustainability driver: better performing resins at comparable total system cost.

Renewable (biobased), biodegradable, compostable

- Developments in processing,
- New modifiers to improve performance (processing, end use),
- New renewably sourced polymers with performance benefit.

Nanotechnology/Nanoparticles in Polymer Applications

- Addition of nanoparticles: taking advantage of surface area, shape, functionality, …
- Nanoparticles (nanocomposites) can be used in some packaging applications: Barrier, Oxygen scavenging, antibacterial,….
- Issues: regulation

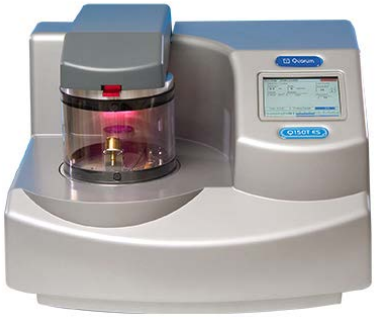
I- Film Processing

What we already have :

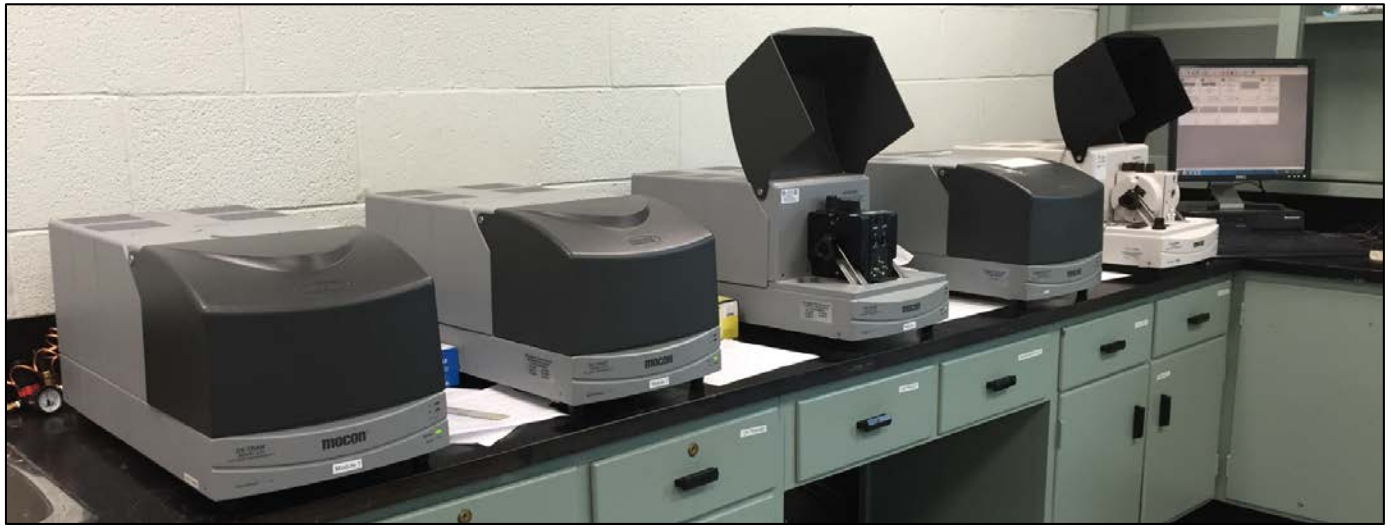
- 4 extruder cast film and blown film line, 1 twin screw extruder
- 9 layer feedblock for cast
- 7 layer pancake for blown film
- Calander
- MDO unit
- Corona treatment (online or offline)

II- Film Morphology analysis and Barrier

-Tabletop Scanning Electron Microscope from Hitachi with EDX
- Carbon/Chromium Sputter/Coater from Quorum
- Ultracryo microtome for SEM and TEM sample preparations



- Oxygen Transmission Rate Equipment (3) with and without Moisture control
- Water Vapor Transmission Rate Equipment (2)



II- Film Characterization

Mechanical Characterization And Sealability

- Seal/Hot tack Tester

- Flex Crack Tester

- Abrasion Tester

- Mechanical Properties Tester with environmental chamber
  - Tension mode,
  - Compression mode,
  - Puncture,
  - Cycling (fatigue)

II- Film Characterization
Other Characterizations

- FTIR with microscope

- Conductivity /Resistivity Tester

- Helium Pycnometer

- Oxygen, CO_2 and Ethylene Reader

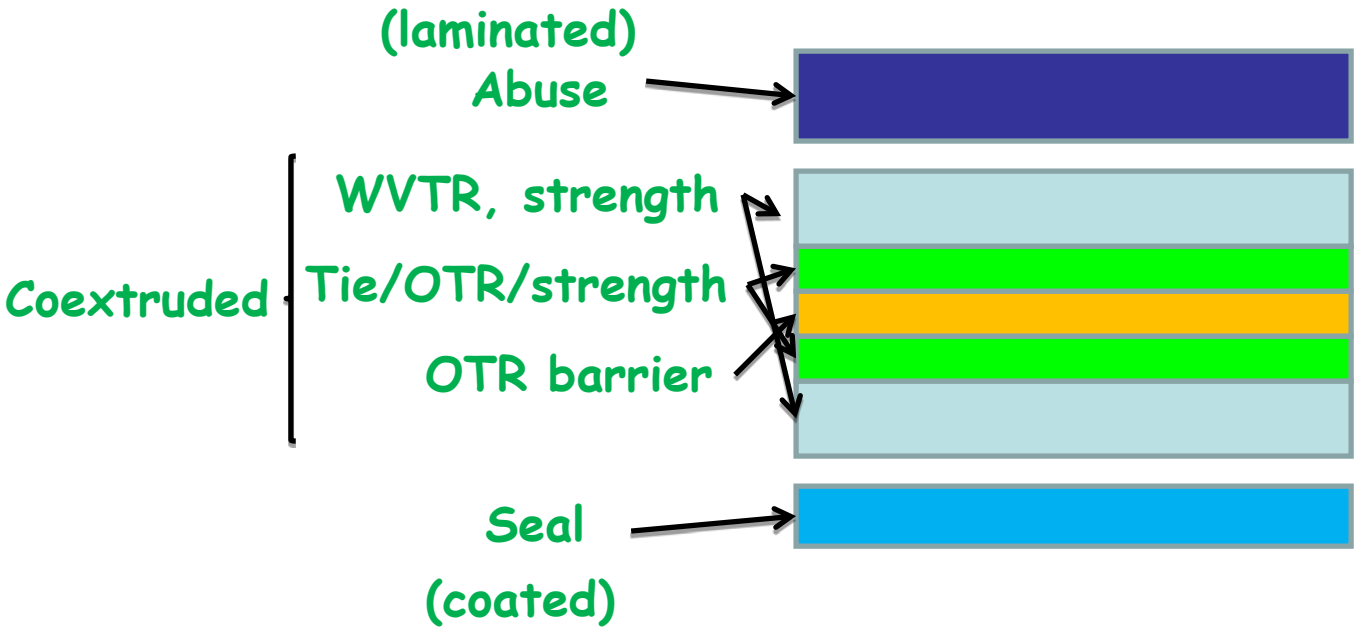
II- Other Processing and Characterization Equipments

Available in CREPEC, Department and Polytechnique:

- Internal batch Mixer
- Injection Molding Machine, thermoforming.
- Single Screw and Twin Screw extruder (lab scales)

- DSC (Differential Scanning Calorimetry)
- TGA (ThermoGravimetric Analysis)
- DMA (Dynamical Mechanical Analysis)
- Rheology
- Impact Tester
- Tear Tester
- Dart impact Tester
- HDT (Heat Deflection Temperature) Tester
- TEM (Transmission Electron Microscope)
- AFM (Atomic Force Microscopy)
- XPS, SIMS,…
- Environmental chamber, Solvant and Water Ovens
-…

Typical Packaging Structure



Nanostructures and Functionnality can be involved in all these layers

PLA based films for packaging

PLA in Packaging

Very Difficult Processing

Brittle film
(Poor Flex-crack and tear)

PLA/PBAT blends

Produce Bio-based or compostable sealant films for environmental friendly packages.

