TAPPI INTERNATIONAL FLEXIBLE PACKAGING & EXTRUSION DIVISION

2024 FlexPack PLACE Conference
April 14-17, 2024 • San Diego, CA • Wyndham San Diego Bayside

Sustainable Flexible Packaging Materials using Microlayer and Nanolayer Coextrusion Process

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Outline

I. TD Polymers

- Capabilities
- Micro- and Nano-layer Coextrusion Technology

II. Bioplastics

- Background
- Layered Bioplastics Materials for Sustainable Packaging

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TD Polymers: A polymer materials technology development company

Mission: To identify and develop next generation polymer materials through nanolayer coextrusion technology

TD Polymers

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TD Polymers: Processing Capabilities

Platform Technology

Co-extrusion

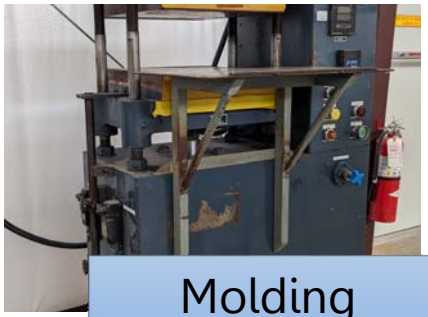
R&D scale Processing Equipments

Twin Screw

Single Screw

Batch Mixer

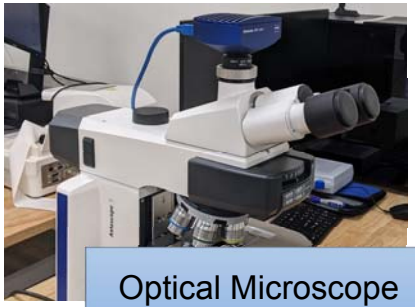
Thermoforming



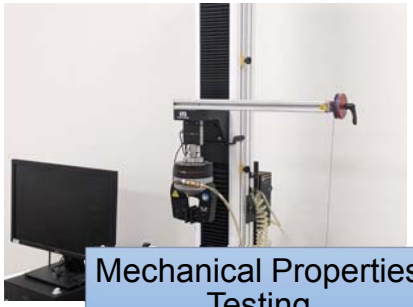
Molding

TD Polymers: Characterization Capabilities

Melt Flow Index

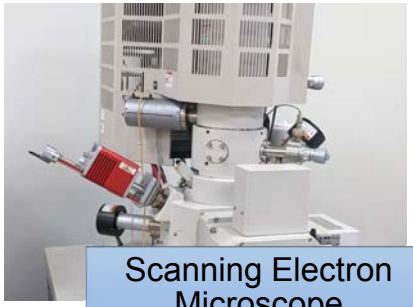


Optical Microscope



Mechanical Properties Testing

Differential Scanning Calorimetry



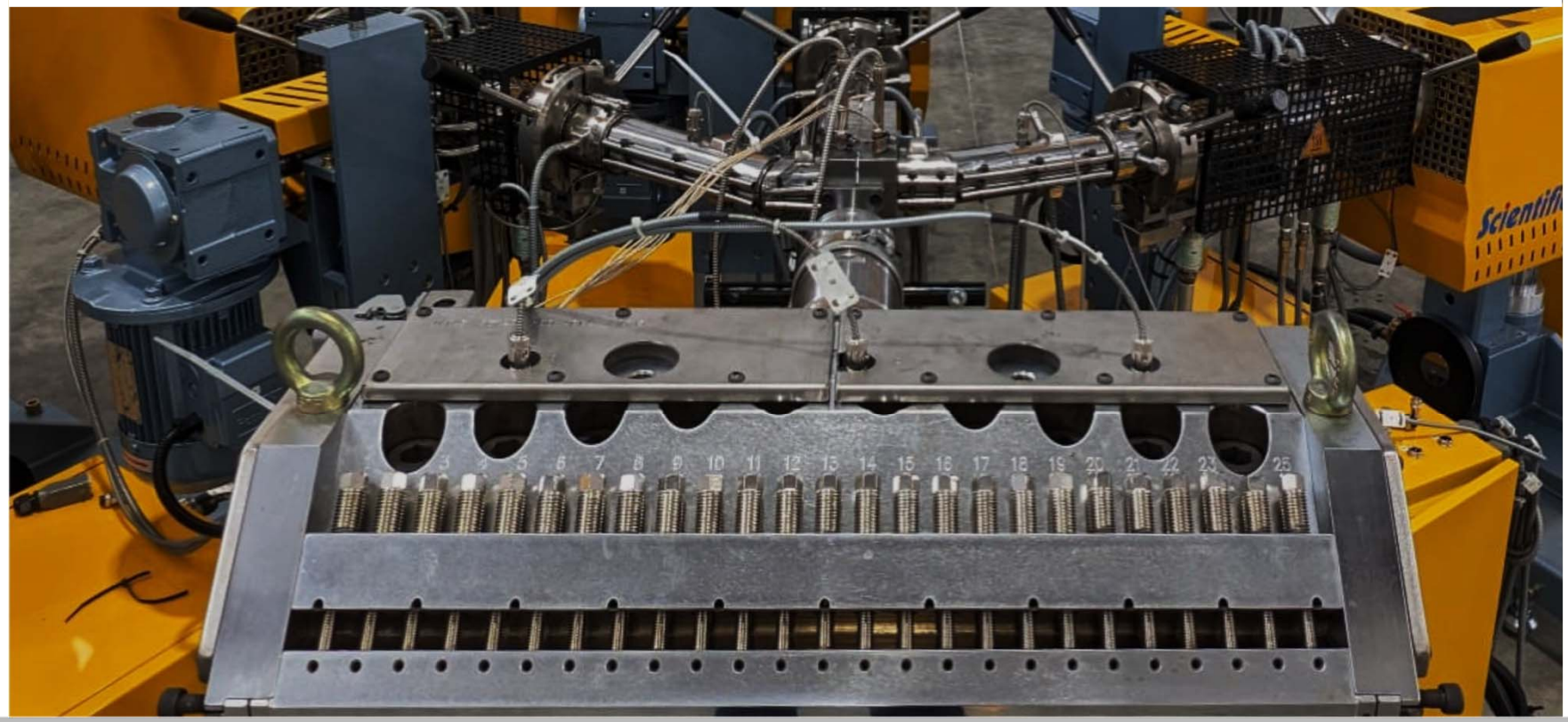
Scanning Electron Microscope

UV Weatherability

Moisture Analyzer

FTIR

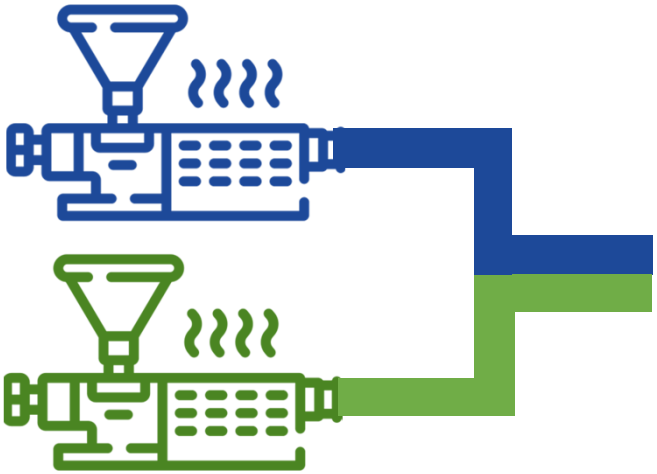
Multilayer Coextrusion Platform



Micro- and Nano-layer Coextrusion Technology

Conventional Coextrusion

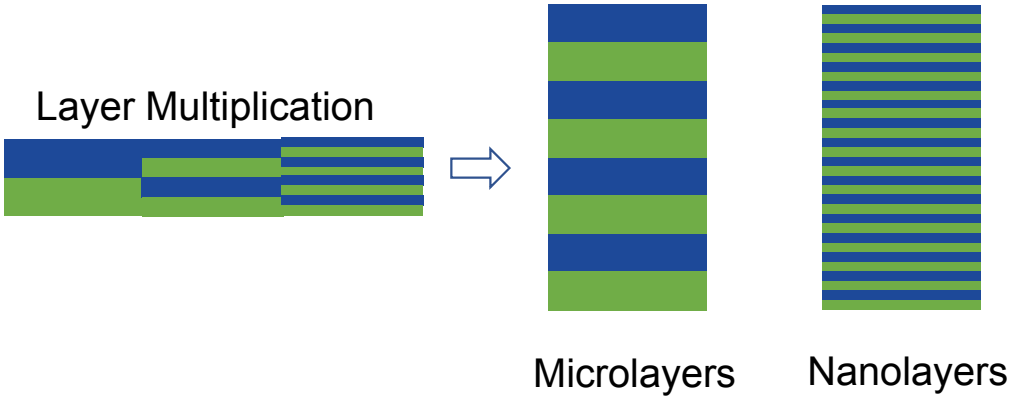
two or more polymers in a layered structure



