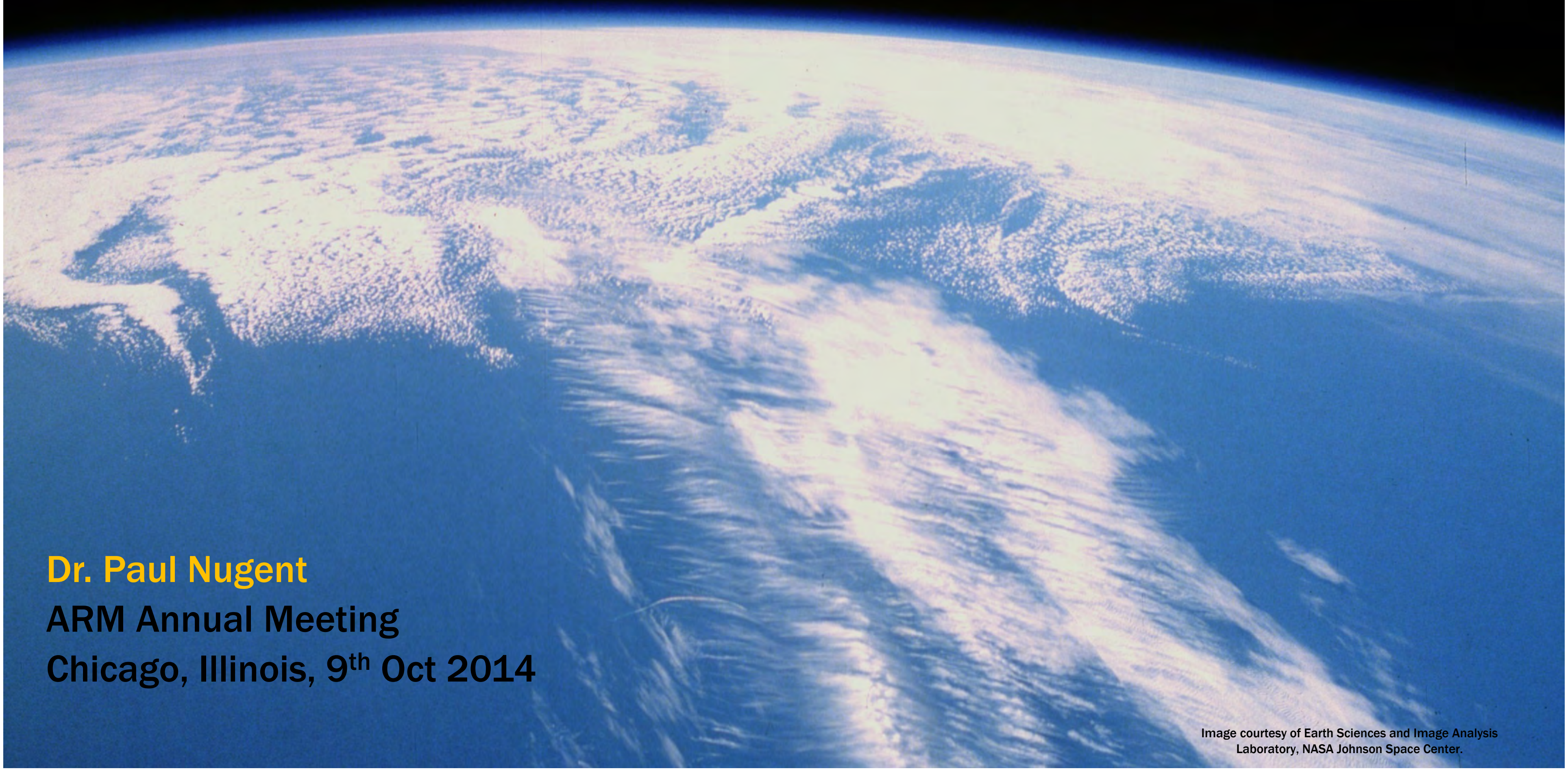
Rotomolding:

New Materials, New Horizons



Dr. Paul Nugent
ARM Annual Meeting
Chicago, Illinois, 9th Oct 2014

Image courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center.

Overview

- A Brief History of Rotomolding Materials
- Properties Affecting Moldability
- Materials – PE & Beyond
- bioPolymers – A New Generation
- Applications – New Possibilities

History

PVC Plastisols

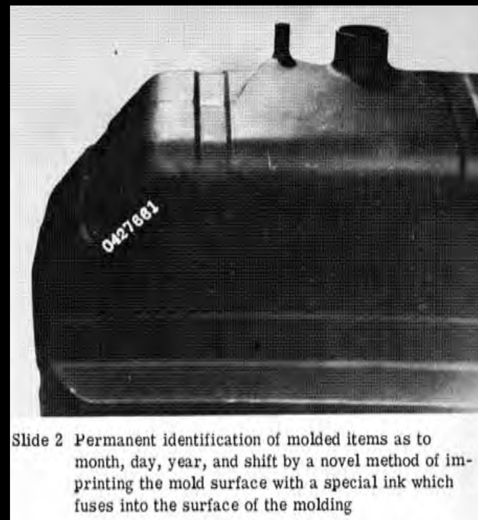
1940s

1951 HDPE
Apple
Bud Lamont

1954 Attrition
Grinding
Pallmann Gmbh

1950s

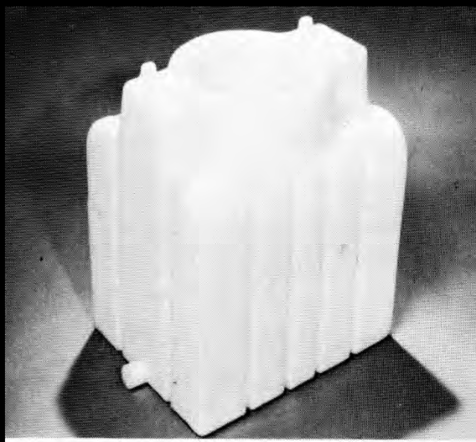
1962 ‘Continuous’
Rotomolding Machine
McNeil-Akron