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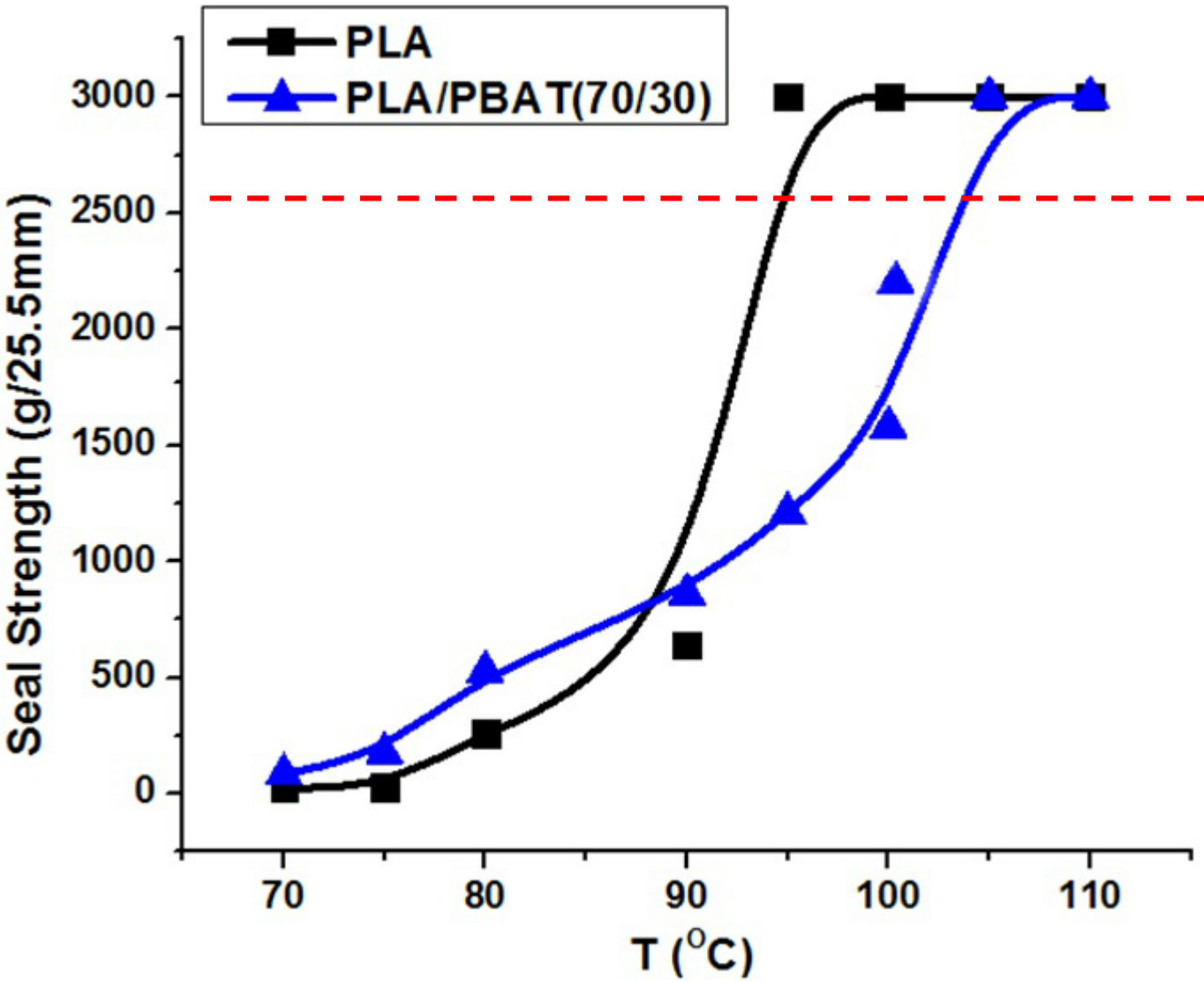
Bioplastic sealants



BUR = 3

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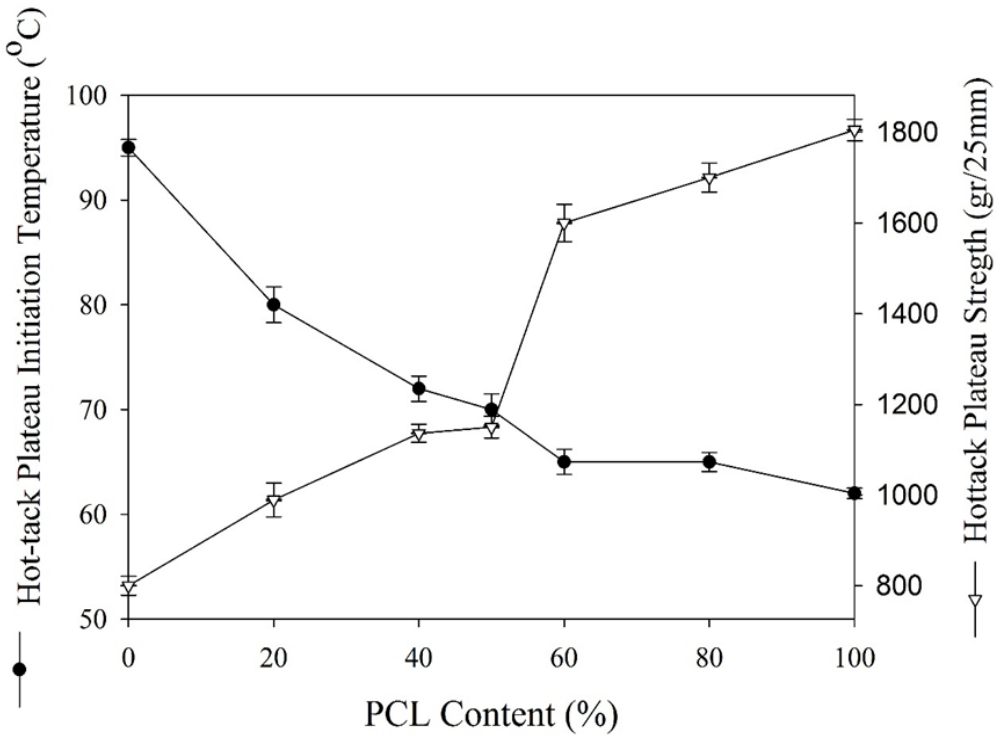
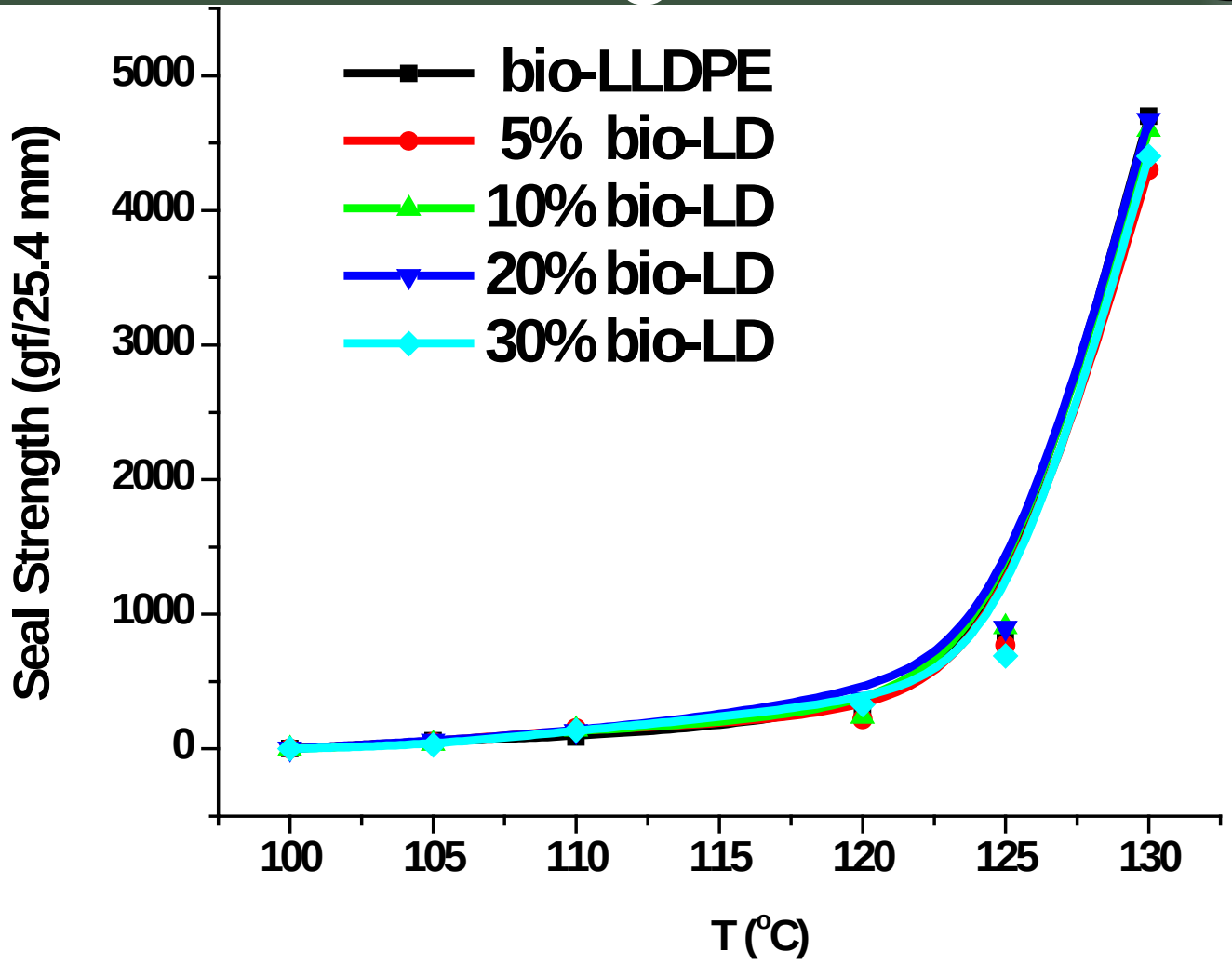
Result: Mechanical Properties and seal behavior of blends