Film
Sheets
Profiles
Tubes, Pipes

Advanced Coextrusion

Two or more polymers with **repeating** layer structures

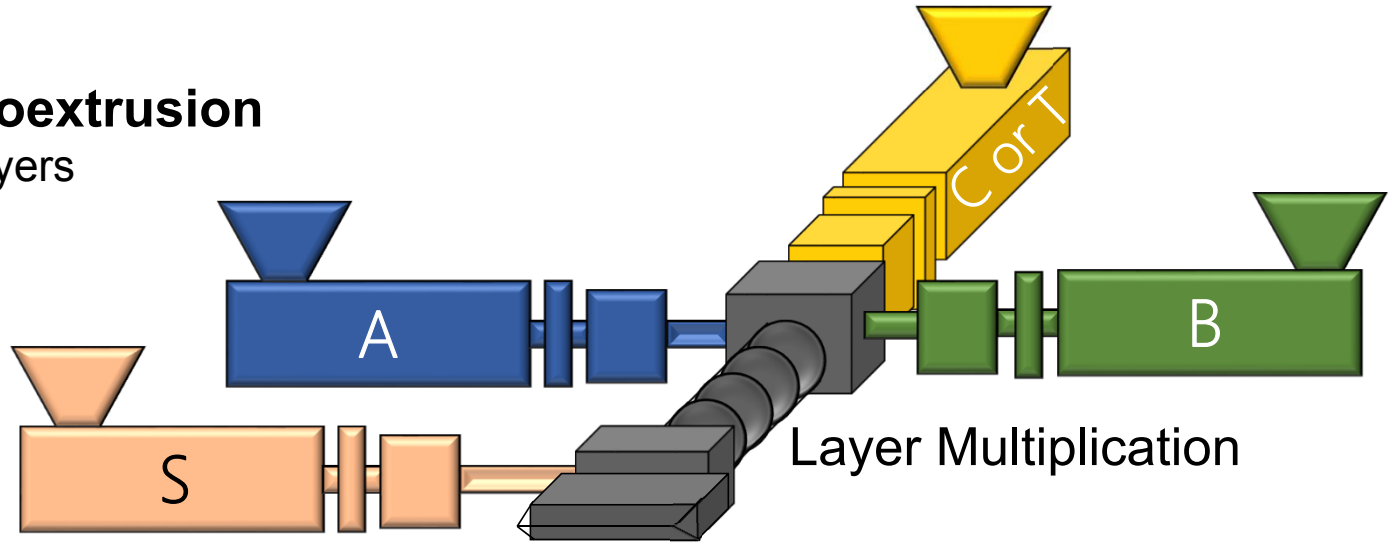


From 2 to 15+ layers
typically several 10s of micron thickness layers

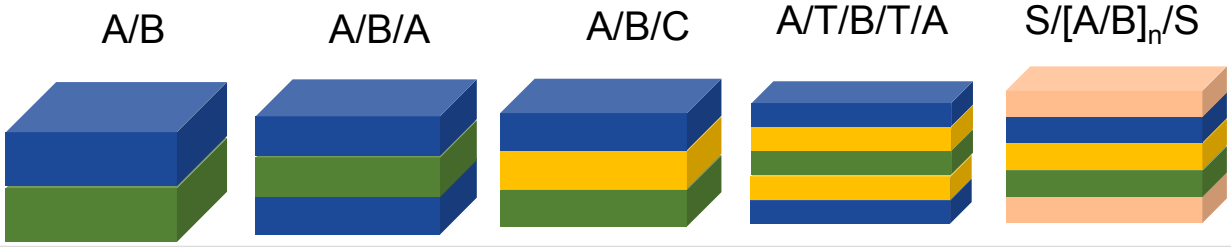
100s to 1000s of layers
micro- and nano-layer materials

TD Polymers Coextrusion Set-up

4-Polymer coextrusion
Up to 64,000 layers
Up to 24” width



Repeating Layer Units

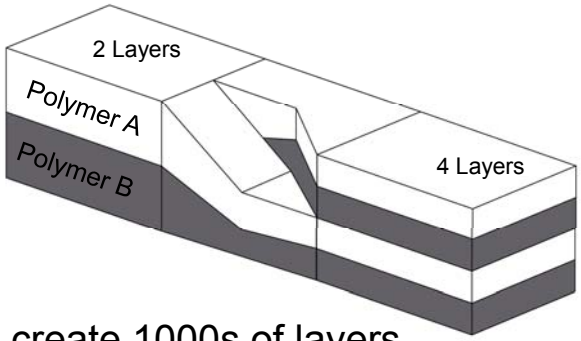


A = Polymer A,
B = Polymer B
C = Polymer C
T = Tie Layer Polymer
S = Skin Layer Polymer

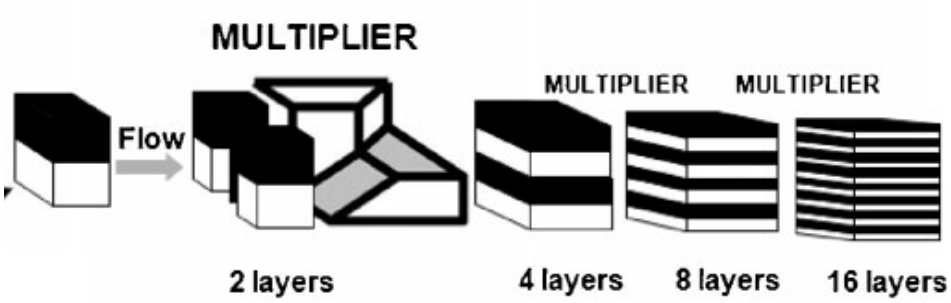
How does layer multiplication work?

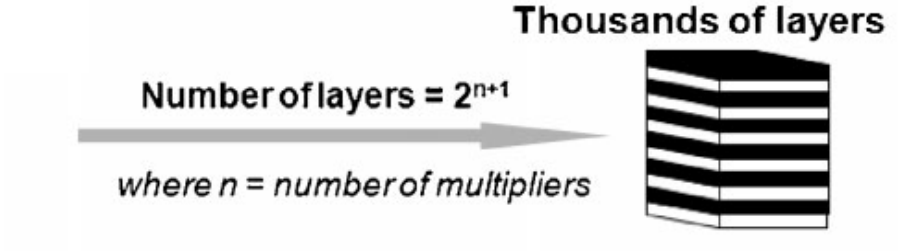
Layer Multiplication Technology

Inside the multiplier die: Physical splitting and recombination of polymer melt



Can create 1000s of layers



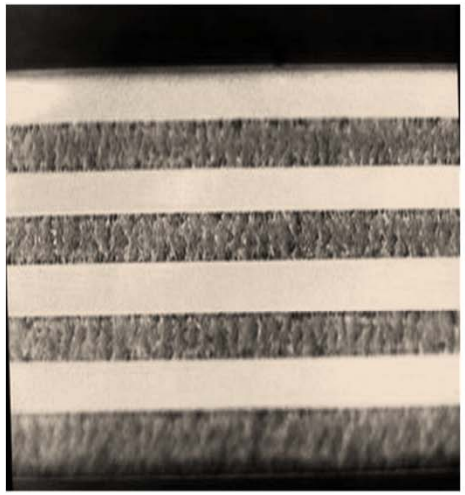


TD Polymers Set-up Specification: Extruders with metering pumps and multiplier dies

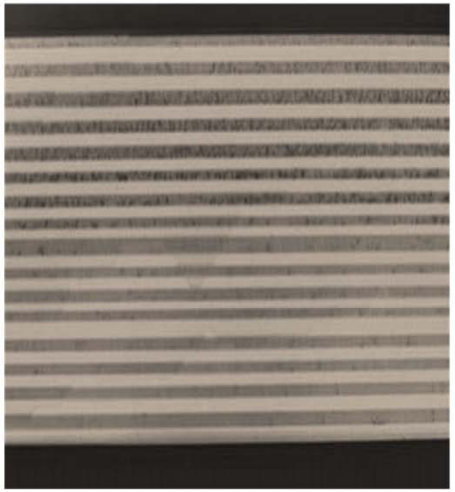
Line	Production Rate	No. of Layers	No. of Materials	Product Thickness	Width	Max. Temperature, °C
Coextrusion	5 - 100 lb/hr	1- 64,000	4	Film: 10 – 250 µm Sheet: 0.25 – 5 mm	Up to 24”	400 °C