1967 First In-Mold
Graphic

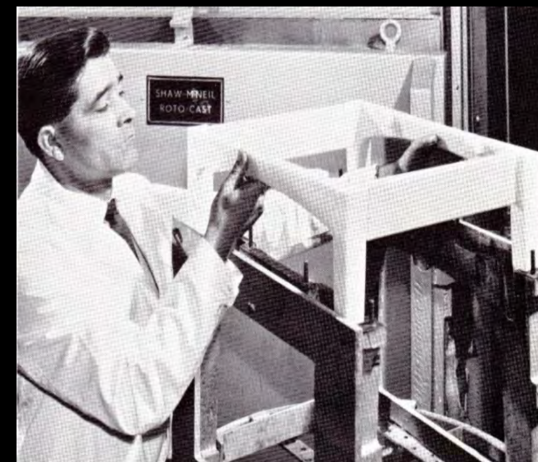
1967 High Impact
Polystyrene
Cosden Oil Co.

1960s



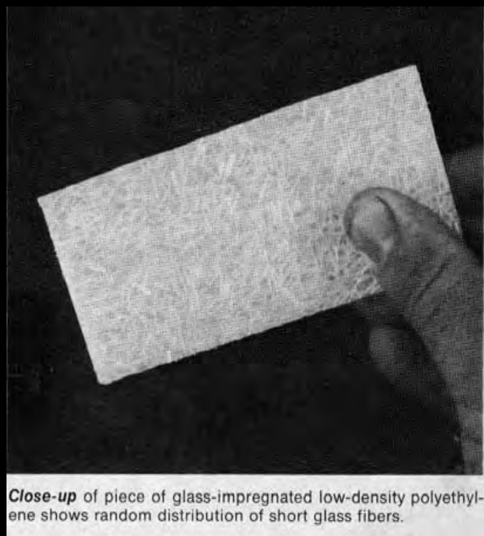
1968 Marlex XLPE
Phillips

1968 Acetal Co-Polymer
Celanese

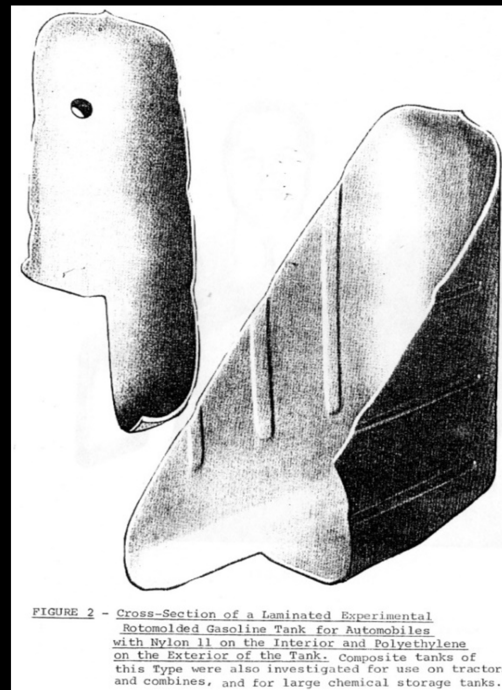


1969 PP Foam
ICI Chemicals

1960s



1970 Glass Fiber + PE
Israel

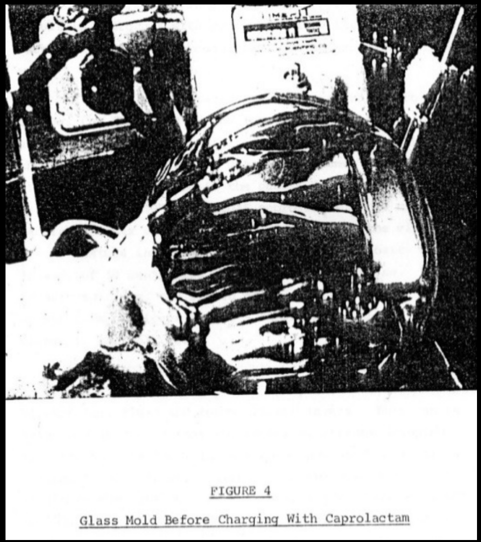


1971 Nylon 11 (Rilsan)
Aquataine Chemicals

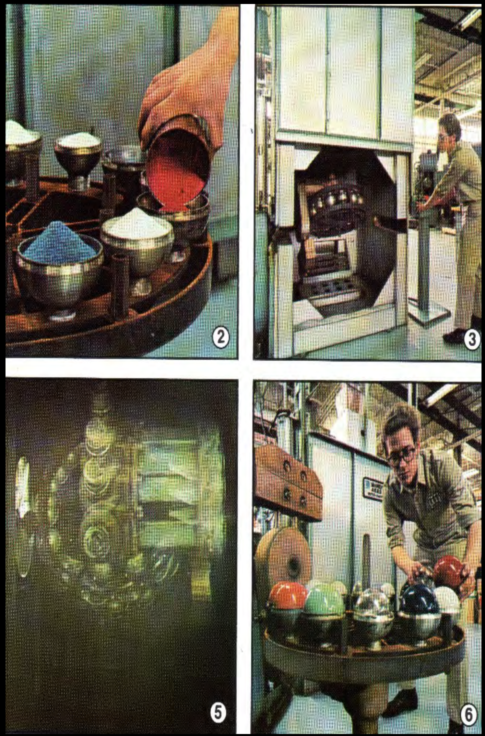
1971 Flamolin 711
Raychem Corp.