- Hottack Plateau initiation temperature Decreases up to 30 °C
- Hottack Strength increases up to twice



Seal Strength*



- ***Sealing were done at 40 psi and 0.5 s dwell time***
- ***Peeling was done at 33 mm/s***

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Nanoparticles addition (Nanacomposites) or coatings for Barrier Enhancement.

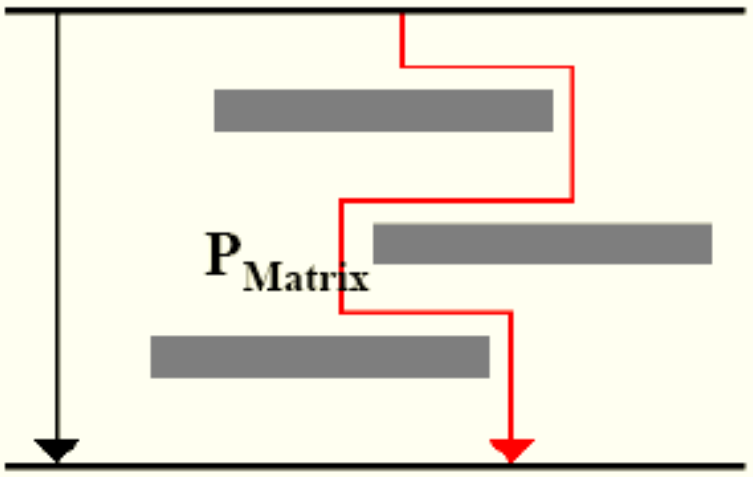
Nanocomposites

PNC based on layered silicates have received very much attention because of their potential to improve:

- Stiffness, strength and impact resistance
- Barrier properties
- Dimensional and thermal stability

Advantage for layered silicate: low content.

Barrier Enhancement: Tortuous Path



What does it take to reduce 50% permeability?

Aspect ratio	Volume %
20	9%
200	1%
400	0.5%

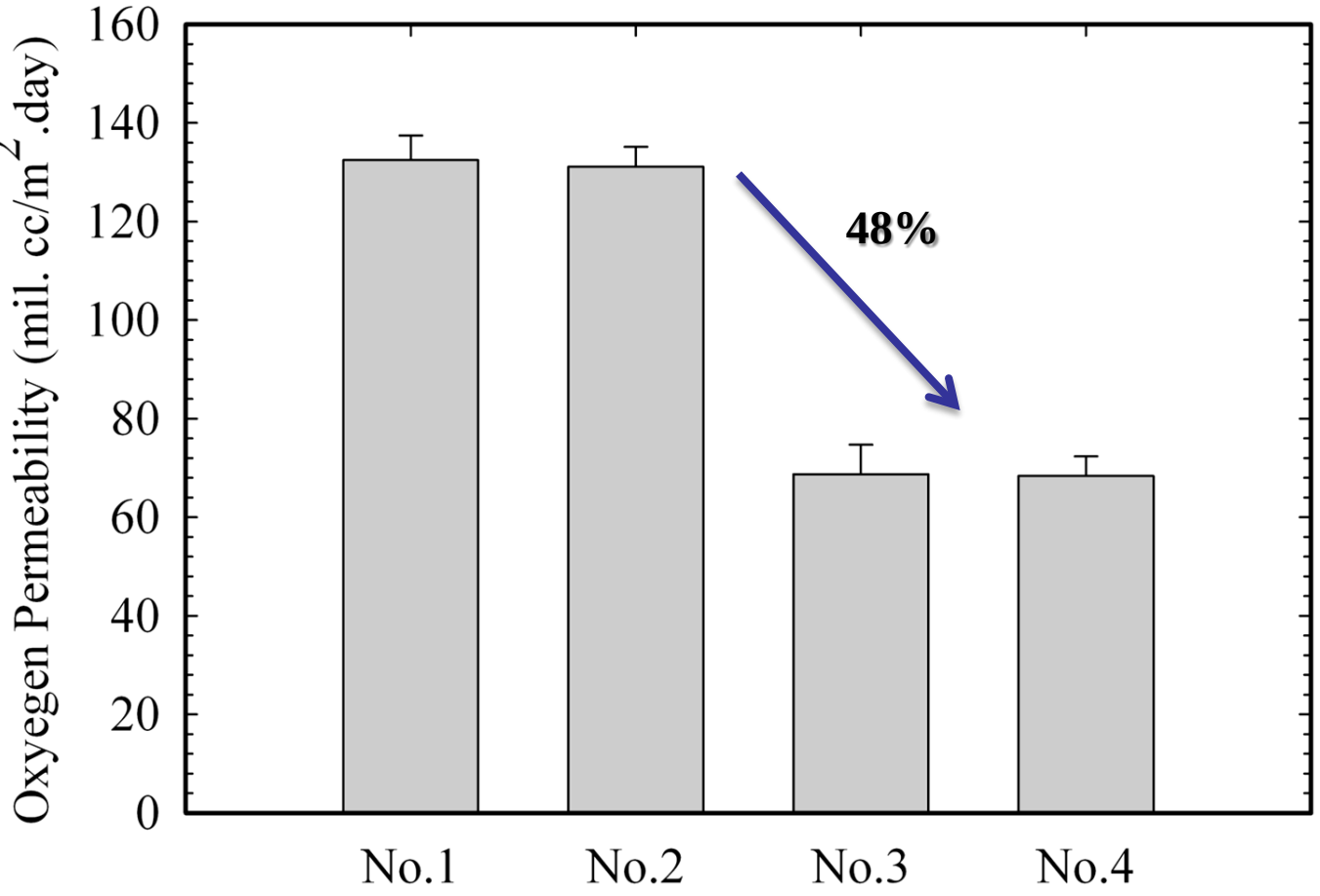
$$P_{nanocomposite} = \frac{(Matrix\ Volume\ Fraction)*(P_{matrix})}{1 + (Clay\ Volume\ Fraction)*(Clay\ Aspect\ Ratio)/2}$$