Examples of Layered Structures

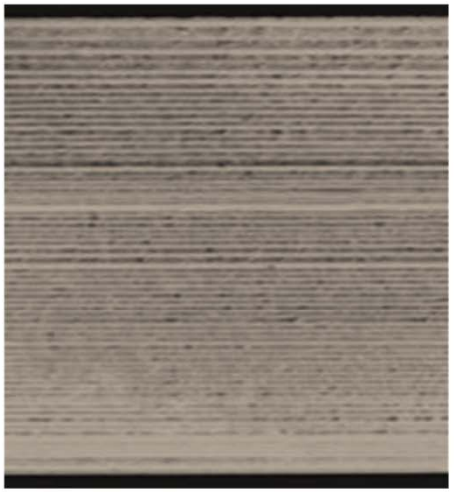
From a few layers to 1000s of layers
From 10s of micrometer thicknesses to 10s of nanometer



8 layers
16 µm layers



32 layers
4 µm layers



128 layers
1 µm layers

4096 layers
30 nm layers

Advantages of Nanolayer Structures

- Increased **surface area** and many **interfaces**
- Unique **Interfacial Interaction** and i**nterphase** properties
- Advanced **energy absorption** and **dissipation** pathways
- **Confined** and/or oriented crystal structures
- Reduced material usage

Property Improvements Demonstrated

up to
10X
mechanically stronger

up to
100X
barrier improvement

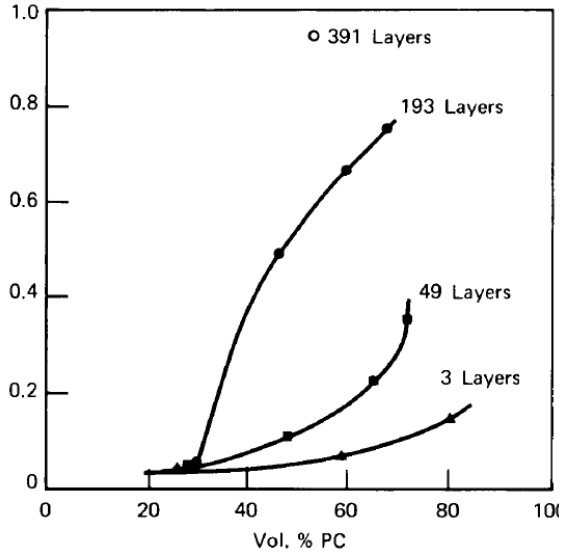
more than
75%
recycle content

up to
80%
Lighter Optics

up to
50%
Smaller capacitors

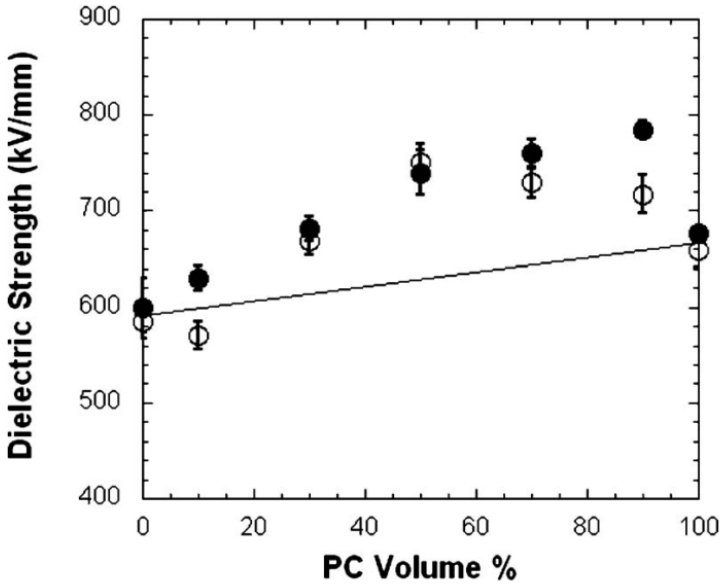
Performance Enhancement Examples

Mechanical



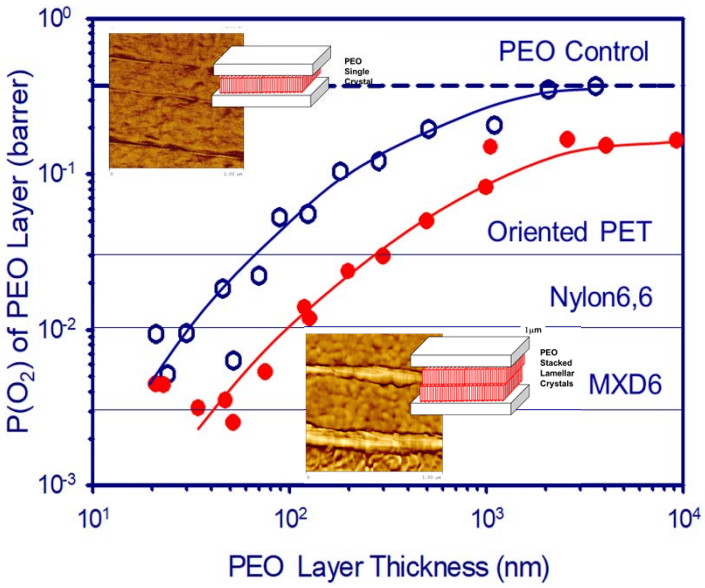
PC/SAN system with comparable impact strength at 391 Layers (55/45, PC/SAN)

Dielectric



3X improvement in energy density (32 layered films)

Barrier

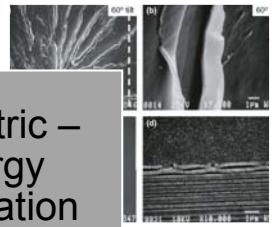


100X improvement in oxygen barrier

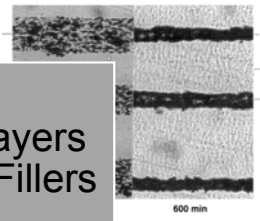
Advanced Nanolayer Structures

Combination of polymers, fillers and additives can create advanced composite structures