1970s

Dry Blend PVC Powder
Rapid American Corp.



Caprolactam Nylon
Allied Signal Corp.



1973 Polycarbonate
(Merlon) Mobay

1970s

ABS (Daicel – Japan)

Cellulosics (Tenite – Eastman Kodak)

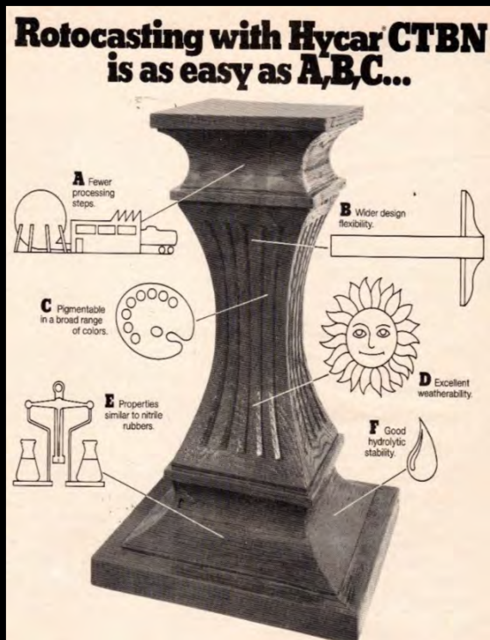
Polybutylene (Witco Chemical NJ)

Hytrel (DuPont)

ECTFE (Halar – Ausimont)

Ionomers (Surlyn - DuPont)

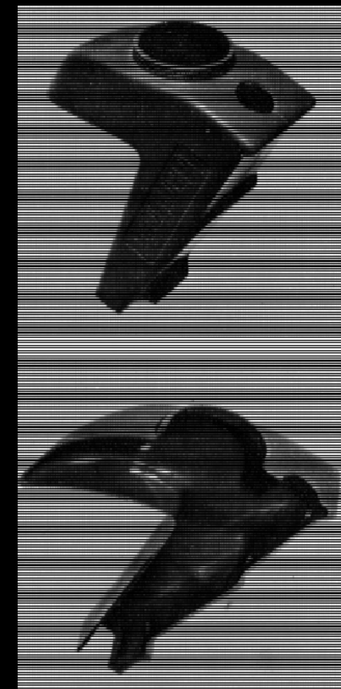
1970s



1976 – Hycar CTBN
BF Goodrich

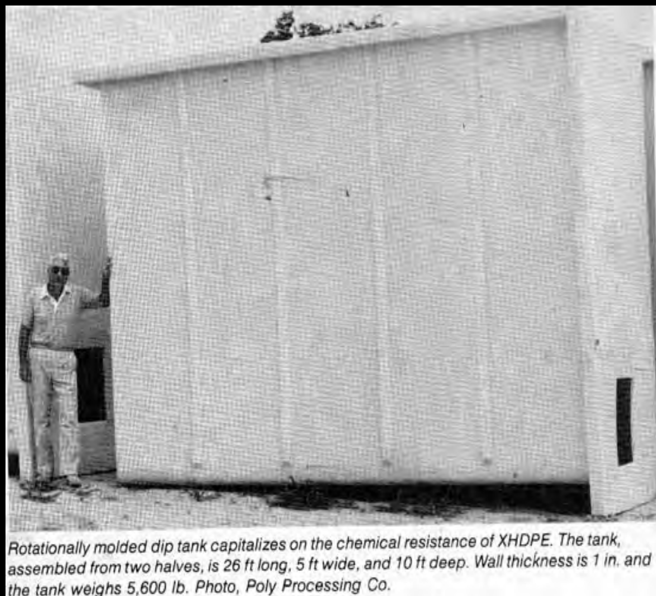
Nearly indestructible self-palletizing containers

1976 – First ARM
Impact Test!



1979 – Liquid
Polyurethane

1970s



Rotationally molded dip tank capitalizes on the chemical resistance of XHDPE. The tank, assembled from two halves, is 26 ft long, 5 ft wide, and 10 ft deep. Wall thickness is 1 in. and the tank weighs 5,600 lb. Photo, Poly Processing Co.

