USING RHEOLOGICAL MEASUREMENT TO PREDICT THE PHYSICAL FOAMING WINDOWS FOR POLYOLEFIN COPOLYMERS

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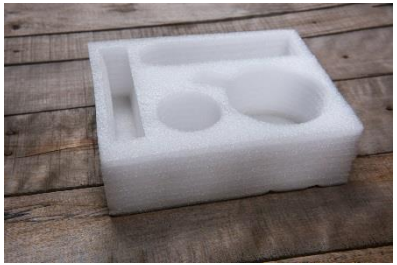
Polyolefins Foam Applications

Protective Packaging



Recreational

Insulation

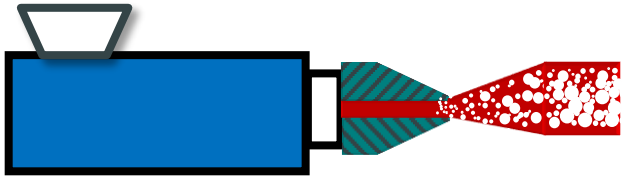
Cushioning

Broad end-use applications for Polyolefin foams

Foaming Methods

Chemical Foaming

polymer
+ chemical blowing agent (ex, azodicarbonamide, sodium bicarbonate)
+ nucleating agent



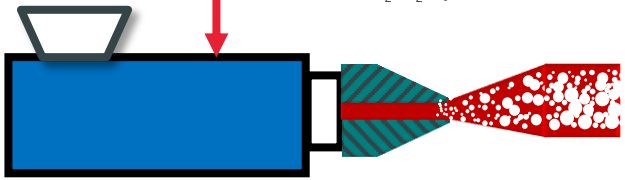
- Easy to transport and store
- No need for extruder modification

- Processing window governed by CBA
- Residues after foaming

Physical Foaming

polymer +
nucleating agent

physical blowing agent
ex, CO_2, N_2, hydrocarbons



- Precise control of foaming conditions
- Environmentally friendly

- Equipment to pressurize, inject PBA
- Extruder/screw modification

Ethylene Copolymers with Different Molecular Architectures

Ethylene Vinyl Acetate Copolymers (EVA)

Elvax™
ethylene vinyl acetate copolymers

Polyolefin Elastomers (POE)