L. E. Neilson, J. Macromol. Sci. (Chem.), A1(5), 929-942 (1967)

PA-6 Nanocomposites: Oxygen permeability

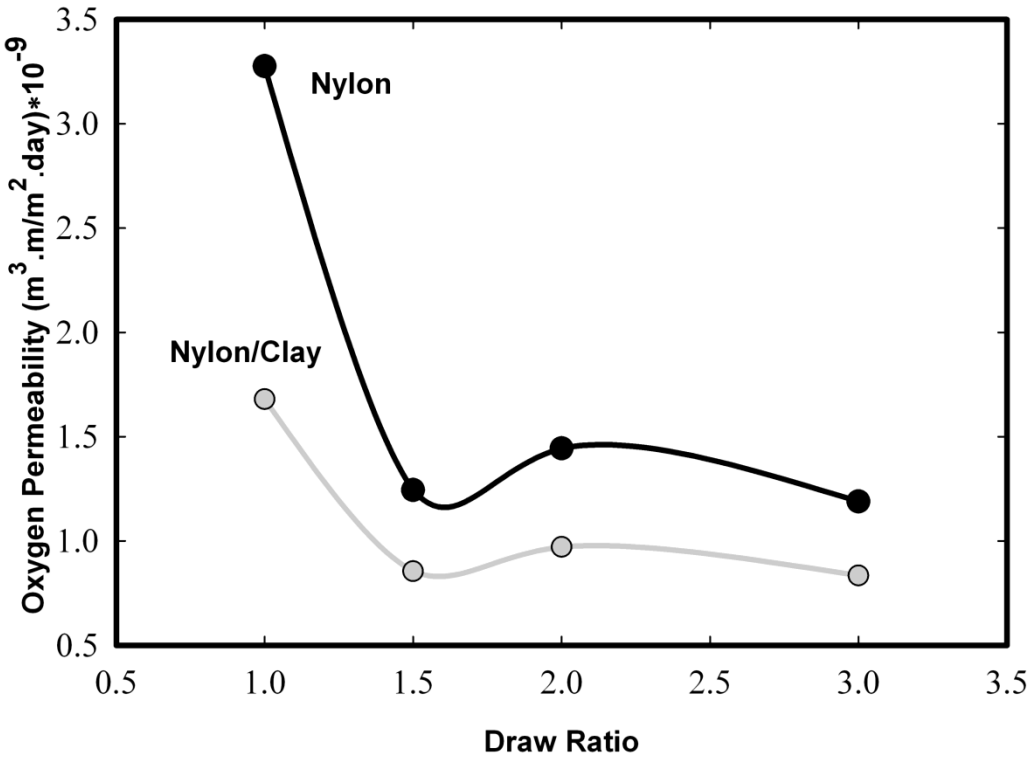
The values are normalized

48% Barrier improvement for 4 % clay incorporation



Total thickness: 50 μm, sample 1: PA 6 μm, 2: PA 12 μm

MDO Effect on Barrier



Oxygen permeability for multilayer films with nylon and nanocomposite

Layer by layer film deposition technique

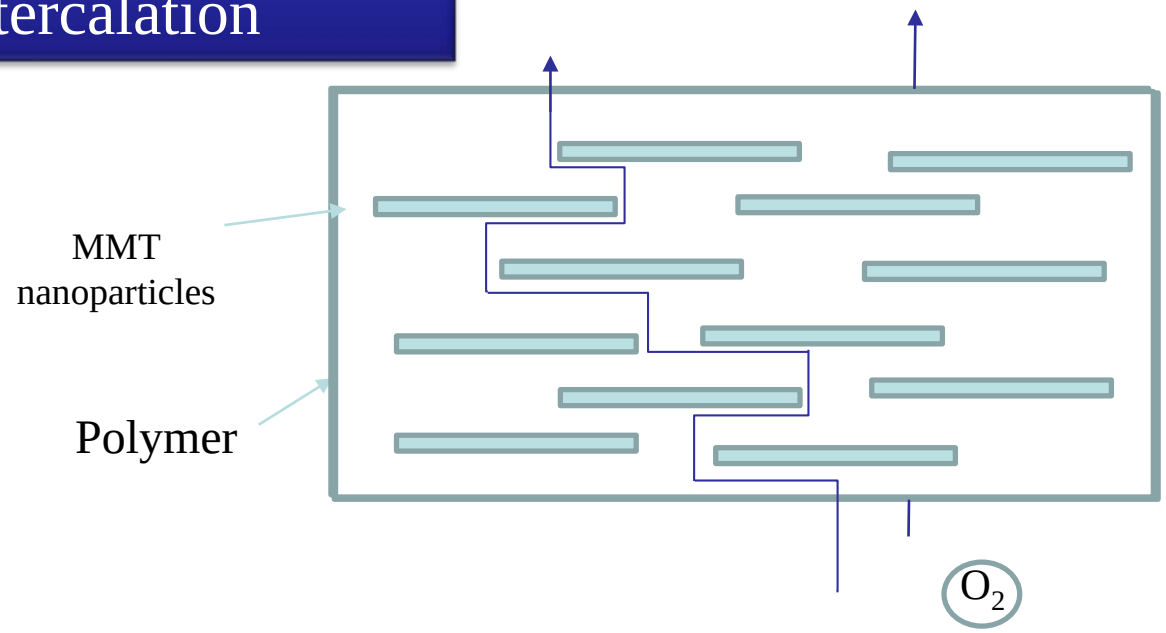
Main characteristics for MMT: Orientation and intercalation