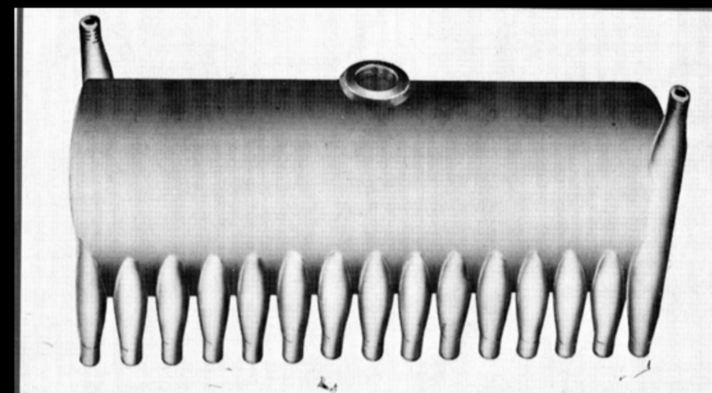
Growth of XHDPE in Large Tanks

LLDPE Supply Grows

- Soltex
- Chemplex
- Rototron
- DuPont Canada
- Phillips
- DOW
- Mobil
- Exxon

1980s

Polycarbonate for Lighting & Canoes



1983 - Solar Water Heater
HDPE & PA11

1980s

NYRIM – Nylon Reaction Injection Molding – DSM

Akron University

- ABS Study
- Regrind Study

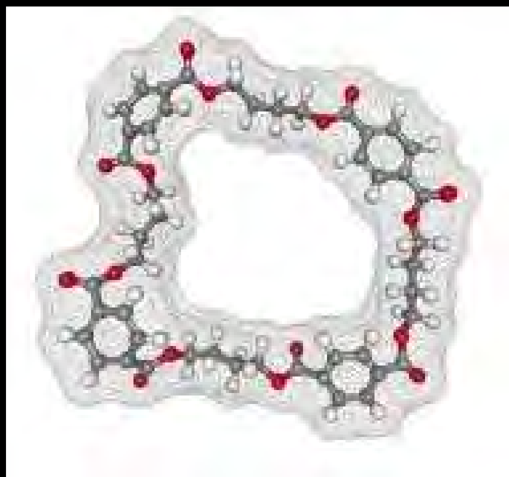
Brigham Young University

- ABS Study

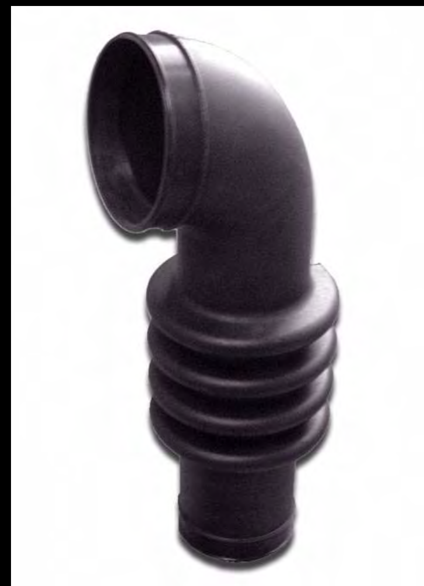
University of Lowell

- XLPE Recycling Study

1990s



Cyclic PBT
Cyclics Corp.



Pibiflex Elastomeric
CoPolyester
Resinex

Liquid Crystal
Polymers
Virginia Tech.

2000s

Properties

Q: Why do Some Materials Work for Rotomolding?