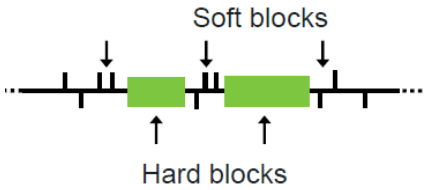
Engage™
polyolefin elastomers by DOW

Low comonomer and High crystallinity

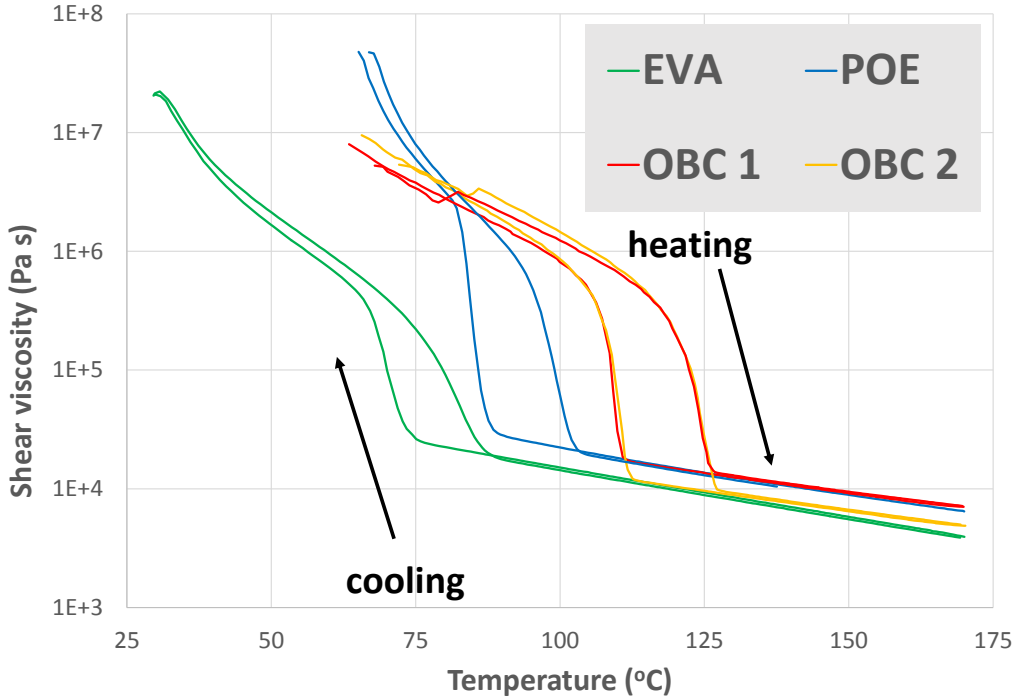
High comonomer and Low crystallinity

Olefin Block Copolymers (OBC)

Infuse™
olefin block copolymers by DOW



Viscosity – Temperature Relationship of Ethylene Copolymers



1% Strain, 3 rad/s, 3 °C/min

Physical Foaming of Ethylene Copolymers

Technical Hypotheses:

- Via physical foaming, ethylene copolymers will form a stable foam without the need for cross-linking.
- Physical foaming of ethylene copolymers has an optimal temperature window.
- The foam processing windows (material and foaming process dependent) can be predicted and linked via the material rheological properties.

Materials used in this study:

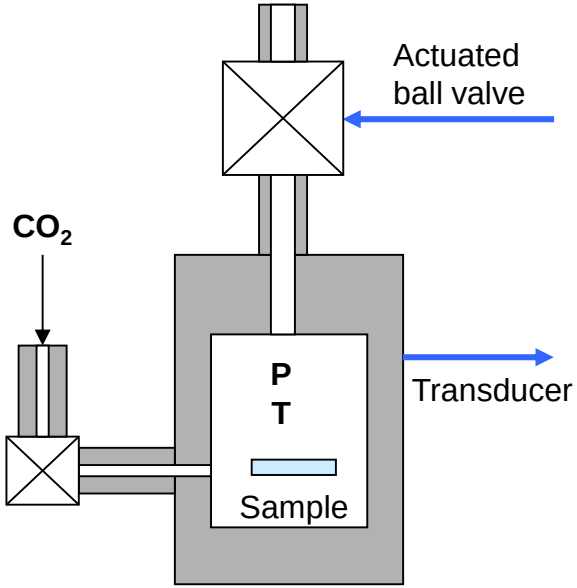
- Ethylene vinyl acetate copolymer (EVA)
- Polyolefin Elastomers (POE)
- Modified Olefin Block Copolymers (OBC)

Material	Remark
EVA	21% VA, 2.5 MI
POE	0.902 g/cc, 1 MI
OBC 1	0.885 g/cc, 1.5 MI*
OBC 2	0.885 g/cc, 5 MI*