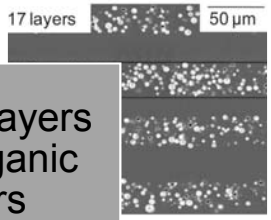
Dielectric – Energy Dissipation



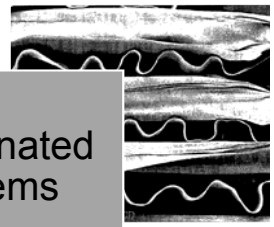
Filled Layers – Metal Fillers



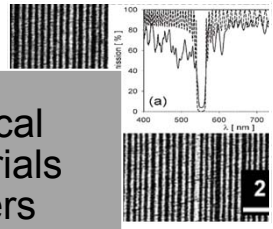
Filled Layers – Inorganic fillers



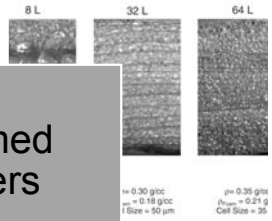
Delaminated Systems



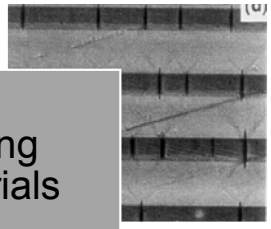
Optical Materials Filters



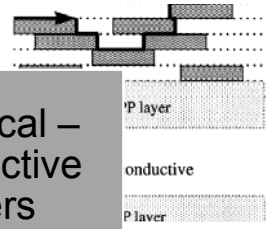
Foamed Layers



Strong Materials

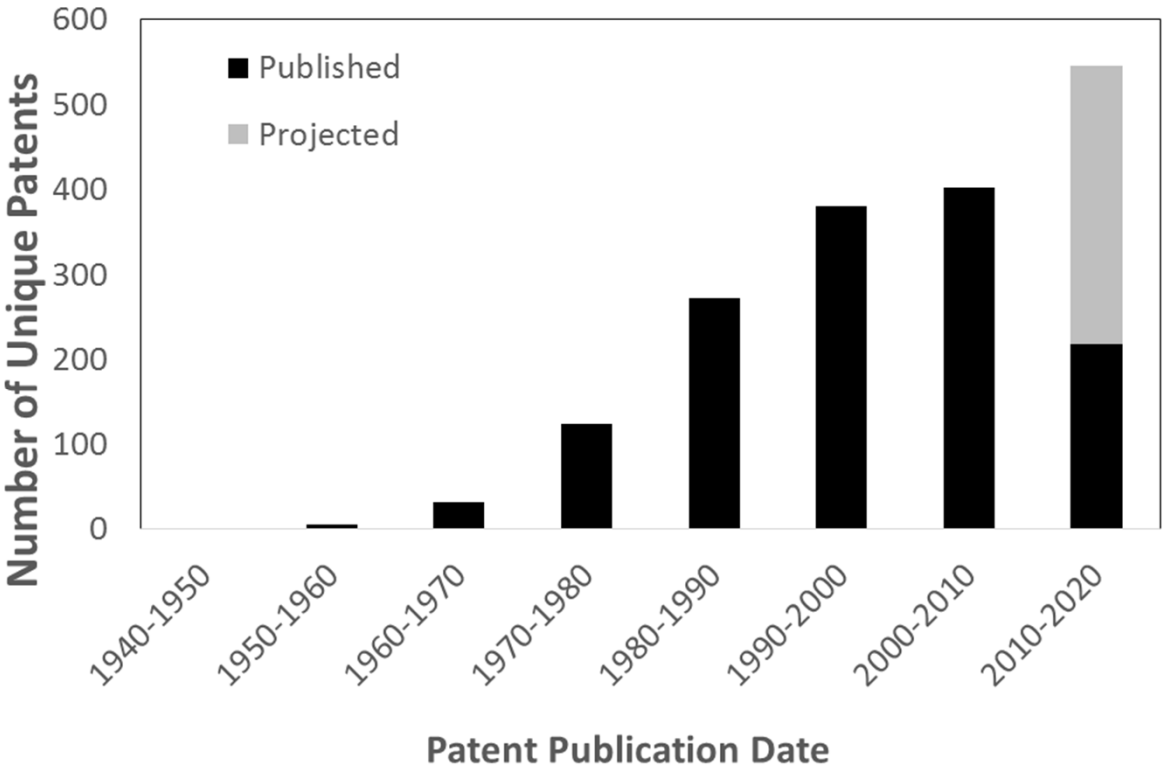


Electrical – Conductive layers

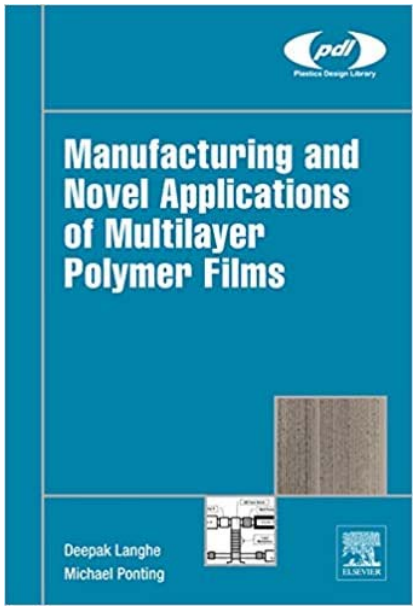


Micro- and Nano- layer technology Growth

Micro- and nanolayered tech patents



Technology Applications
Published book



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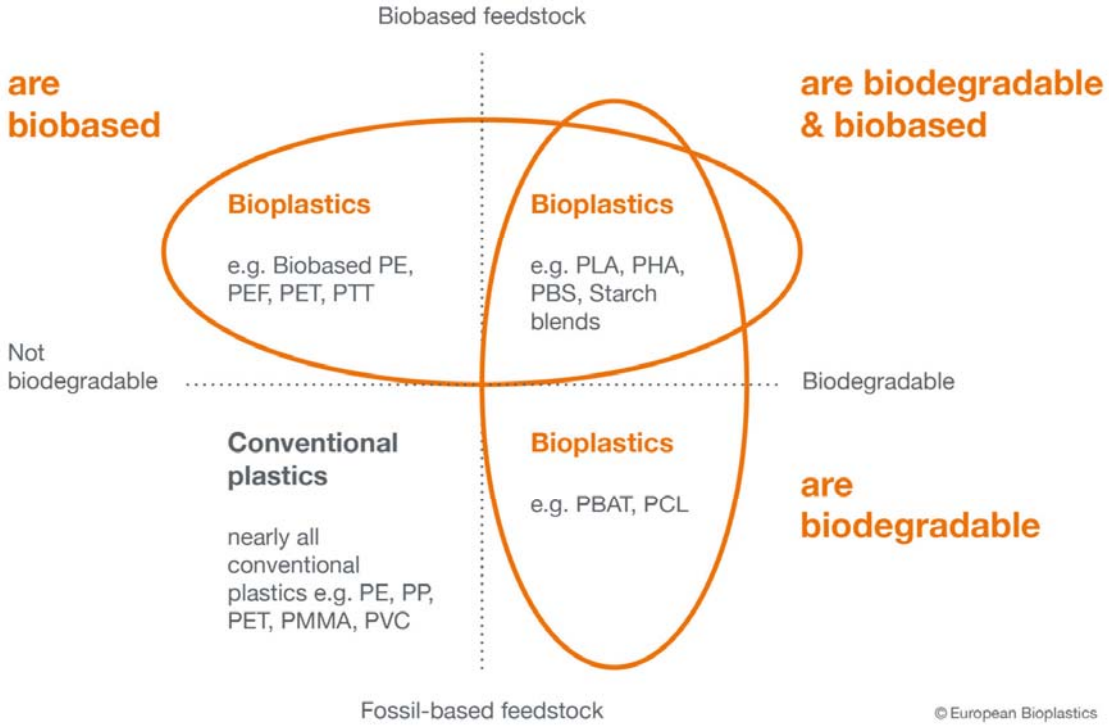
Bioplastics Materials:
Layered Materials for Sustainable Packaging

Bioplastics Materials

Material coordinate system for bioplastics

Bioplastics are biobased, biodegradable, or both.



Source: Institute for Bioplastics and Biocomposites (ifBB) and European Bioplastics (EUBP)

Typical Sources for Bioplastics Production: Sugarcane, Corn, Soyabean, Canola Oil, Wood, Algae, Mushrooms, Castor beans