while others don't…

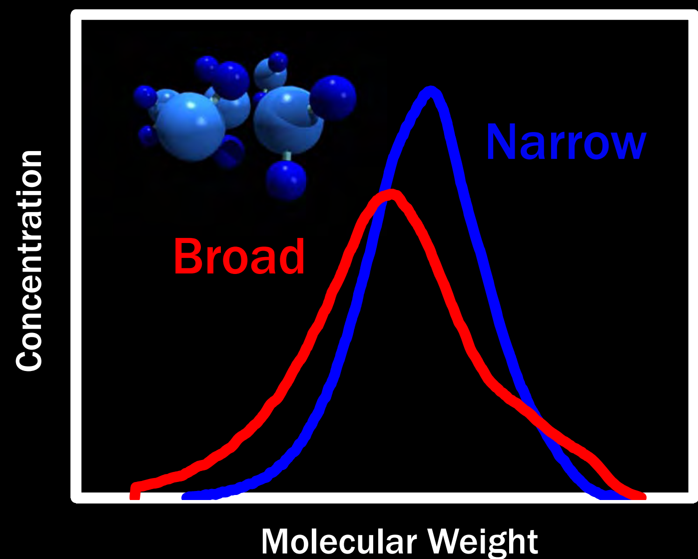
A: Rheology

Additives

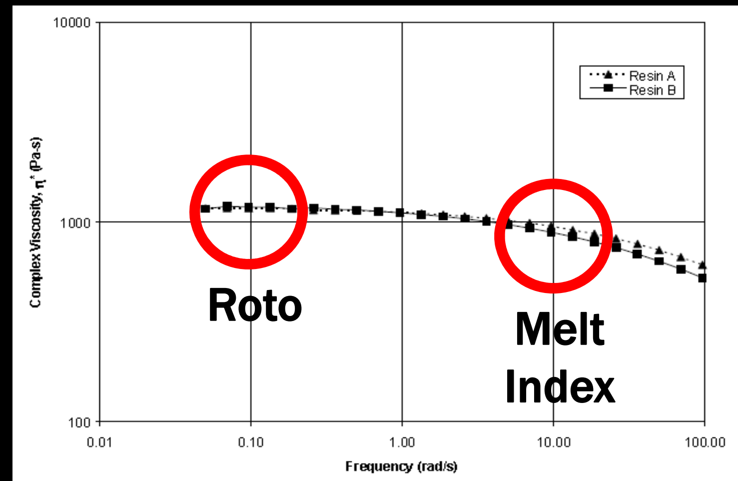
Powder Properties

Process Control

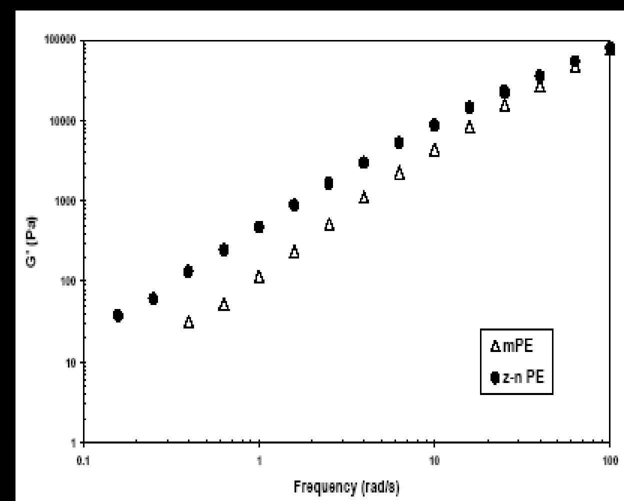
Rheology



Affects Viscosity, Melting Range, Moldability, Physical Properties



Low Shear Viscosity

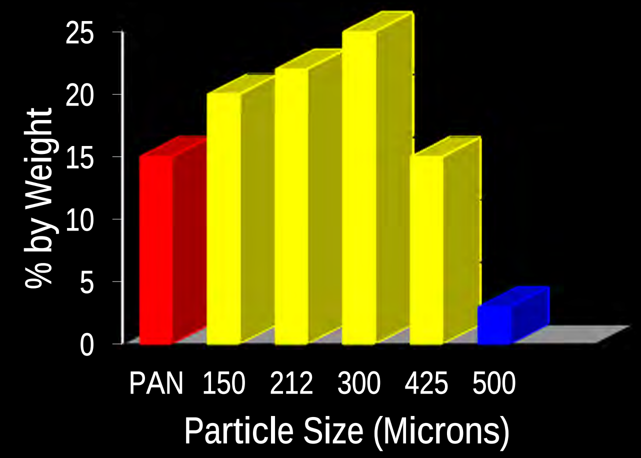


Melt Elasticity

Additives

- UV Systems
- Anti-Oxidants
- Dry-Blending or Compounding
- Pigments
    - Organic or Inorganic
- Nucleating Agents
- Slip Agents
- Anti-Stats
- Semi-Conductive Systems
- Flame Retardants
- Fluorescents
- Pearlescent & Metallic Effects
- Antimicrobial
- Repellents

