Advances in Polyolefin Foaming Technology

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Advances in Polyolefin Foaming Technology

- Influence of polymer structure on crystallinity and rheology
- Chemical foaming – polymer-property relationships
- Ionomer addition for ultra low density foams

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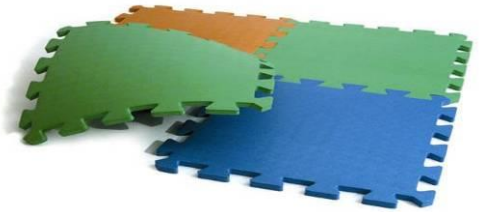
Features of Polyolefin Foams

- Light Weight
- Soft and Flexible
- Easy to Process
- Good Foamability
- Low Temperature Use
- Recyclable/Sustainable
- Safety

Performance Footwear

Comfort Shoes

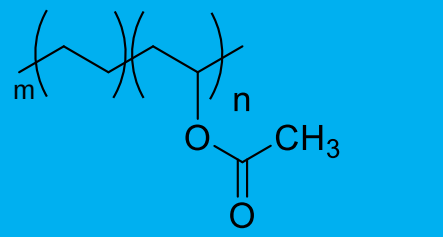


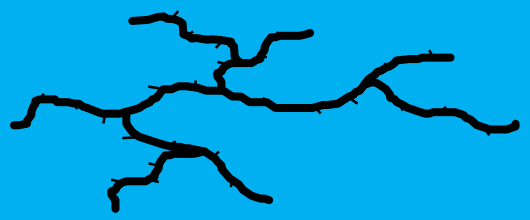
Protective Mats

Safety Equipment

EVA

Ethylene vinyl-acetate

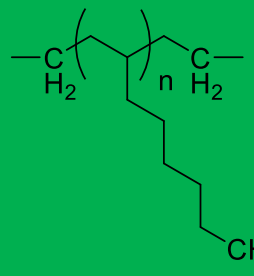


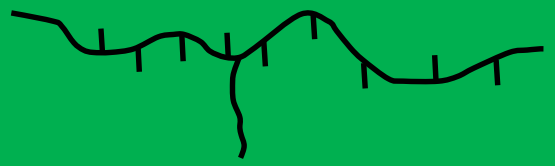


- High pressure process
- Free radical catalyst
- Polar functionality (VA)
- High melt strength
- High density

POE

Polyolefin Elastomer

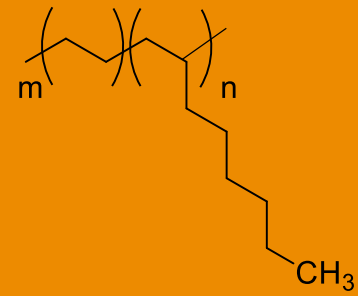


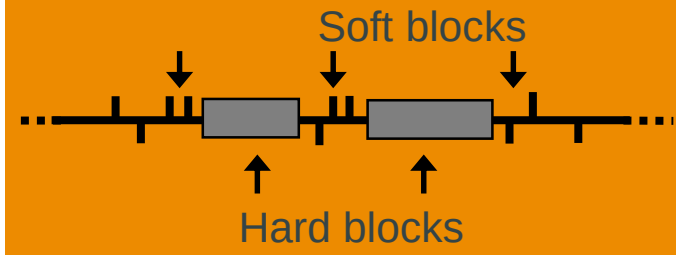


- Solution process
- Molecular catalyst
- Non-polar functionality
- Linear, high strength
- Low density

OBC

Olefin Block Copolymer





- Solution process, chain shuttling catalysts
- Non-polar functionality
- Segmented blocks
- Low density, high Tm

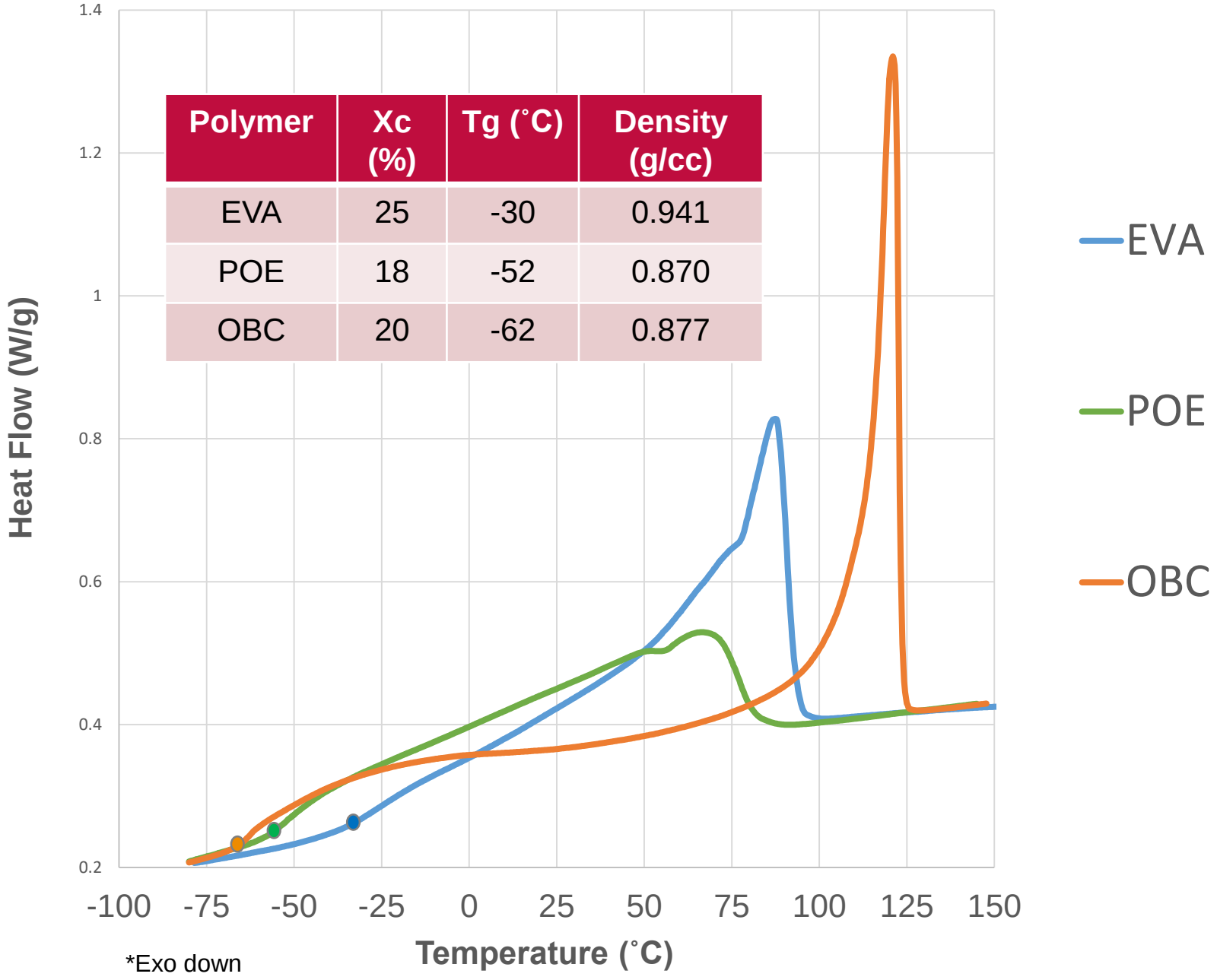
DSC Crystallinity

EVA has higher crystallinity and higher density (due to VA)