Good properties

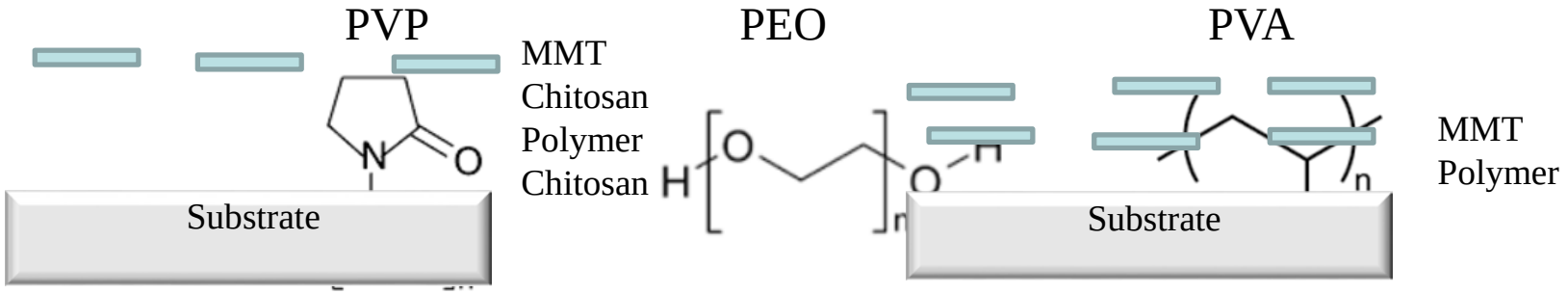
Availability

Nontoxicity

MMT: improve polymer barrier



Hydrogen bonding

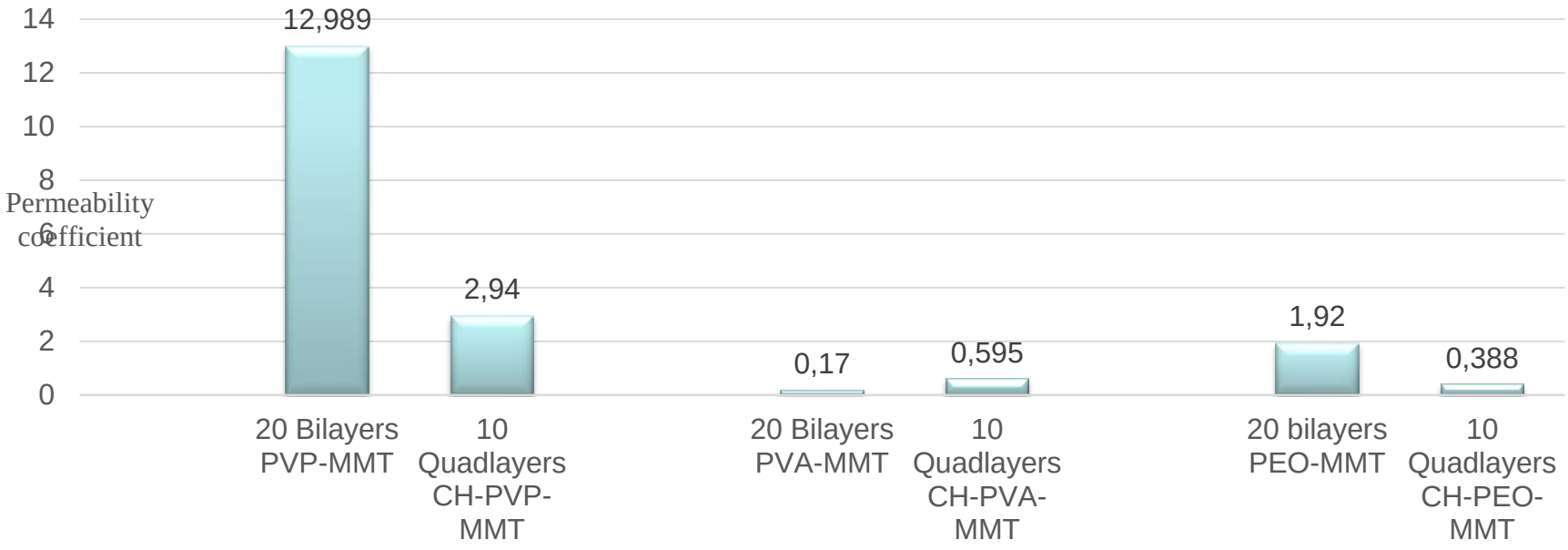


Quadlayer structure

Bilayer structure

Parameters optimization and main results

Dipping time	Polymer solution (% wt)	MMT suspension (% wt)	CS solution pH
1min	0.1	0.5	6



Conclusions – Barrier Layer

- Barrier properties of polymers can be improved using nanocomposites,
- Clay intercalation/exfoliation plays a significant role in barrier properties improvements,
- Barrier coatings are good alternatives, if process and moisture allow,
- LBL technique is promising, but needs developments for large scale applications.

Active Packaging: Antibacterial and Oxygen Scavenging Films: Less wasted food, product sustainability.

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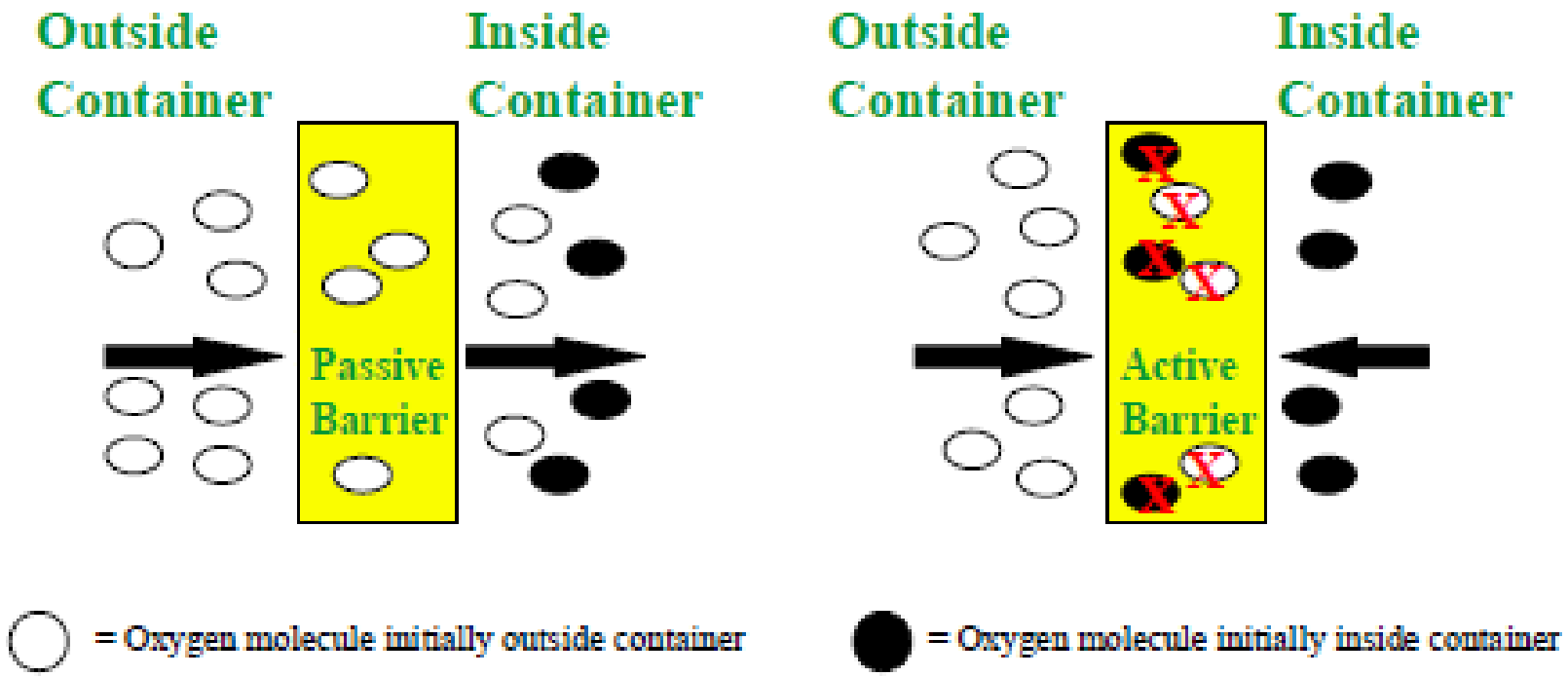
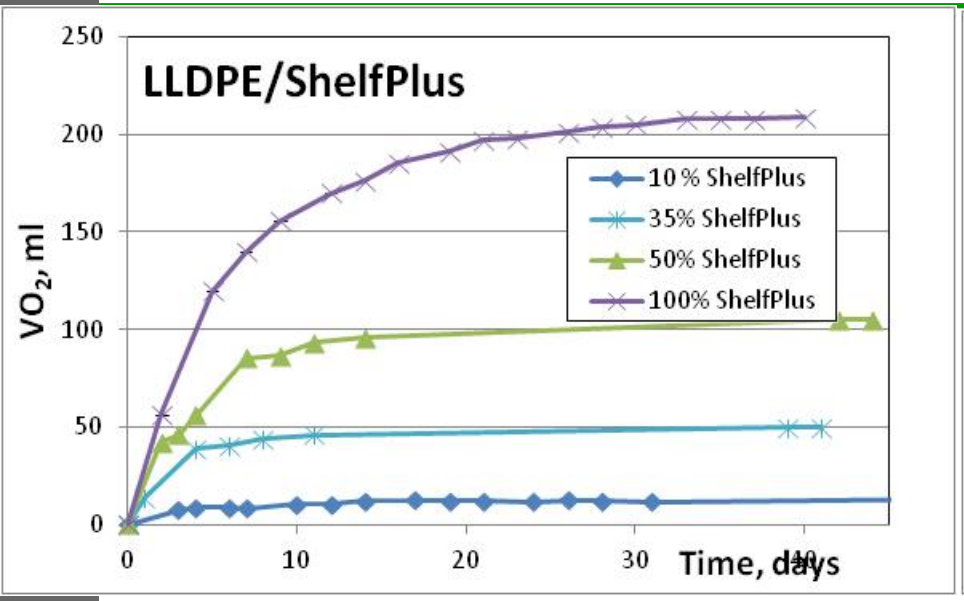
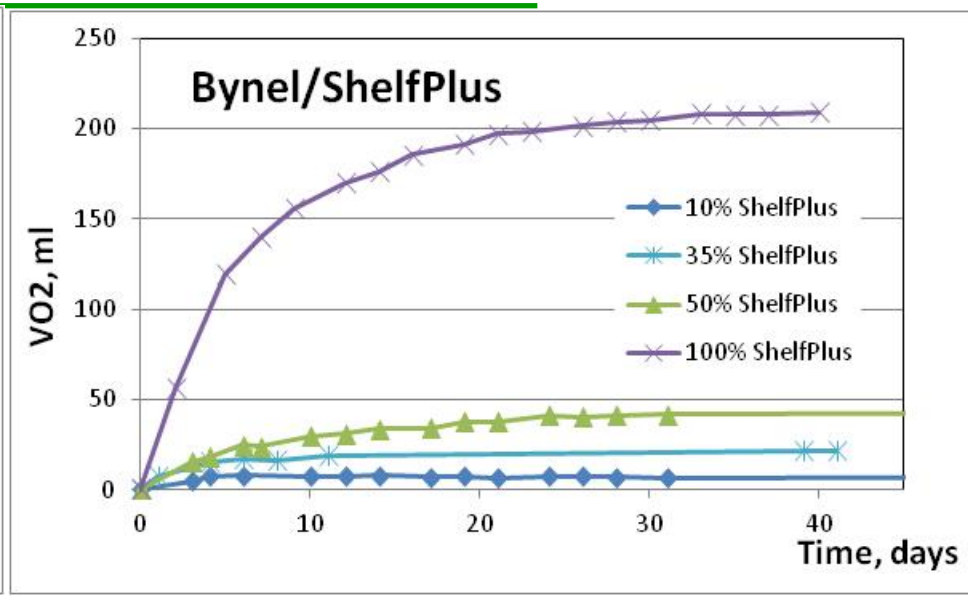
Active layer using OS