Powder Properties



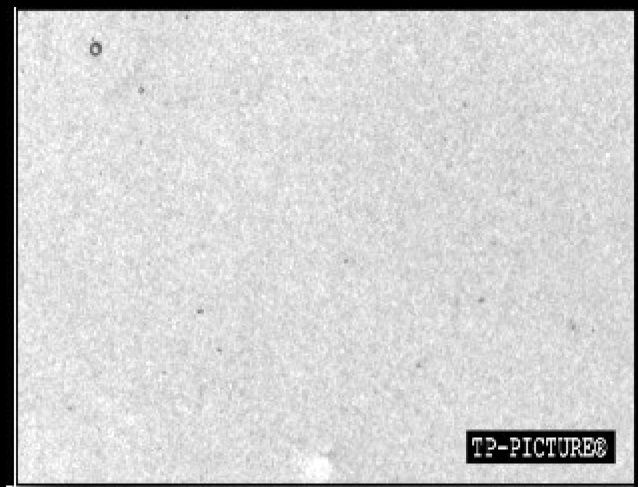
Powder Flow

Particle Shape

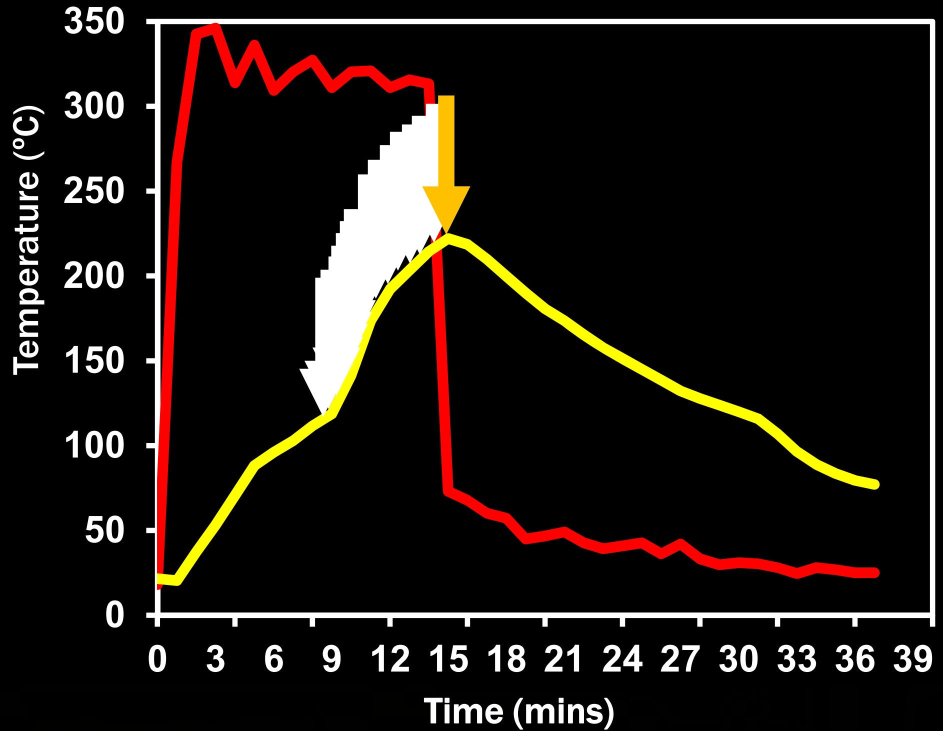
Particle Size Distribution

Process Control

Properties vs. Bubble Dissolution vs. Process Conditions

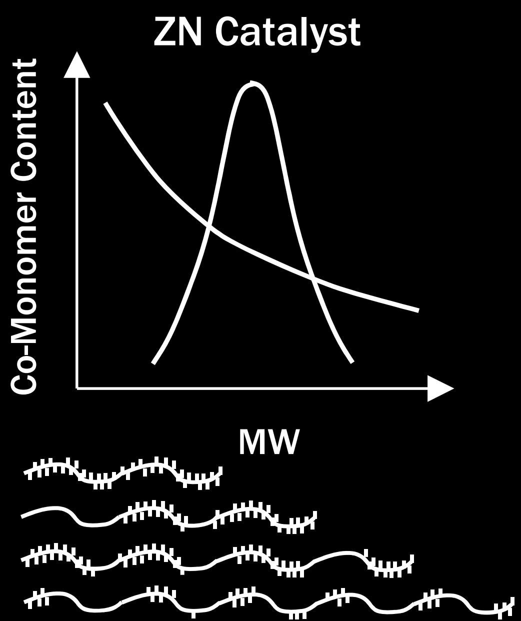


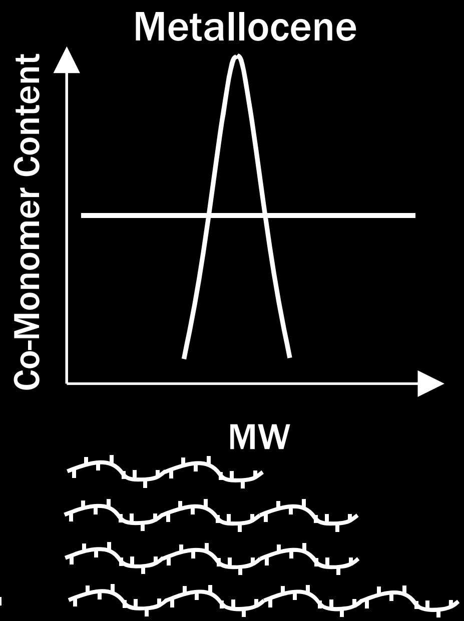
TP Picture®

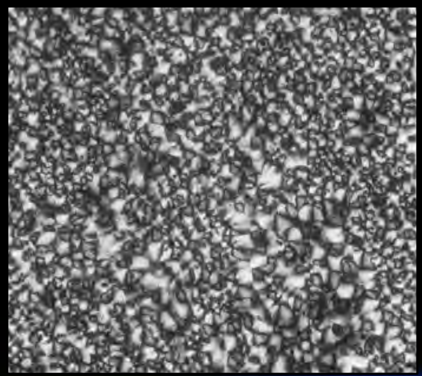


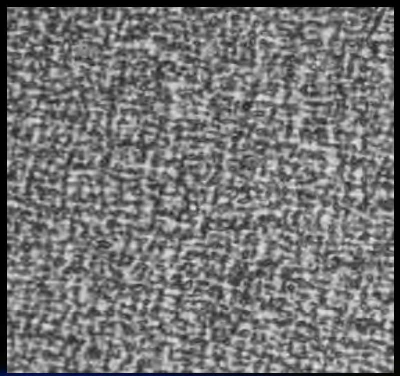

PE & Beyond

Polyethylene – Now & Future





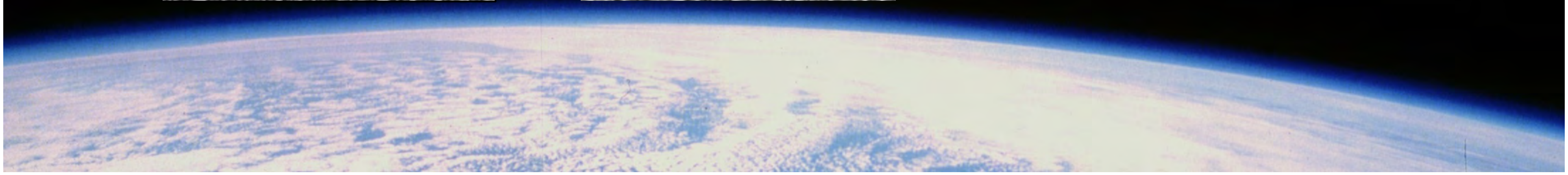




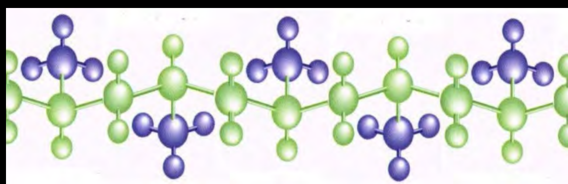
Total Metallocene Catalysis Leads to a Self-Nucleating Process that Results in Much Smaller Spherulites

A Positive Effect On:

- ✓ Creep
- ✓ Impact
- ✓ Fatigue
- ✓ Permeation
- ✓ Adhesion Properties
- ✓ Dimensional Properties

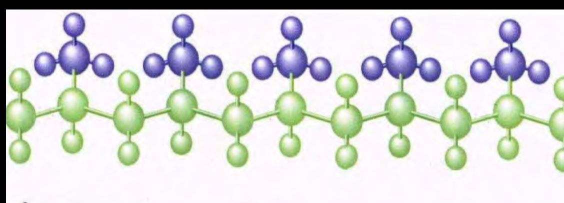


Polypropylene



Syndiotactic PP (sPP)

Regular (Alternated) Structure
Semi-Crystalline
Soft, Transparent



Isotactic PP (iPP)

Regular Structure
Semi-Crystalline
Rigid, Transparent
Most Common Industrial Plastic

Total Petrochemicals

iPP vs. PE

+ Rigidity (Flex Mod = 1300-1700 MPa)
+ Temp. Resistance (Melt = 165°C)
+ ESCR
+ Optical Properties
+ Hardness

- Cryogenic Grinding
- Impact Strength Below Freezing
- Thermal / UV Stability
- Melt Strength