POE has low crystallinity and low Tg

OBC has low crystallinity, low Tg, and a high melting point

Polymer	Xc (%)	Tg (˚C)	Density (g/cc)
EVA	25	-30	0.941
POE	18	-52	0.870
OBC	20	-62	0.877



*Exo down

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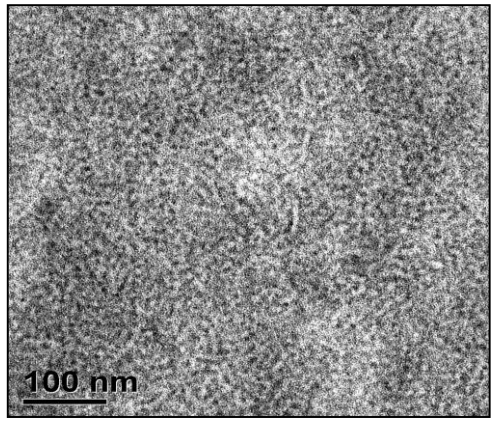
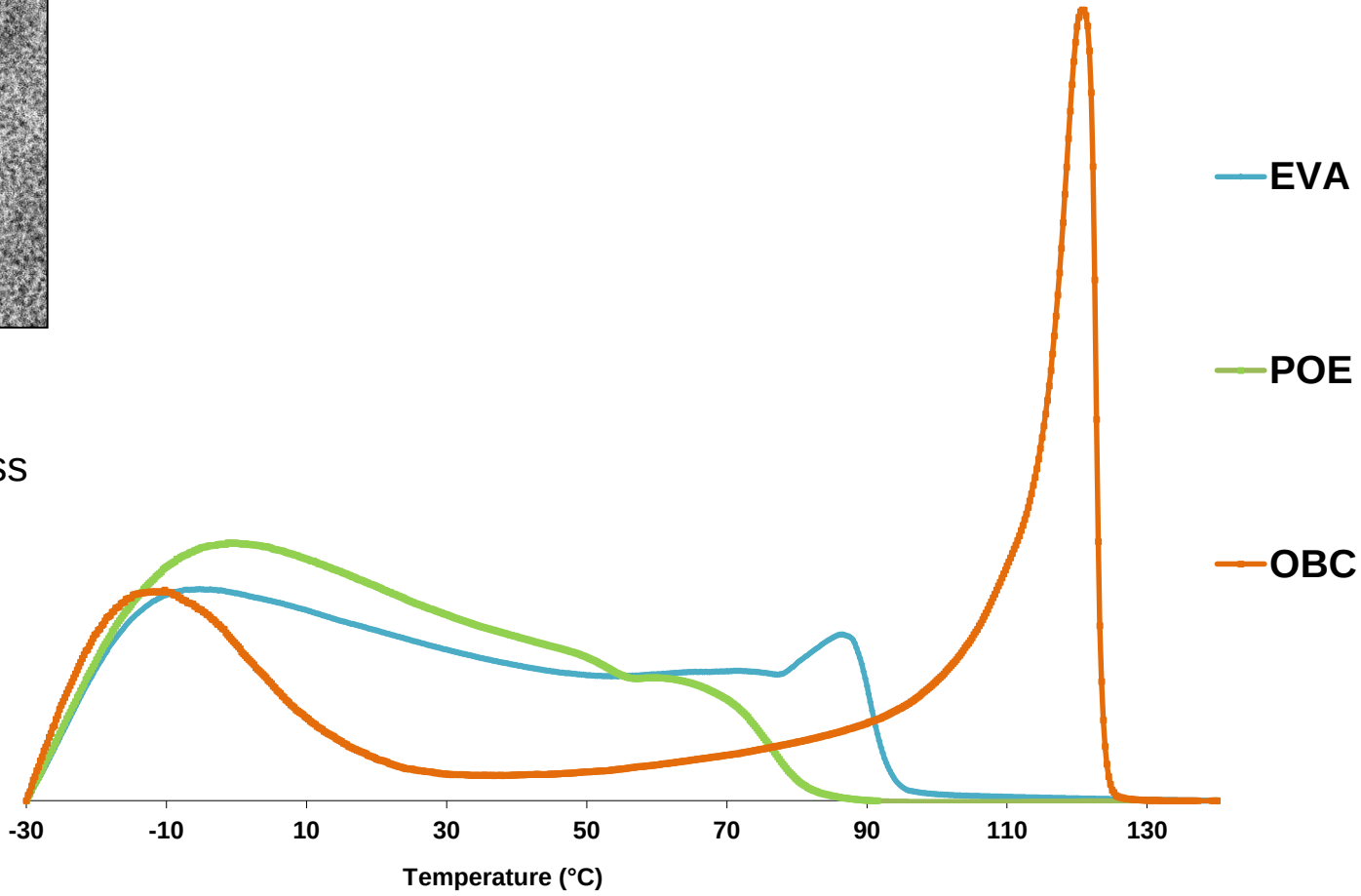
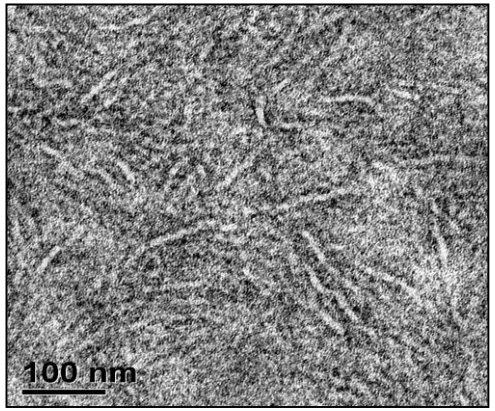
Crystallinity Distribution using Enthalpy Corrected DSC