Evaluation of ShelfPlus: Main findings



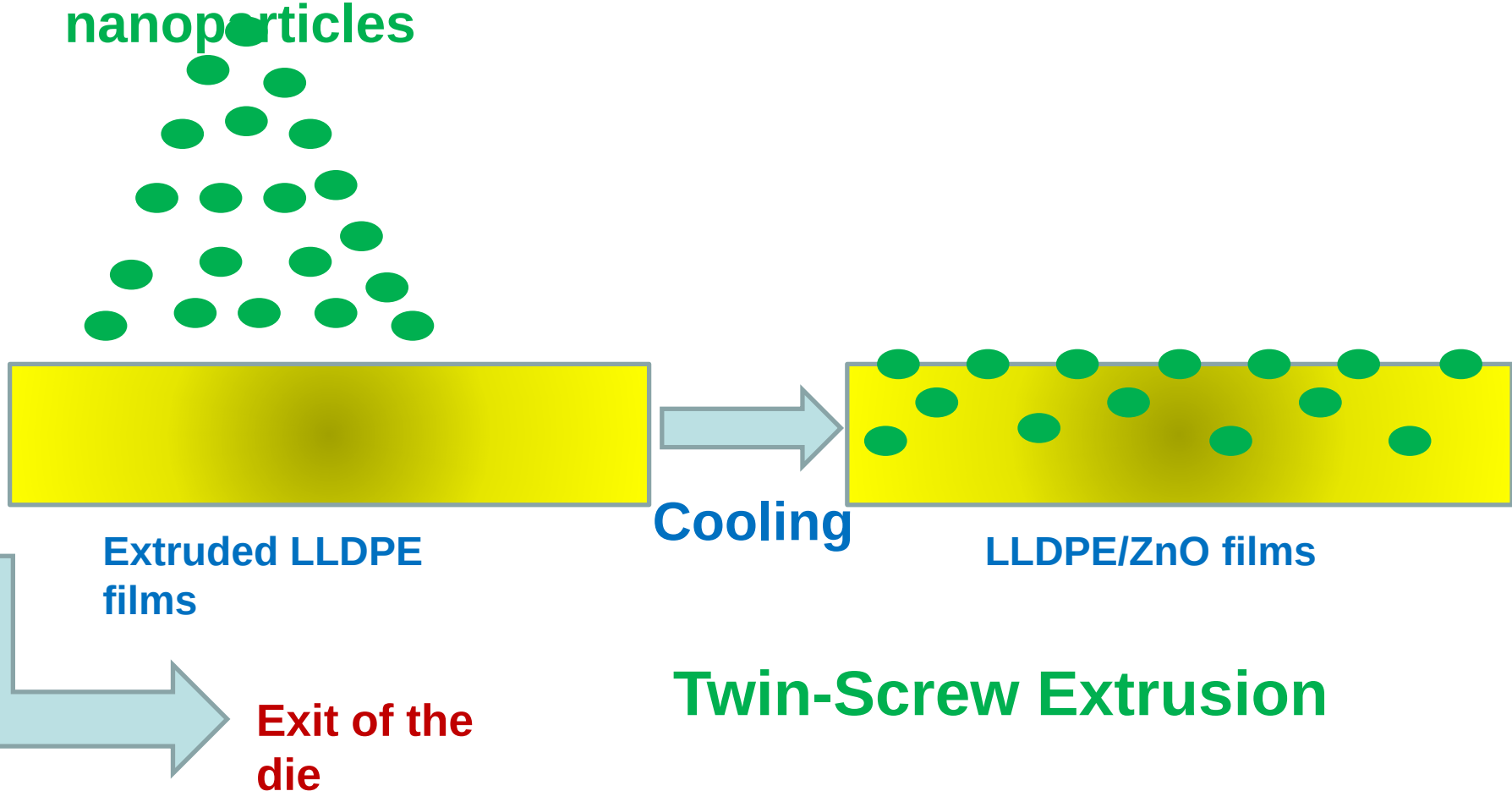


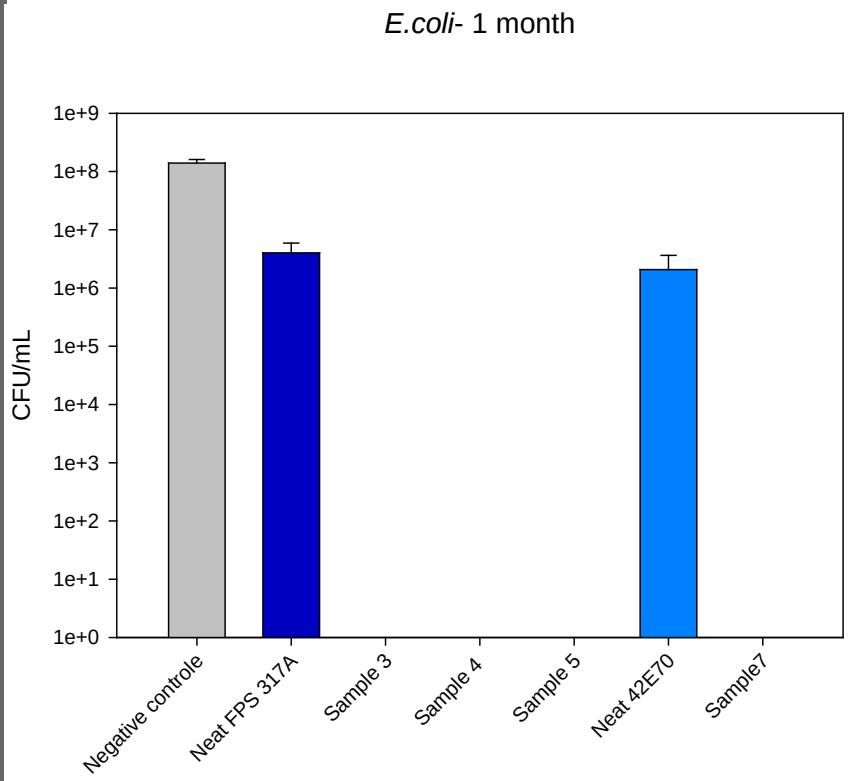
- **Blends with LLDPE have better oxygen depletion behavior.**
- **Shelfplus blended with Bynel exhibit lower OS.**
- **EVOH+ShelfPlus lowest effect.**

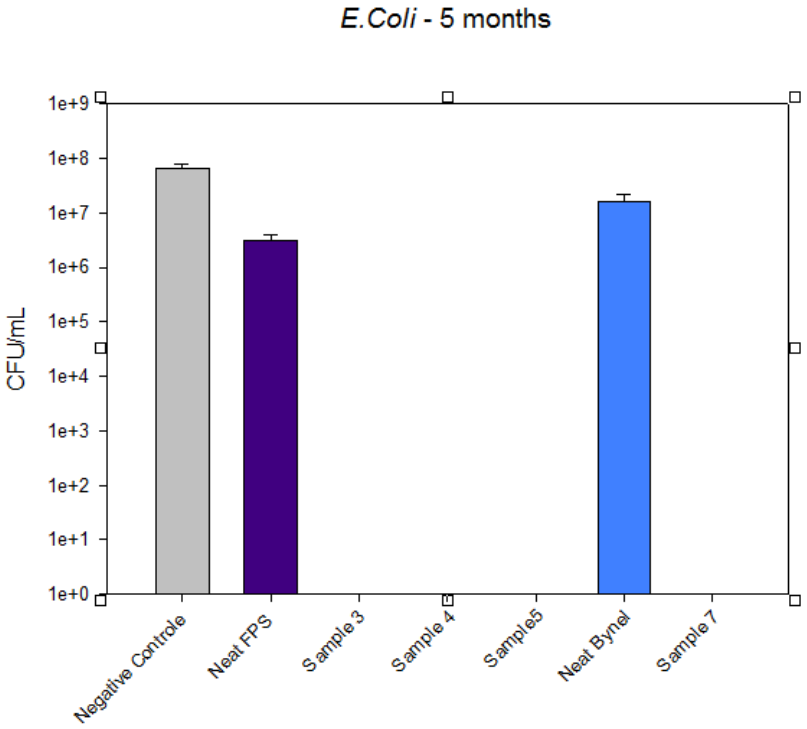
Methodology

Grade	FPS 317A+ ZnO Novachemicals 4 g/10min			LLDPE/AM (Tie layer) Bynel 42E703 Du Pont 6,4 g/10 mn