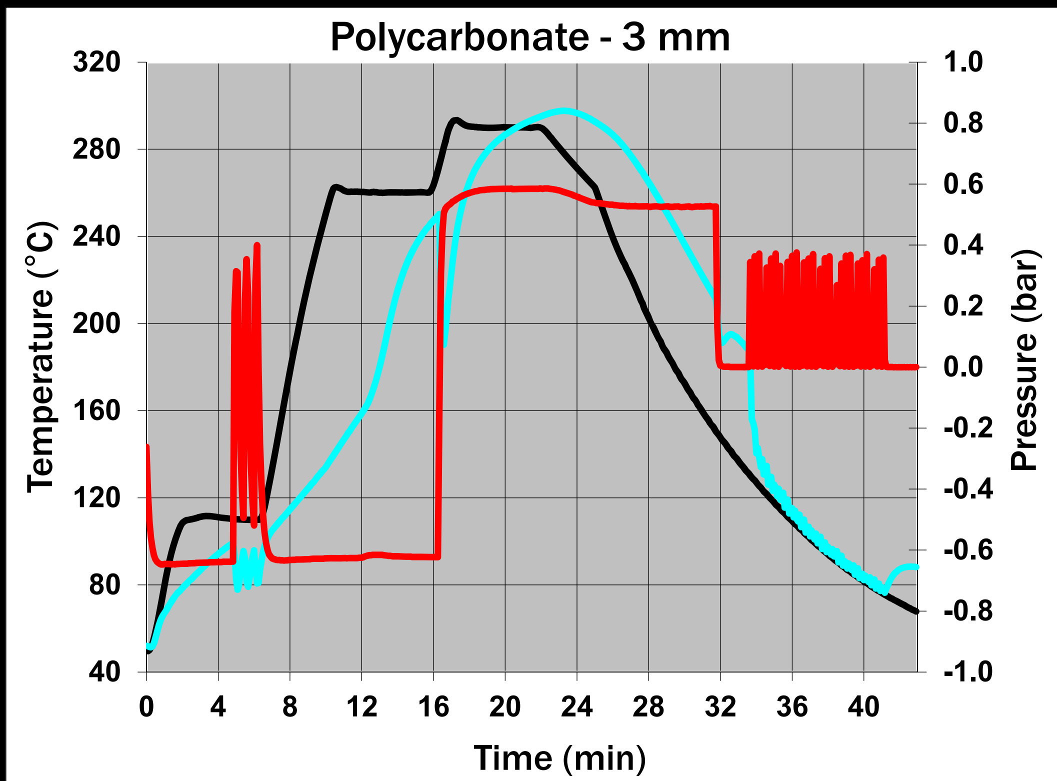
Persico smart Technology

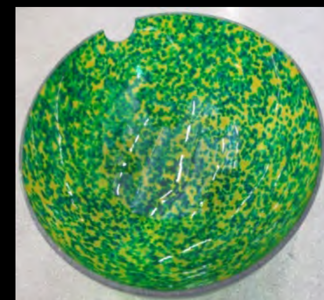
- Direct Electrical Heating of Molds
- Zoned Temperature Controls
- Vacuum & Pressure Control
- On-Board Cooling Fans
- Heated Insert Holders

Steel Molds

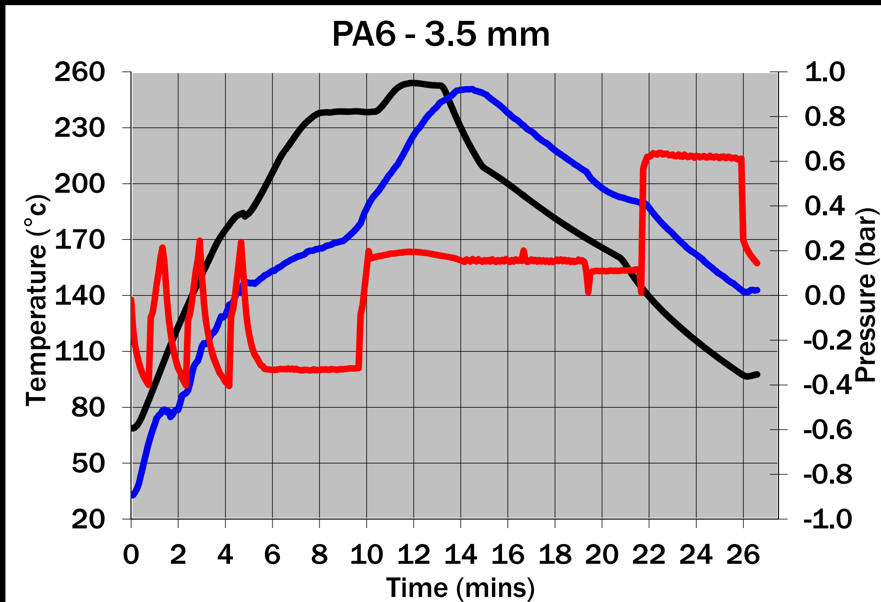
Aluminum Molds

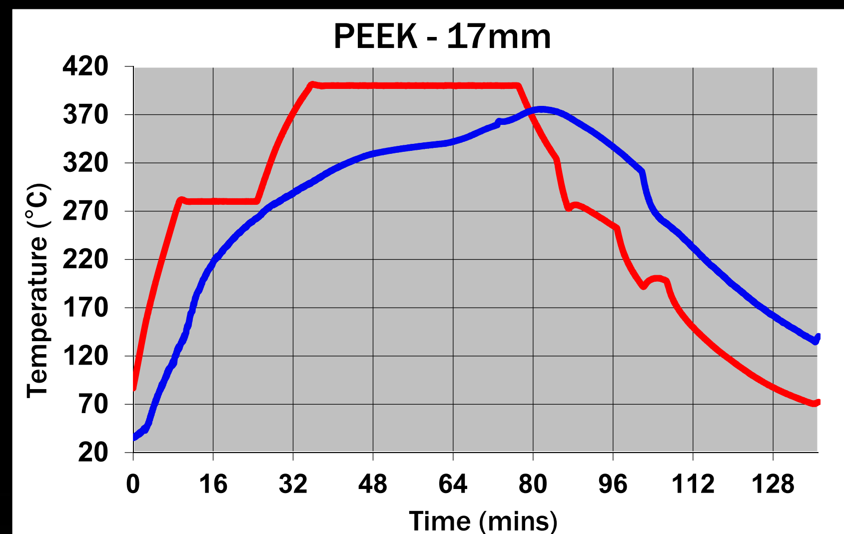
Expanding Control – PC





Expanding Control – PA6 & PEEK





More to Come…

Permeation Additives

Carbon Fiber Reinforcement

Conductivity

FLAME RETARDANCY

bioPolymers

PLA – bioSourced Polyester

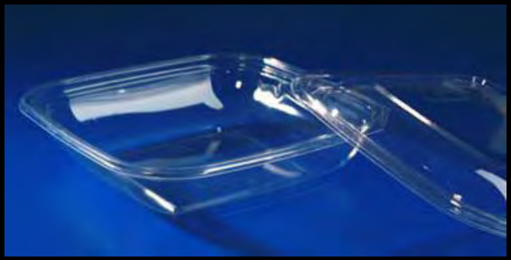
(Poly-Lactic Acid)