Random Copolymer
Flexibility and Toughness





Olefin Block Copolymer
Elasticity and Heat Resistance

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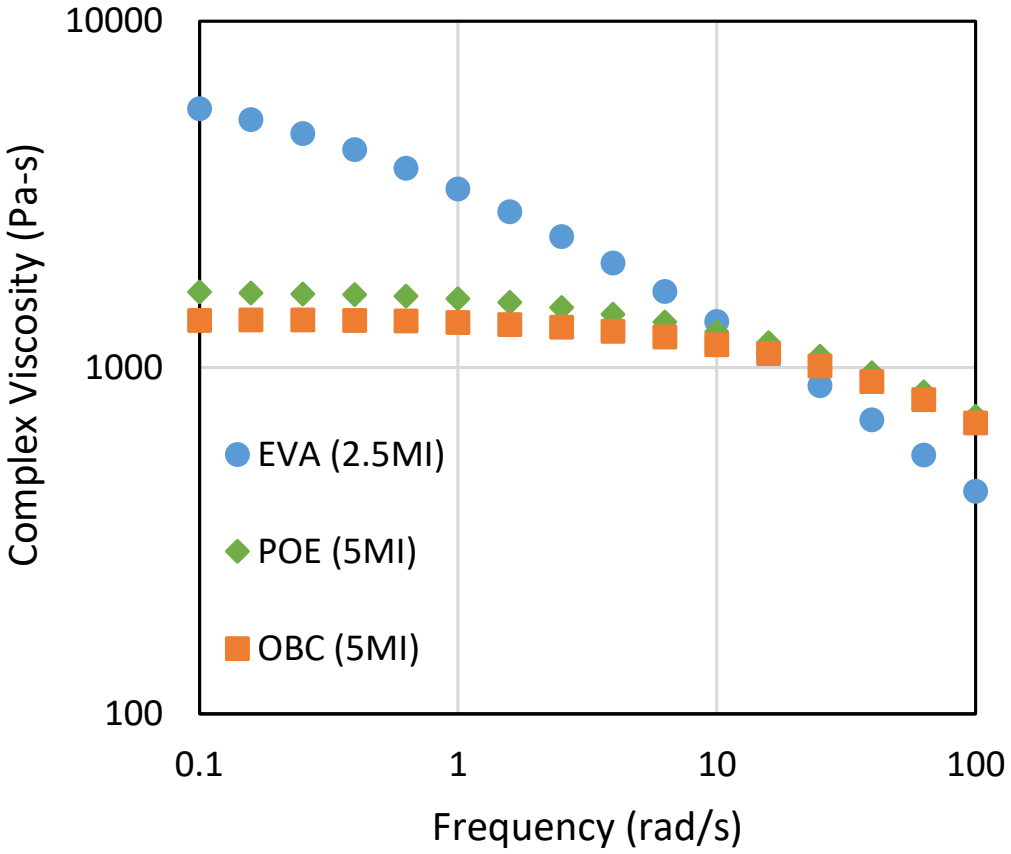
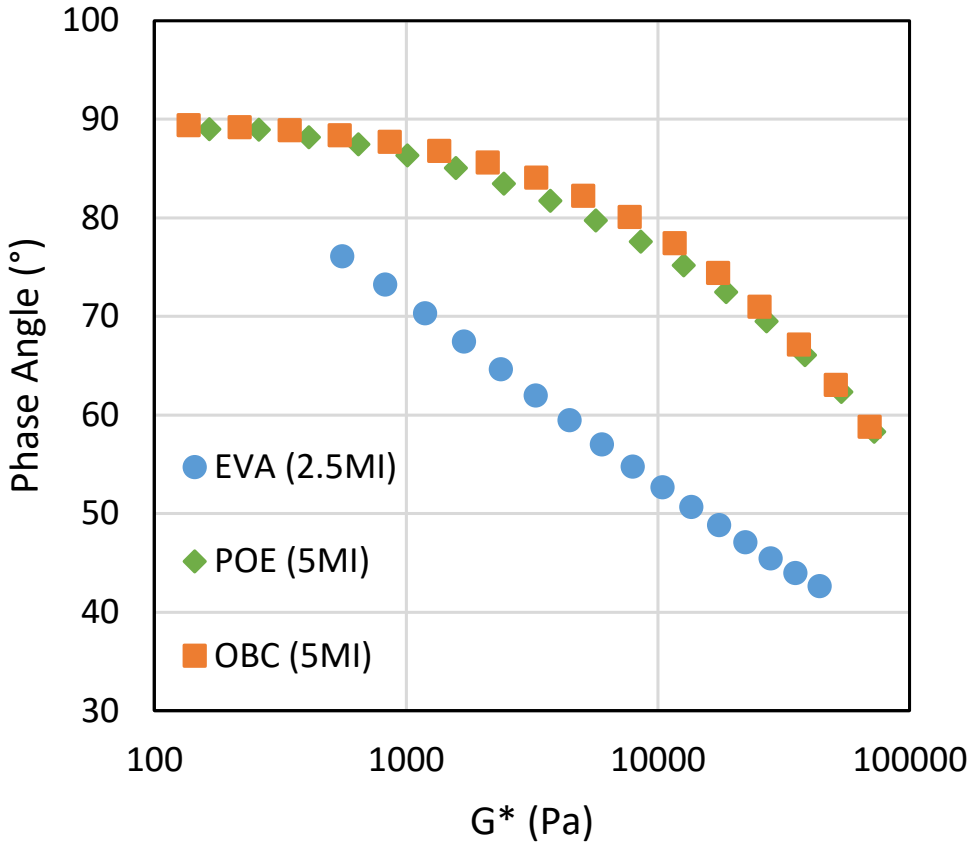
Rheology Comparison



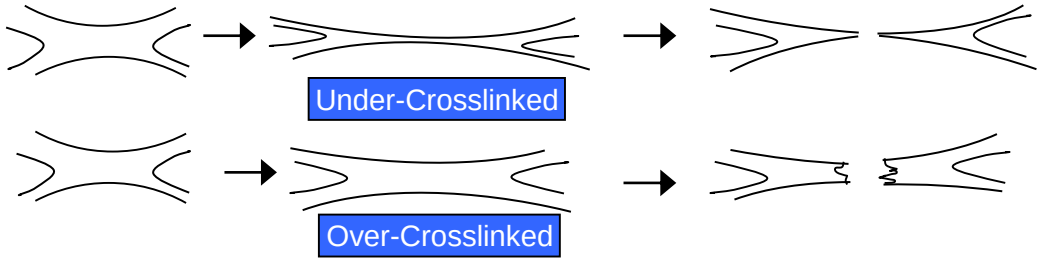


*DMS Rheology measured at 190˚C

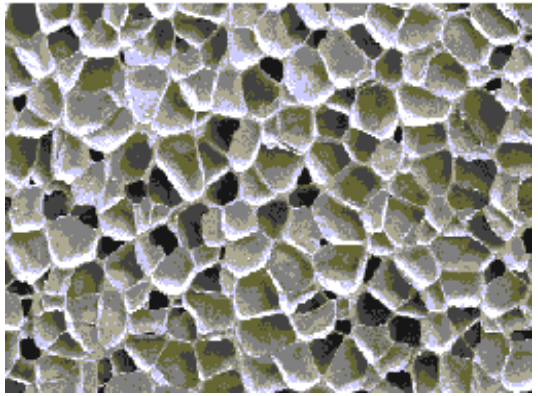
Foaming Technology

Foam Properties

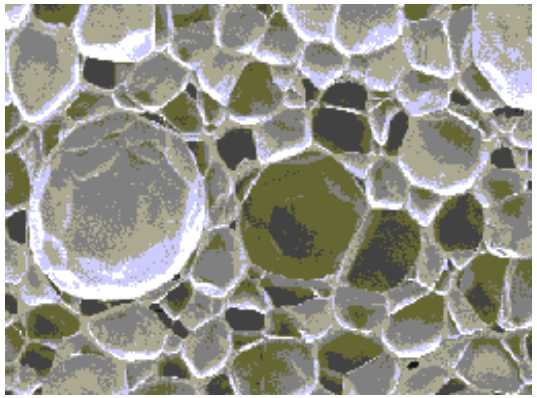
- **Foam Density**
- **Closed cell**
- **Cell size, distribution**