Sample	**3**	**4**	**5**	**5**
Temperature	190	200	1-4 :200 5-9: 220	1-4 :200 5-9: 220
Thikness µm	70			

Spray of ZnO nanoparticles on the LLDPE films







November 2016

March 2017

Selective Degradation of Biodegradable Blends in Simulated Laboratory Composting

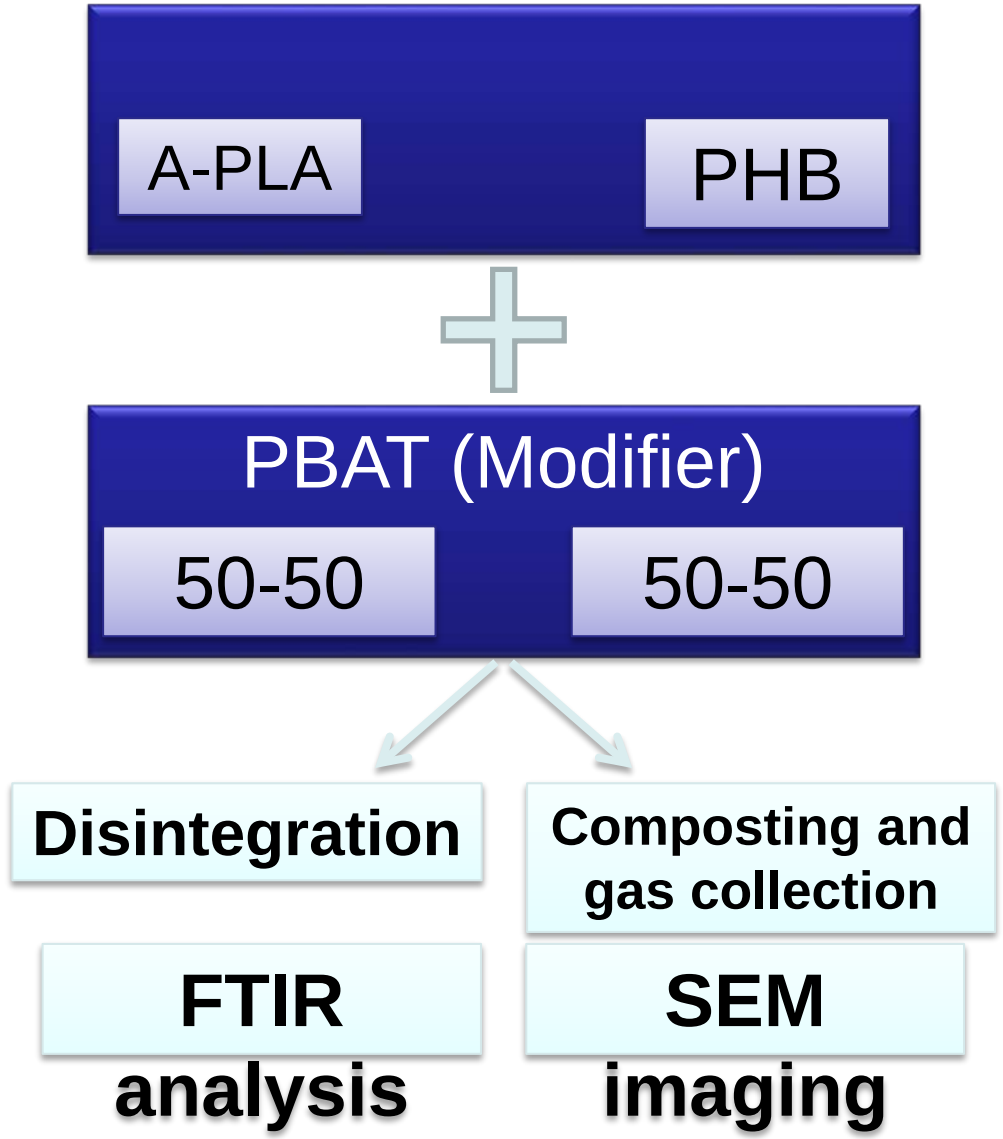
Submitted to polymer degradation and stability