bioSource
Sugar Beet
Sugar Cane

Extraction

Fermentation
Lactic Acid

Lactide



Applications

Polymerization
PLA

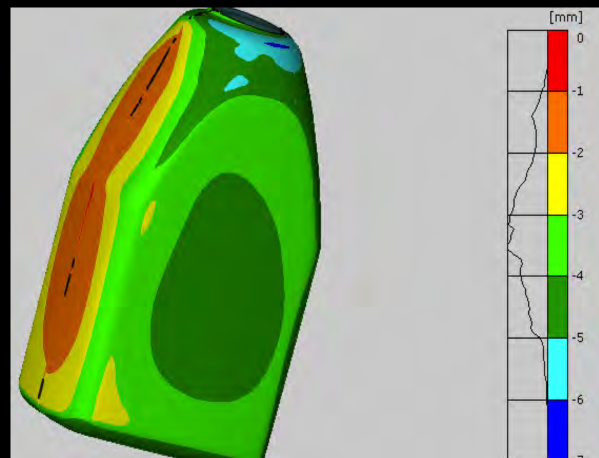
PLA – Property Differentiation

- Stiffness Improvement
  - PLA (3000 MPa) vs. PE (600-800 Mpa)
  - Alloys of PLA & PE allow for Customized Properties
- Shrinkage and Warpage Control
  - Reduced 3D Shrinkage Values for PLA/PE Alloys
- Surface Appearance and Finish
  - Improved Gloss
- Paintability
  - PLA Surface Accepts Paint Directly
- Higher Temperature Resistance

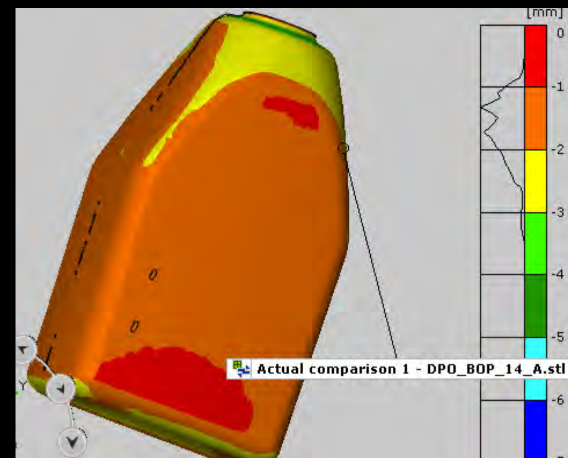
PLA – bioRotomolding

- Processing Makes a Difference
- Controlled Cooling Creates an Amorphous or Crystalline Form
- Amorphous = Transparent
- Crystalline = Opaque

3D Imaging & 3D Shrinkage



M4041UV 0.940g/cc = 8.16%



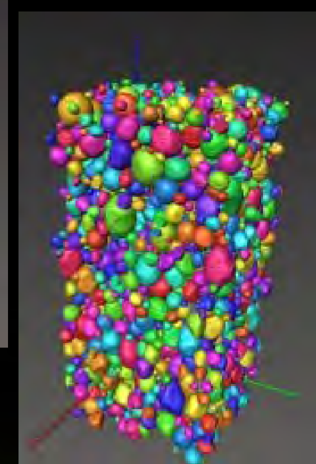
BTPS 0650_05 = 3.72%

bio-TPSeal®

Total Car Concept

Triple Layer
Foam
Cross-Section

Single Piece
Construction



Foaming Analysis

Automotive Panels (France)

- Tractor Body Panels
- Multi-Layer Solution
- PLA/bioTPSeal®
- Painted Version
  - Outer Polar Surface

bio-TPSeal®


Applications

ROTOMOLDING
Existing Apps

Toughness
Size Range
Design-Complexity
Low Cost

bioPOLYMERS
New Horizons

Stiffness
Warpage-Control
Surface Appeal
Clarity

Existing

Design Basis – Tolerance, Flatness, Stiffness

Existing

Surface Appearance & Finish

New Horizons

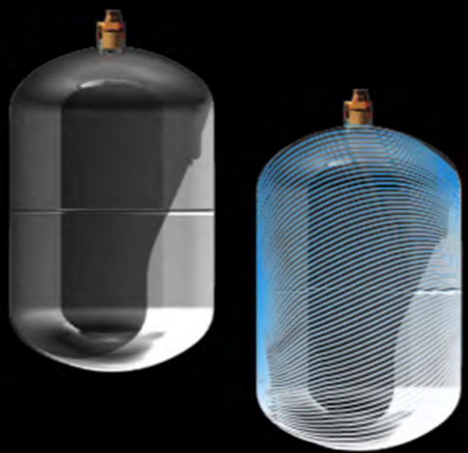
Technical Differentiation

- Multiple Layers
- Foam / Structural Integrity

iPP Outer Layer &
mPE Inner Layer

New Horizons

Technical Differentiation



New Horizons

Surface Appearance & Finish

In Closing

- Rotomolders have Tested a Lot of Materials Over the Years – Few Work Readily
- Fundamental Material Properties are Key
- Moving Beyond PE Requires Understanding of Fundamental Properties & Process Control
- New Possibilities with bioPolymers
- Revisit Old & Current Applications While Looking for New Ones

Thank You!

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