Potential for Bioplastics Resins

Global plastics production

860 Billion lbs.
($600 billion)

Potential for bioplastics

10-100s of Billion lbs.

Current Bioplastics Market Share

1%

Bioplastics are great,
but not good enough, yet!

Process Innovations are critical in expanding bioplastics use.

Current Limitations of Biodegradable Bioplastics

Poor Mechanical Performance

Biodegradation in 5 to 300 days

Plastic	Tensile Strength	Elongation at Break	Modulus	Chemical Resistance	Maximum Biodegradation
PBAT	☐	✗	☐	✗	120 days
PLA	☐	✗	☐	✗	180 days*
PHB	☐	✗	☐	✗	280 days
PHA	☐	✗	☐	✗	260 days
PBS	☐	☐	✗	✗	160 days

- This limits use in long-use consumer goods applications
- Both, mechanical and degradation properties, are desired for long term use

Our Approach

Multilayer Bioplastics

- **Tunable performance** – Mechanical, surface properties, barrier properties
- **Maximum biodegradation** and bio-content feasible
- Mix and match resins feasibility

Coextrusion of Bioplastics

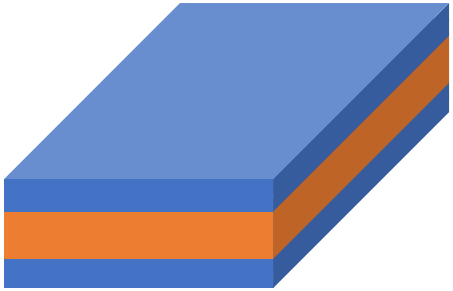
Examples of three types of biobased material systems are discussed