Materials

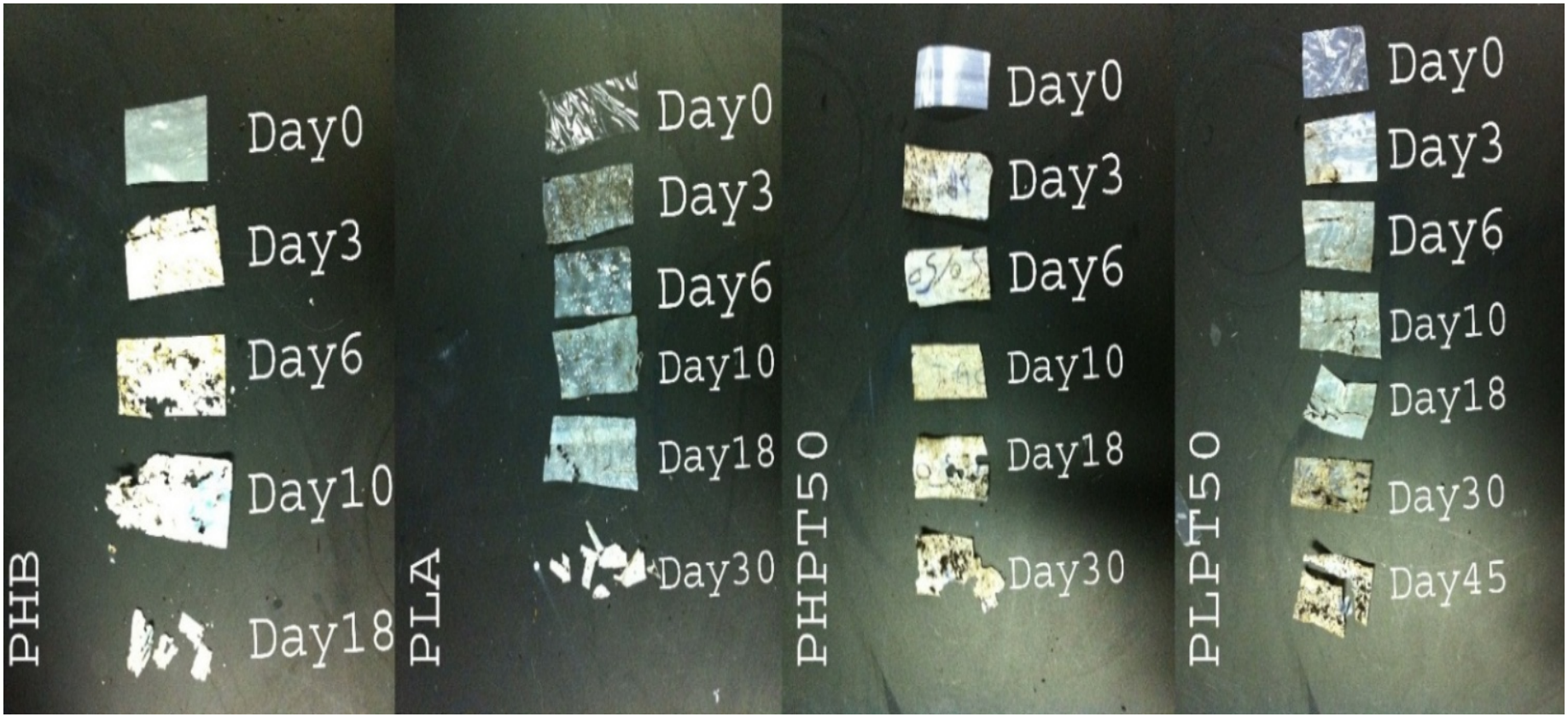
PLA Natureworks 4060D

PBAT F Blend C1200

PHB P290 Biomer

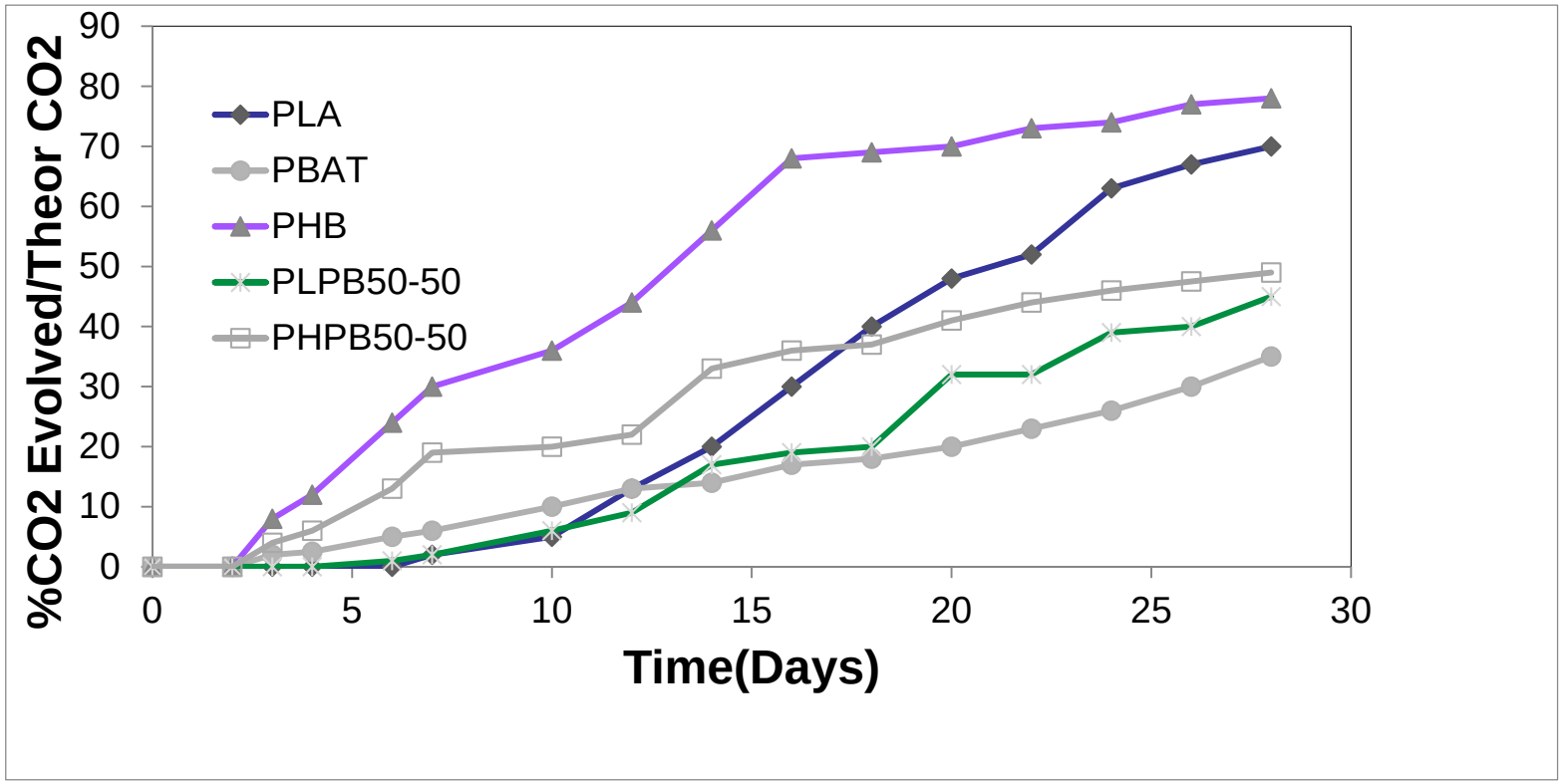


Result: Disintegration and mechanical strength



Integrity of samples are lost ⇨ loss of mechanical properties

Result: Composting and gas collection



Faster bacterial digestion ⇨ Larger amount of CO_2 evolved

Concluding Remarks:

- Many challenges still remain for the development of more sustainable packages with the use of nanoparticles / nanostructures in Packaging:
  - Dispersion,
  - Manipulation and Regulation,
  - Appropriate Performance.