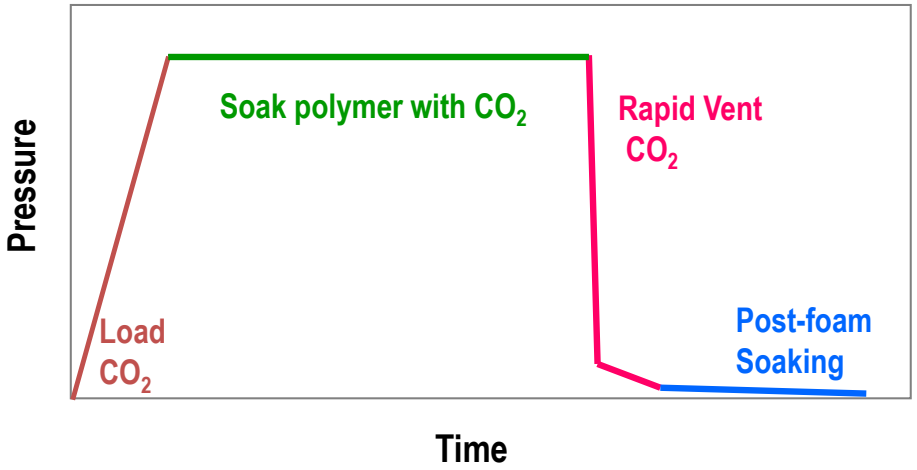
* Properties before modification

Batch Foaming

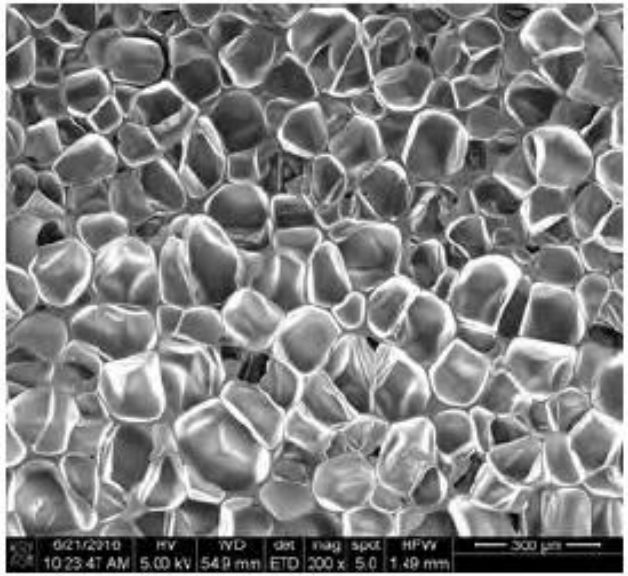
Batch foaming apparatus



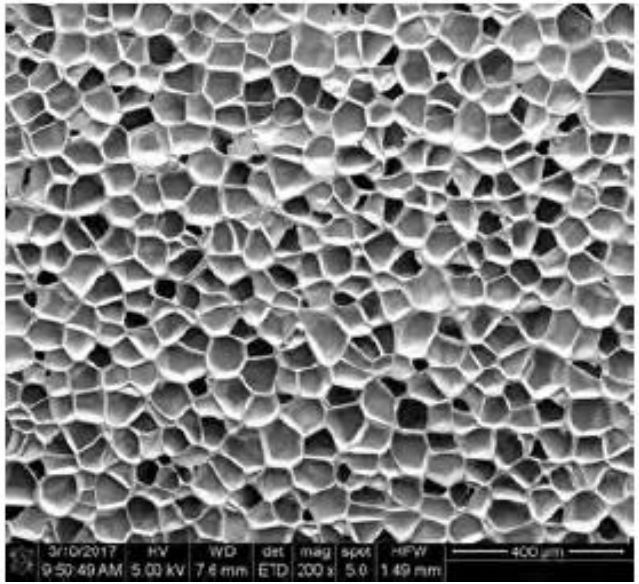
Batch foaming cycle



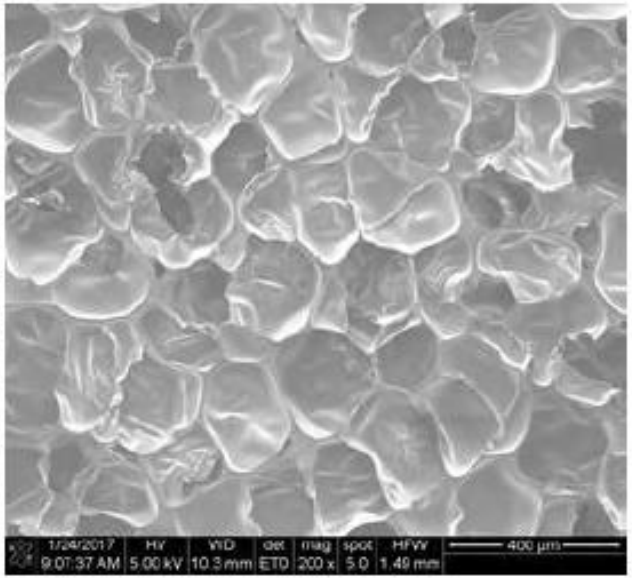
Foam Morphology: Batch Foaming



EVA, 0.11 g/cc
Foamed at 75 °C



POE, 0.08 g/cc
at 100 °C