Good foam cell structure



Poor foam cell structure



Balance of Foaming and Curing

- Melt Strength
- Nucleation and Crystallization
- Crosslinking agent – peroxides, sulphur
- Solubility and diffusivity of blowing agent

Chemical Blowing Agents

– organic and inorganic blowing agents

- azodicarbonamide, OBSH, sodium bicarbonate, citric acid

Experimental

Ingredients pre-compounded and mixed together in 1.5L Banbury mixer

- Polymer
- $CaCO_3$ + Filler
- Blowing agent + Curatives

Compression Molding

- 110˚C pre-molding, 4 min
- 180˚C foaming/Curing, 8 min

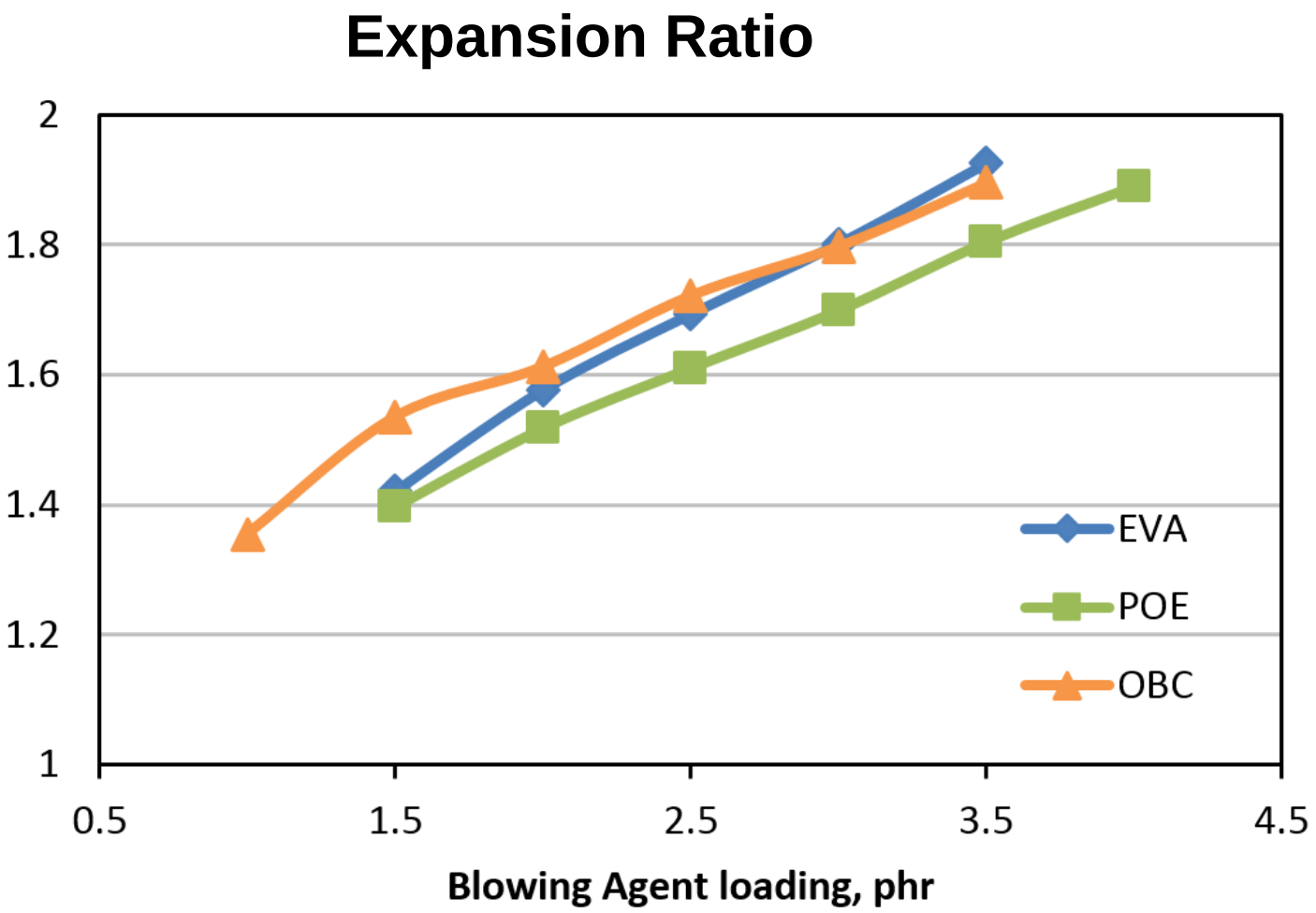
Property Testing of Foams

- Oven aged shrinkage
- Tensile, tear, compression set, resilience

Foam Ingredients	EVA	POE	OBC*
EVA	100		
POE		100	
OBC			100
Luperox 40DC SP2	0.9	0.9	0.99
Luperox 40DC	1.35	1.35	1.485
AC9000	X	Y	Z
ZnO*	0.1X	0.1Y	0.1Z
ZnSt*	0.1X	0.1Y	0.1Z
CaCO3	5	5	5

*Based on prior experiments, POx level was increased by 10% for the OBC.