100% Bioplastics

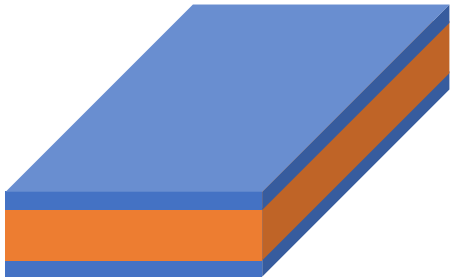
20-80% Bioplastics

Biobased Fillers

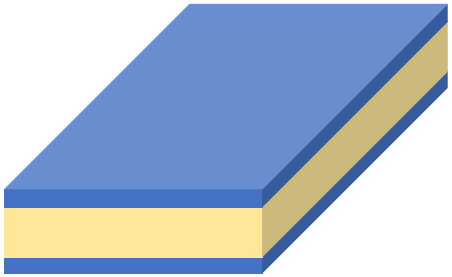
Coextruded Structures: PHA/PLA System



PLA/PHA/PLA
15/70/15



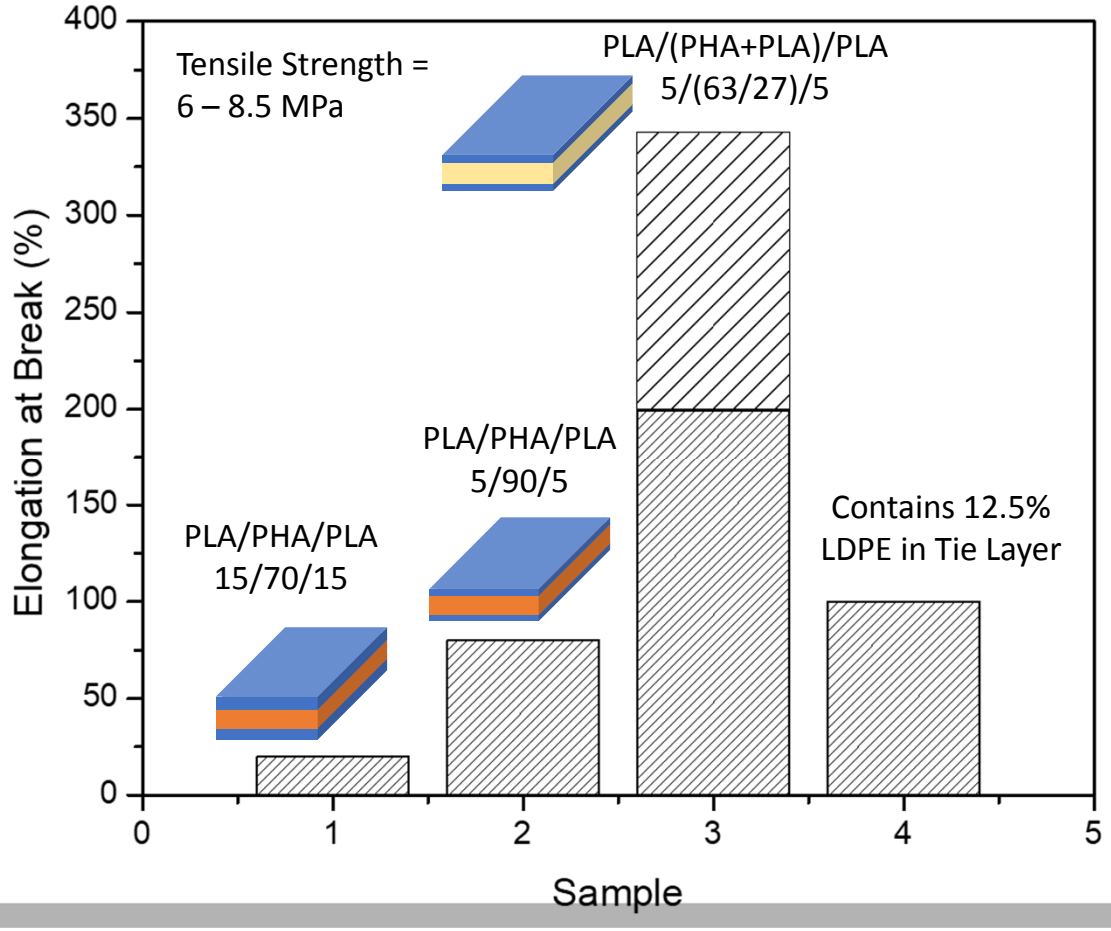
PLA/PHA/PLA
5/90/5



PLA/(PHA+PLA)/PLA
5/(63/27)/5

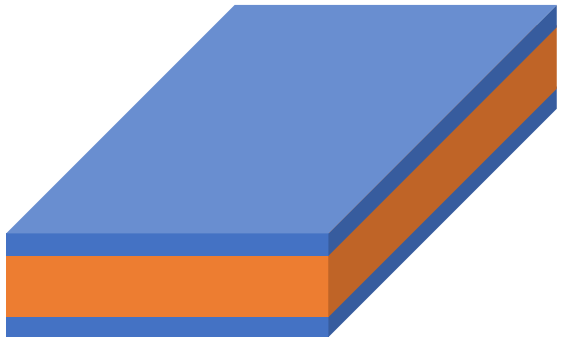
PLA PHA PHA/PLA Blend (50/50)