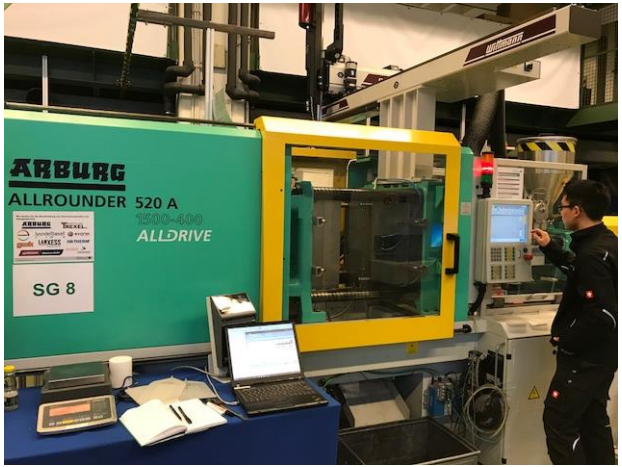
OBC*, 0.12 g/cc
at 115 °C

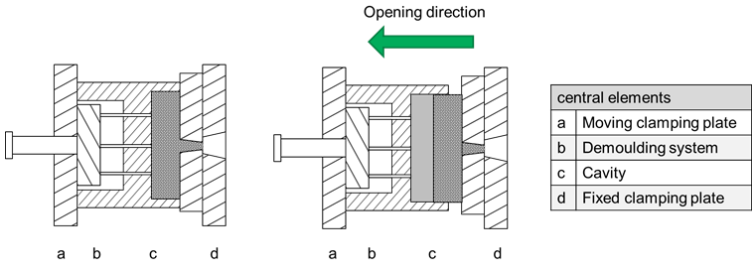
Homogeneous cell morphology, minimal cell coalescence.

* Un-modified OBC

Foam Injection Molding

- Collaboration with IKV, RWTH Aachen University
- MuCell process using CO_2
- Arburg 520 A injection molding press
- Precise control of mold temperature, opening speeds / distance