Foam Expansion



Higher and similar expansion ratio observed for EVA and OBC

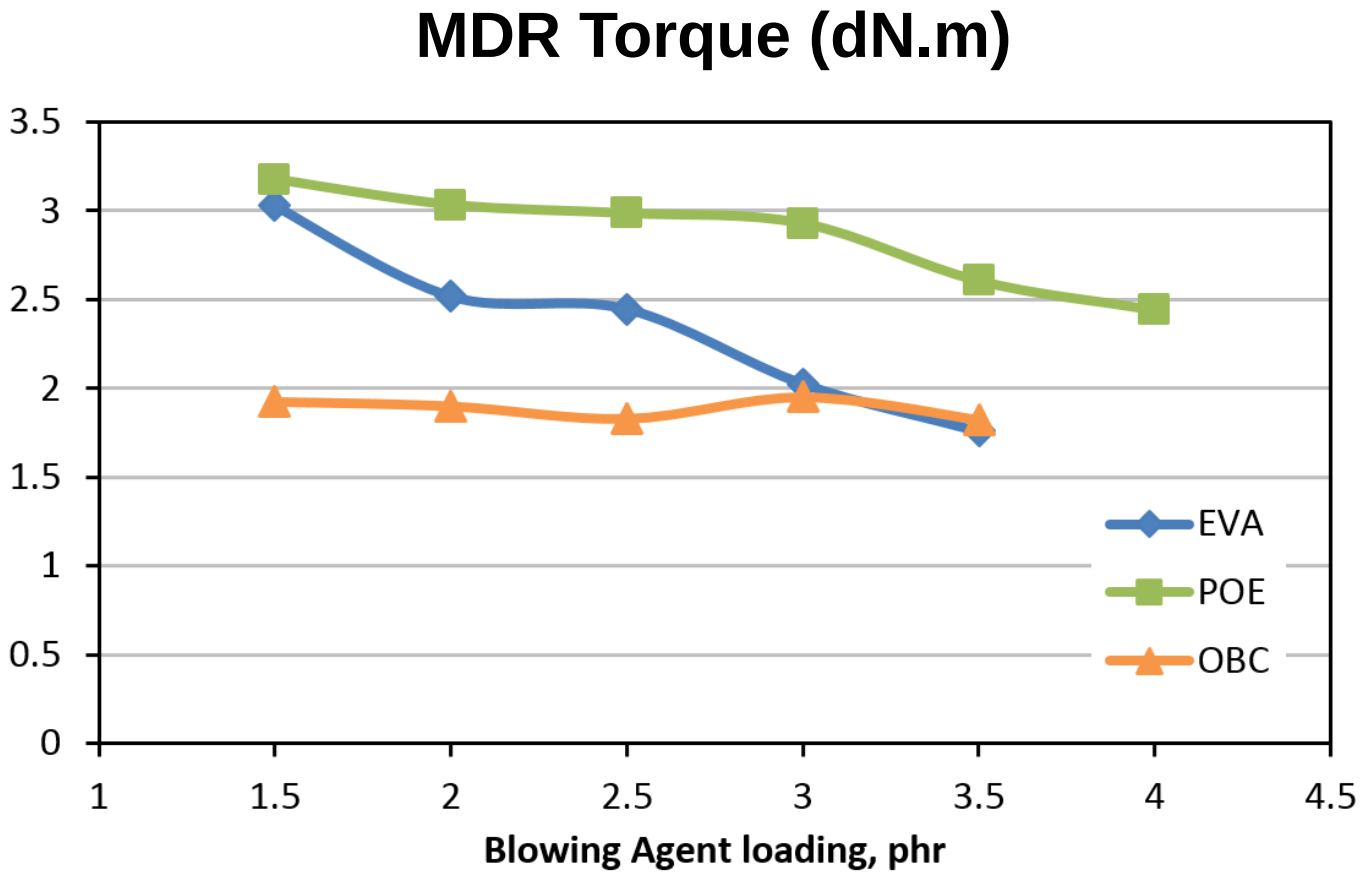
POE had the lowest expansion ratio

Degree of Curing

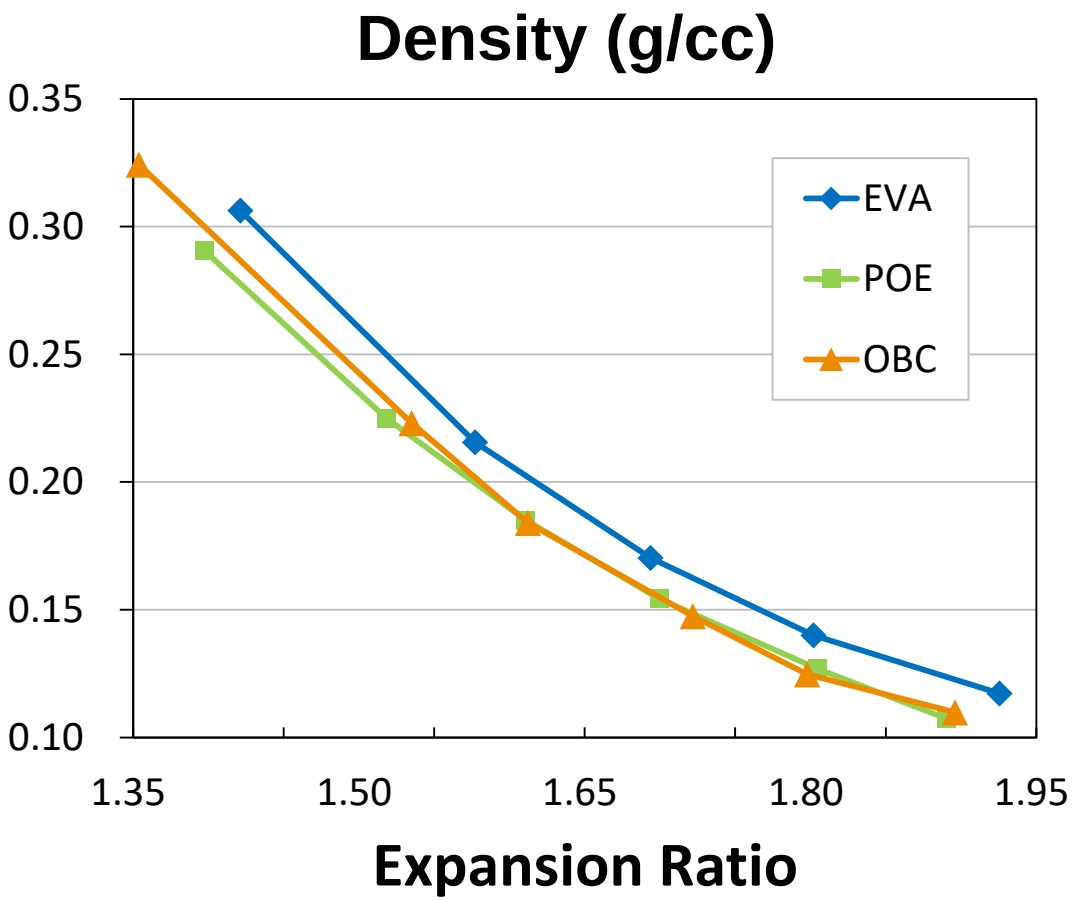
POE cured the fastest and had the highest degree of cure