Elongation properties of PHA/PLA Systems



Coextruded Structures with LDPE

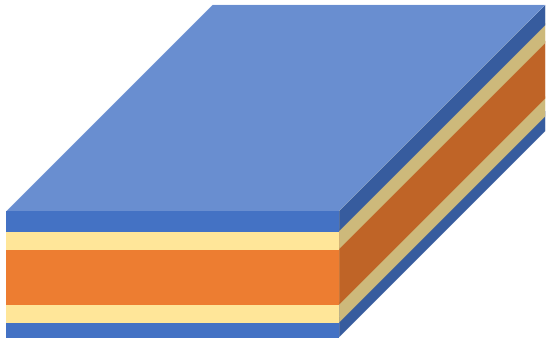
3-Layer



LDPE / Bioplastics / LDPE

22-25 MPa

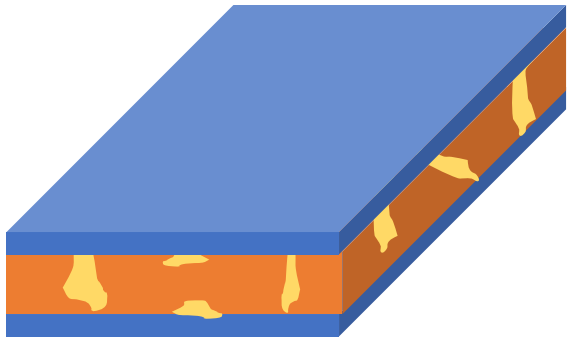
3-Layer with Tie Layers



LDPE / Blend / Bioplastics / Blend / LDPE

12-25 MPa

3-Layer with Blend Core Layer



LDPE / Blend / LDPE

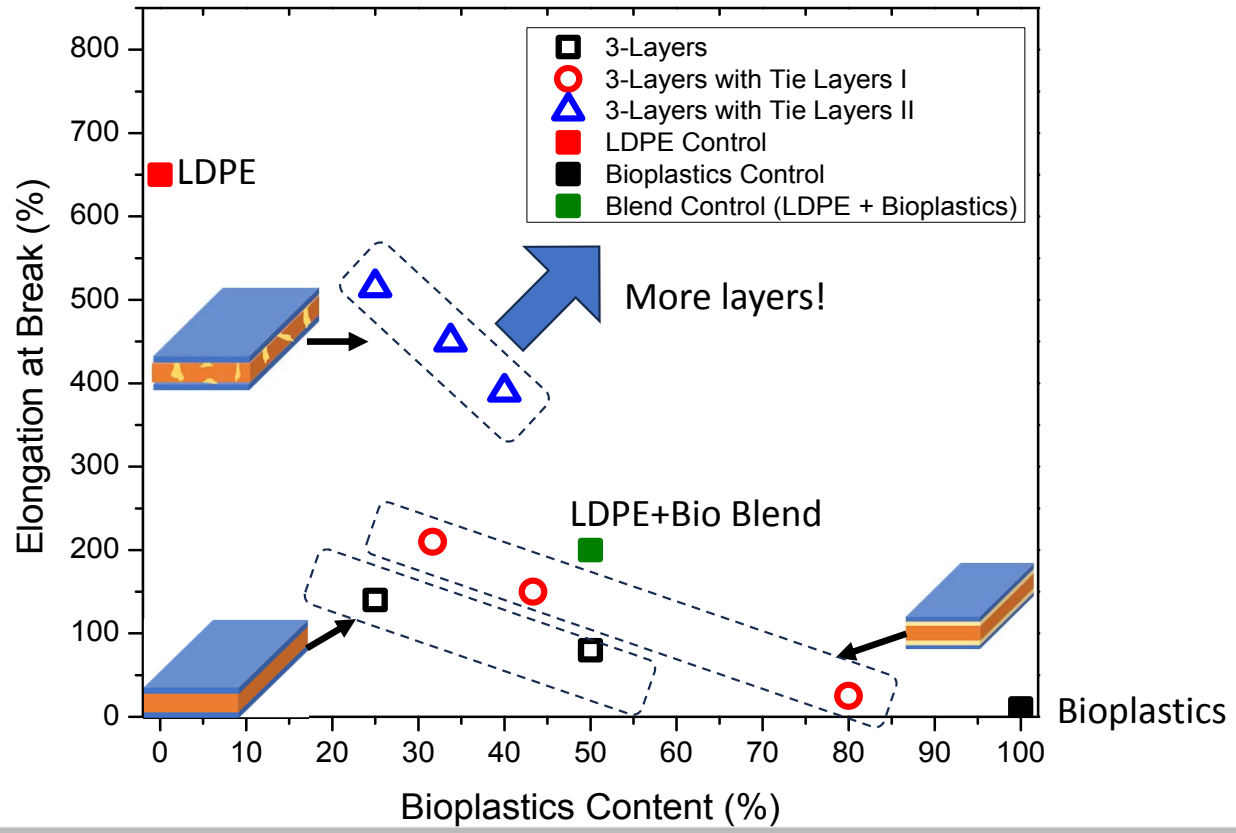
18-25 MPa

LDPE

Bioplastics Blend

LDPE/Bioplastics Blend (50/50)

Layering Effect of Mechanical Performance



Micronized Hemp filled Microlayers: 5 Layers

Base System: **LDPE** / (Hemp+LDPE) / **LDPE**/ (Hemp+LDPE) / **LDPE**

5% hemp

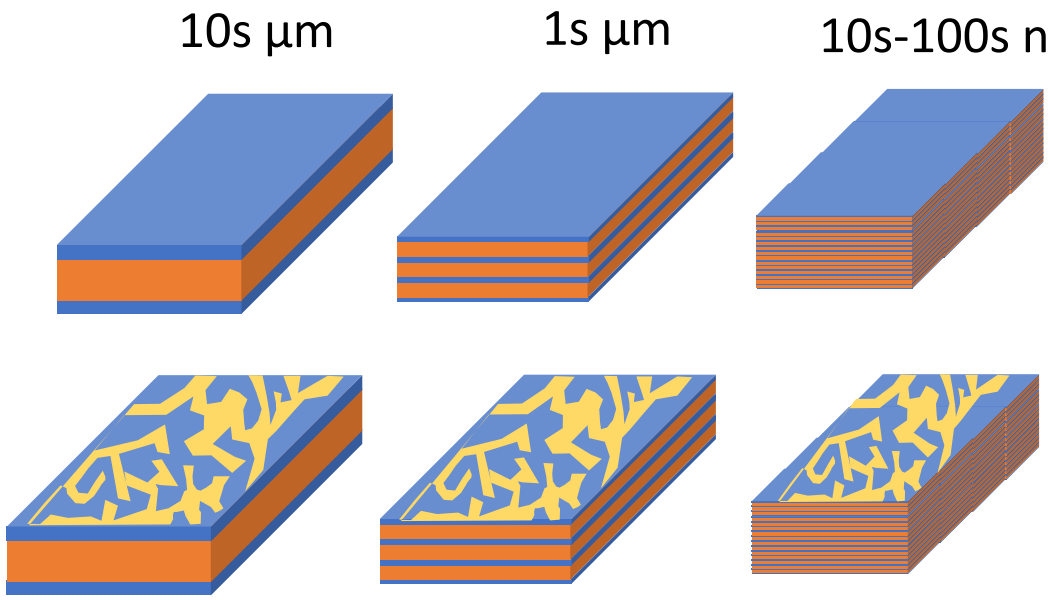
10% hemp

17% hemp

30% hemp

Process feasibility of filled materials is observed.

Next Steps
Micro- and Nano-layered Materials Investigation



Biobased, slow compostable or non-compostable polymer

100% home-compostable polymers or blends

Blend Component and/or filler

Thank you!

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Early-stage start-ups, innovation, technology development and translation