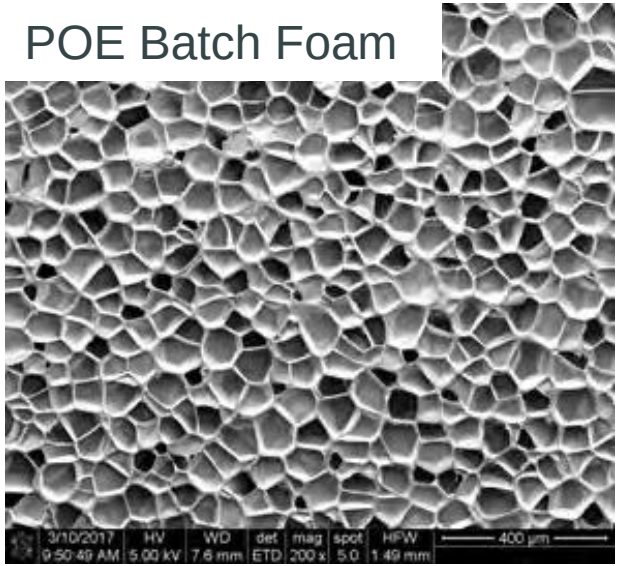




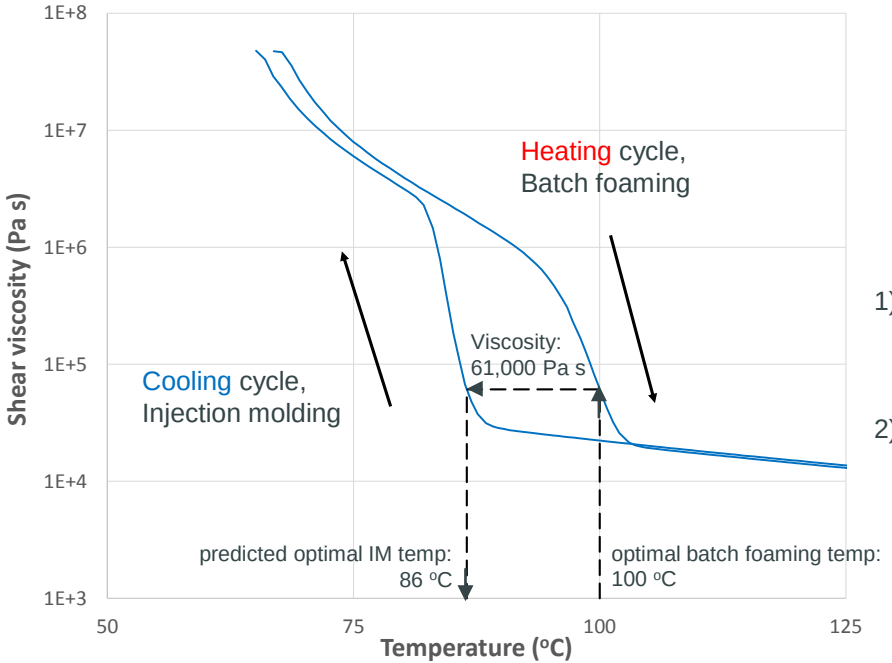
central elements	
a	Moving clamping plate
b	Demoulding system
c	Cavity
d	Fixed clamping plate

Predicting Foam IM Conditions from Batch Foaming Results

POE Batch Foam



Optimal foaming temp: 100 ºC



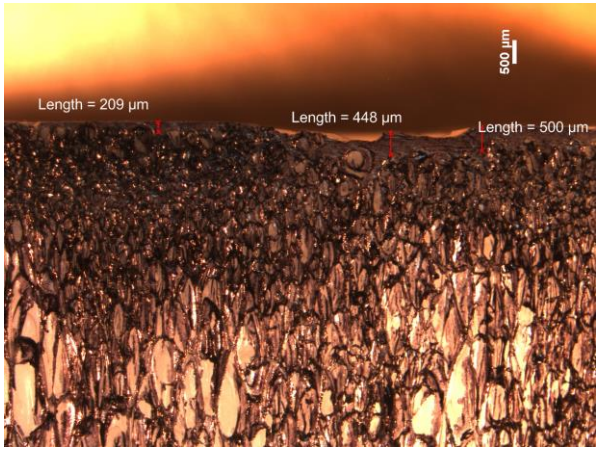
1) Read viscosity at batch foaming temp from heating cycle.

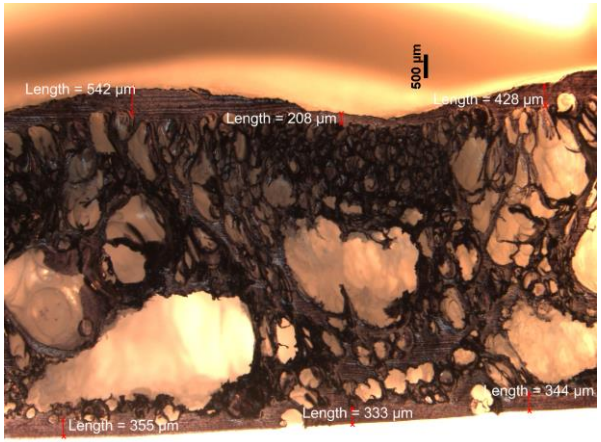
2) Find the temp from cooling cycle for the same viscosity.

Optimal IM foaming window determined from batch foaming results.