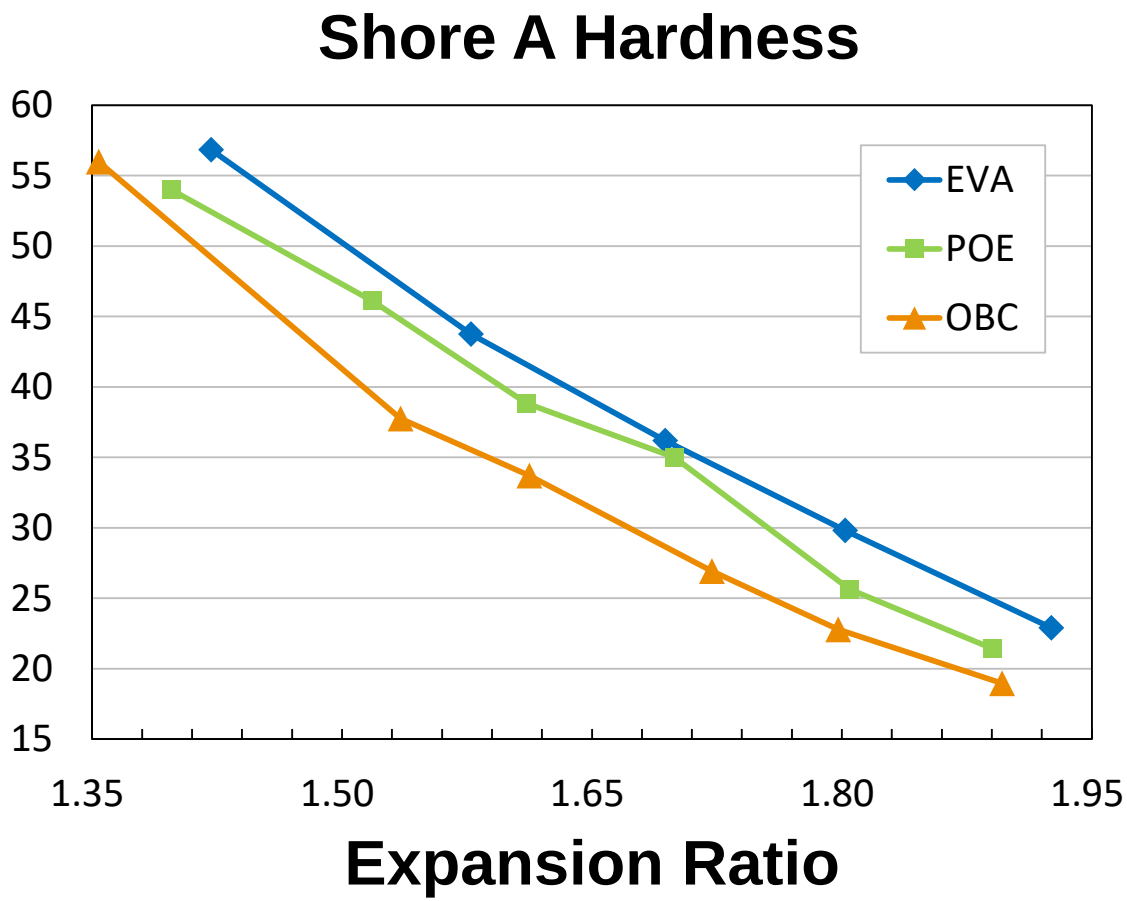
OBC cured the slowest and showed the lowest degree of cure

EVA showed an intermediate degree of cure

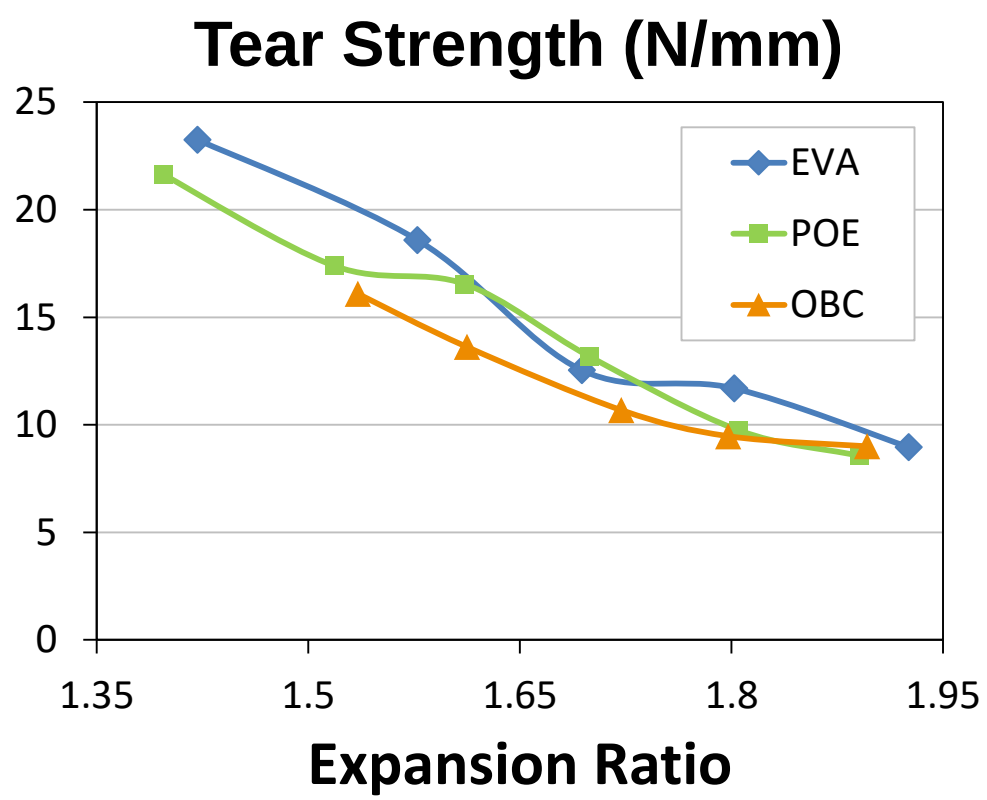


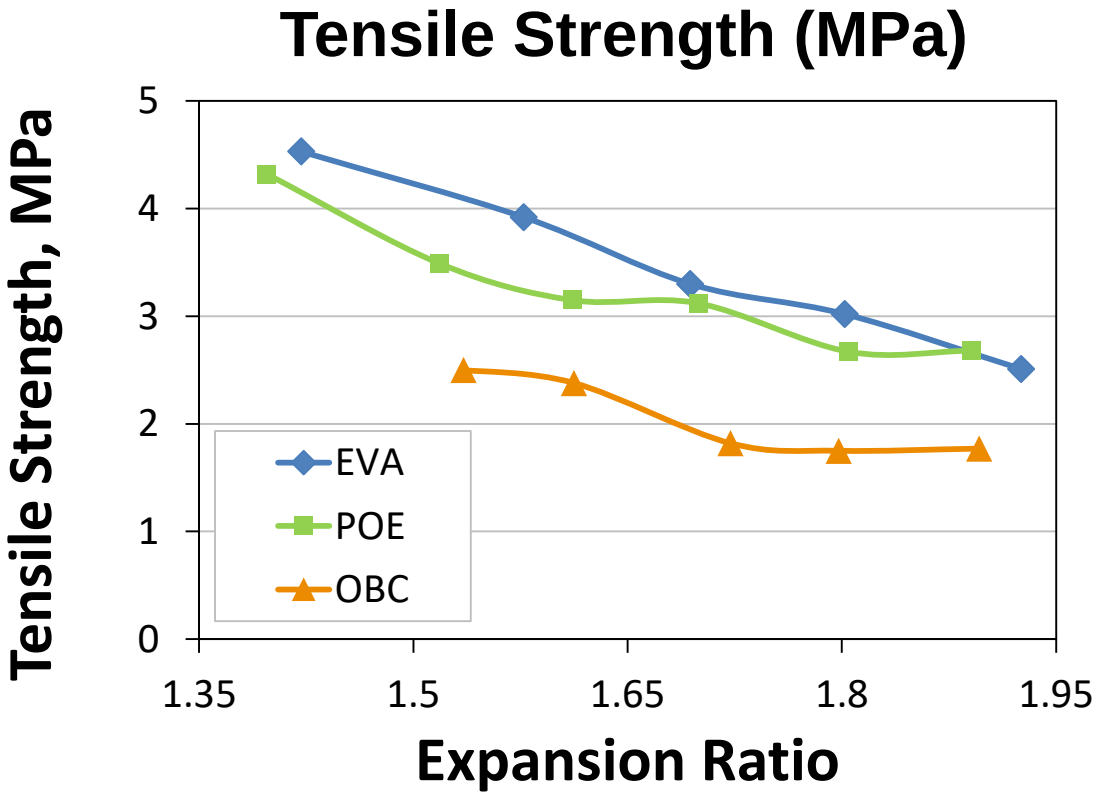
Foam Density and Hardness



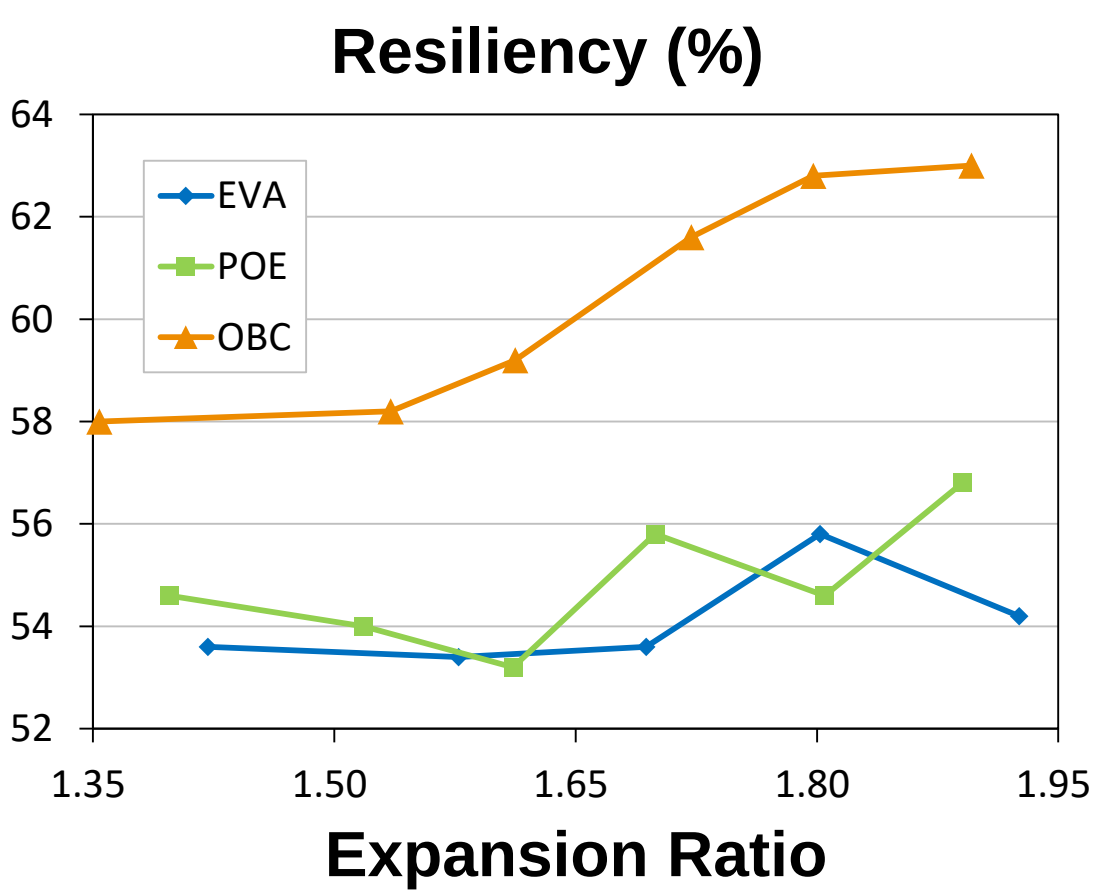


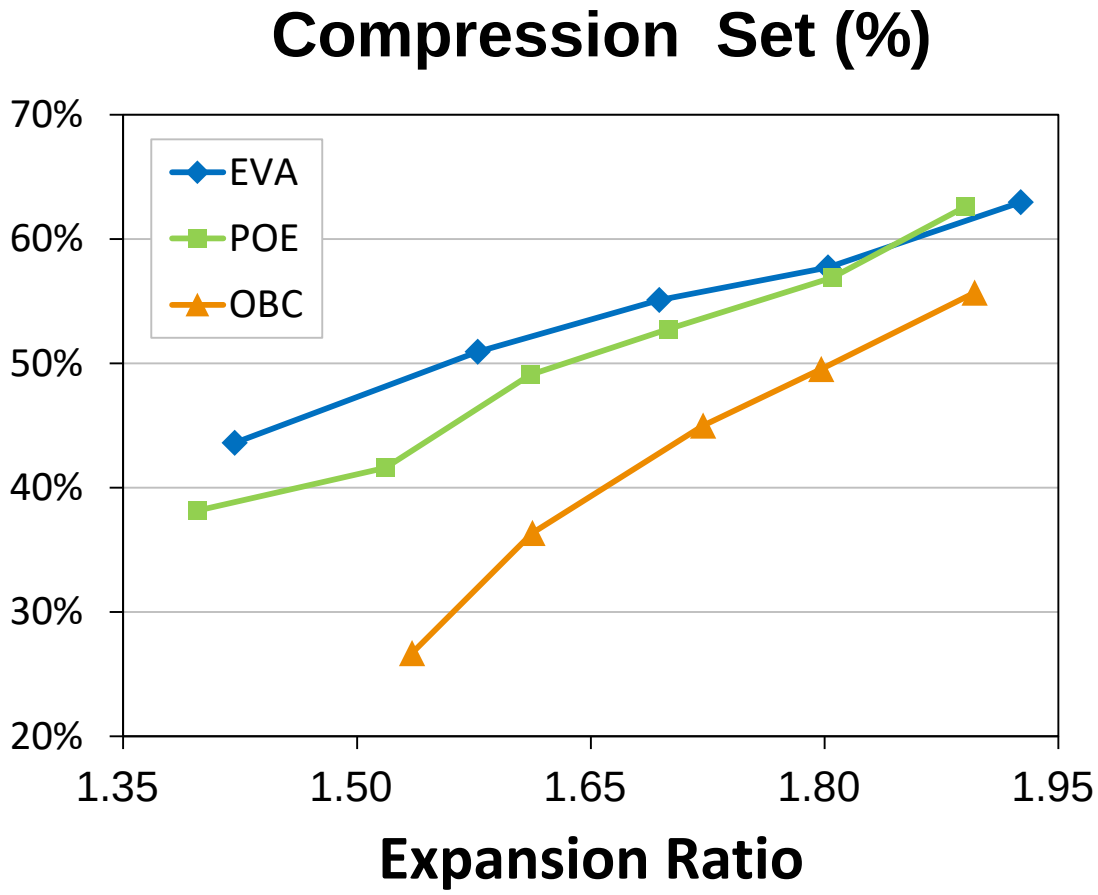