Defining Processing Window: EVA

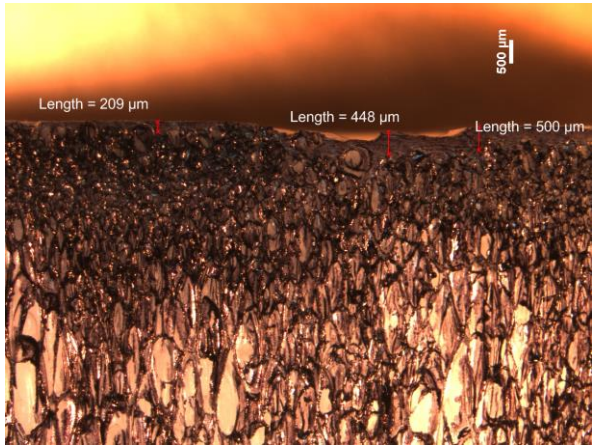
Foamed at 65 °C	at 70 °C (Optimal)	at 75 °C



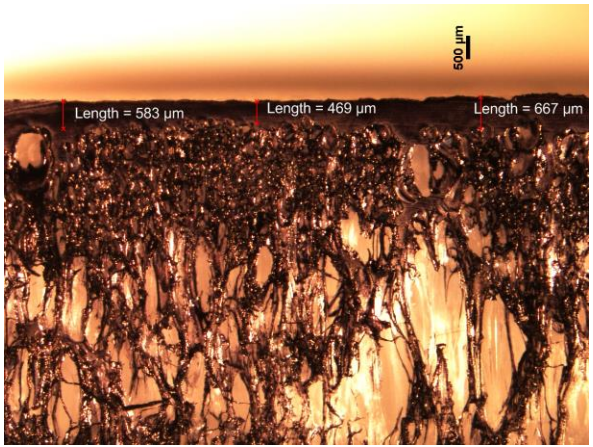


- Materials displayed a very narrow processing window in foaming temperature.
- Foam quality changed dramatically even with 5 °C deviation from the optimal temperature.

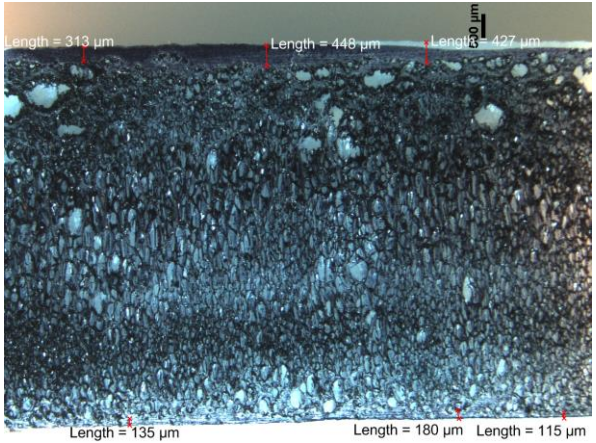
Foam Morphology: Core Back Injection Molding



EVA, 0.25 g/cc
Foamed at 70 °C



POE, 0.23 g/cc
at 85 °C



OBC 1, 0.27 g/cc
at 103 °C

Coarser but homogeneous cells for low foam density.

Foam Window Prediction / Actual Summary

Material	EVA	POE	OBC 1	OBC 2
Optimal batch foaming temp (°C)	75	100	124	124
Shear viscosity (Pa s)	220000	61000	46000	50000
Tan delta (from heating)	0.17	0.54	0.7	0.65
Optimal injection foaming temp (°C) deduced from batch foaming	**68**	**86**	**110**	**110**
Actual optimal foaming temp for injection molding	**70**	**85**	**103**	**105**
Shear viscosity (Pa s)	100000	200000	600000	460000
Tan delta (from cooling)	0.35	0.5	0.38	0.4

Good agreements in predicted and actual IM foaming window.

Summary

- Thermoplastic foams of EVA, POE and OBC resins were prepared via batch foaming and injection molding.
- Optimal foaming temperatures for these ethylene copolymers were determined based on the cell sizes and foam density: very narrow foaming temperature window.
- Optimal windows for these two foaming methods are somewhat different but can be related via the rheological properties for resins.
- Based on the batch foaming results, optimal foaming temperatures for foam injection molding were predicted. These predictions correlated well with the best foaming conditions found in injection core-back foaming.

Thank You

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