Foam Strength





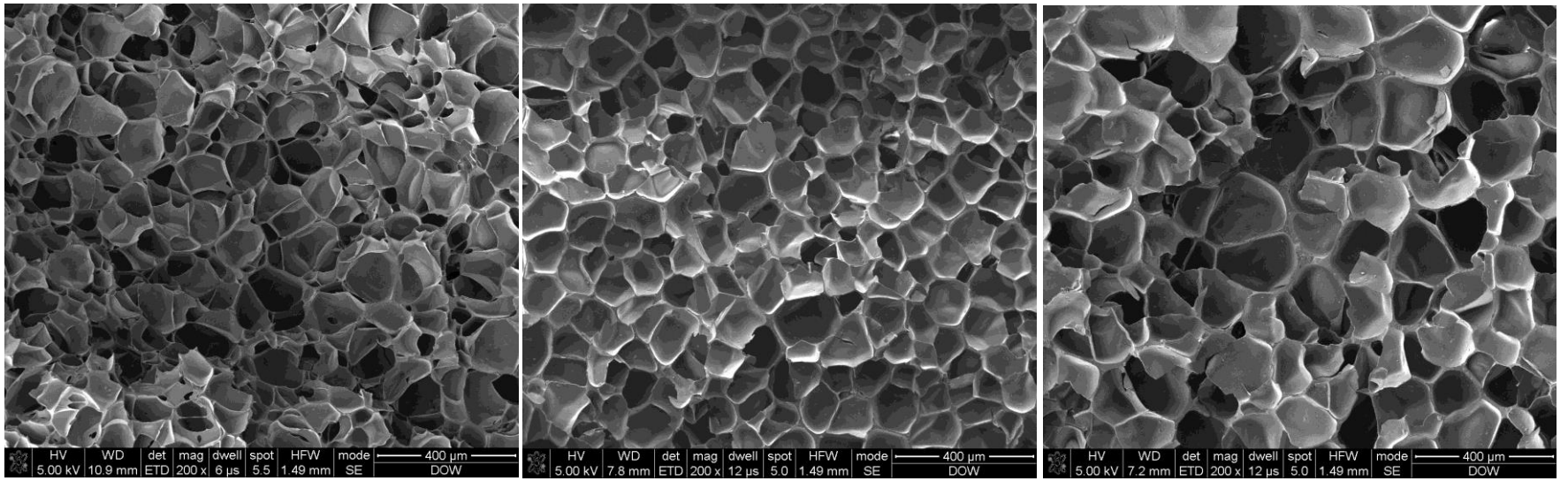
Foam Resiliency



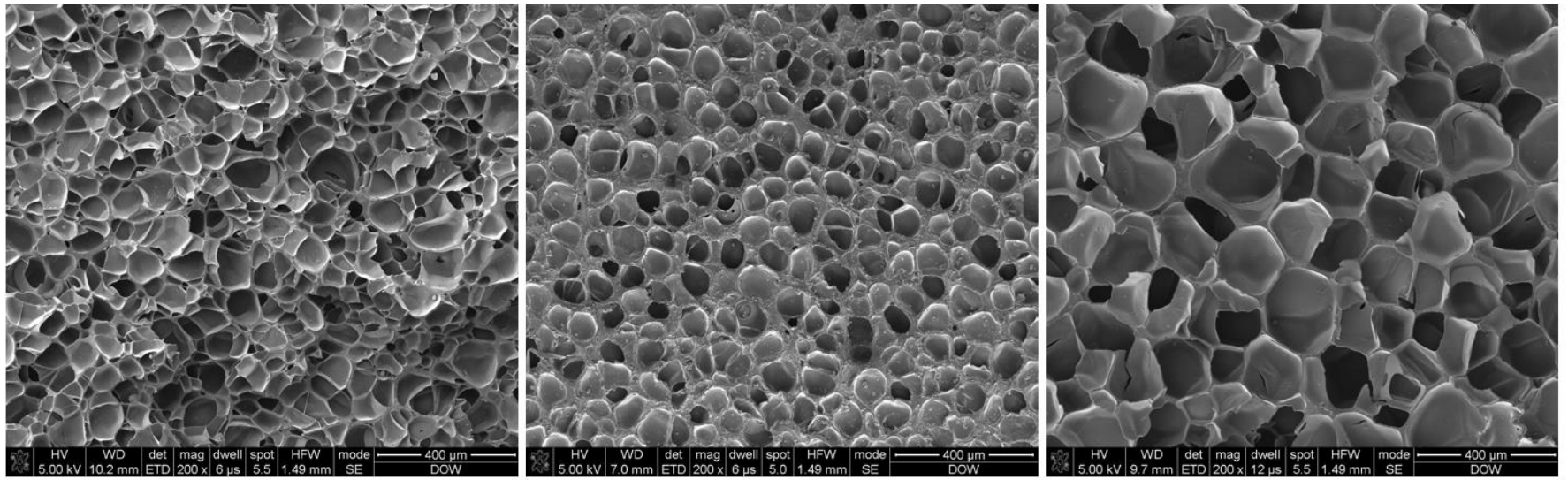


Foam Shrinkage

Before Oven Aging



After Oven Aging (70˚C)

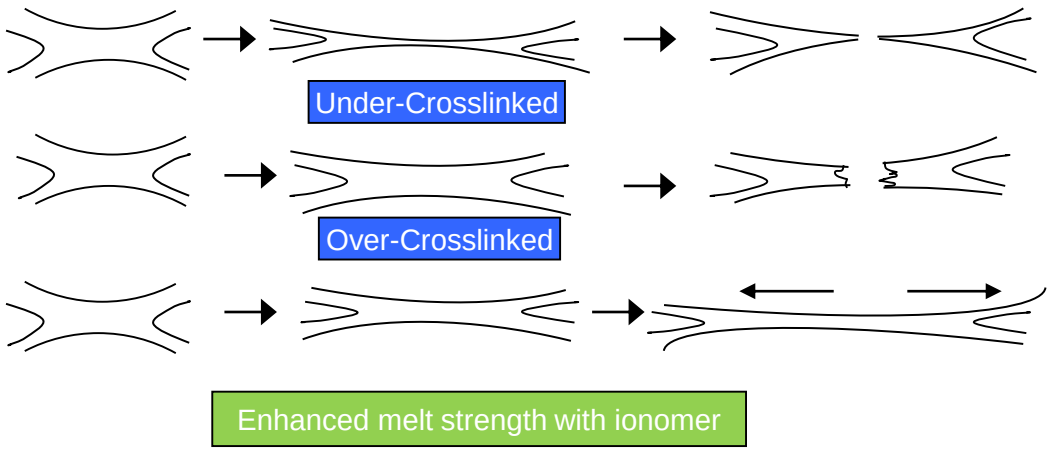


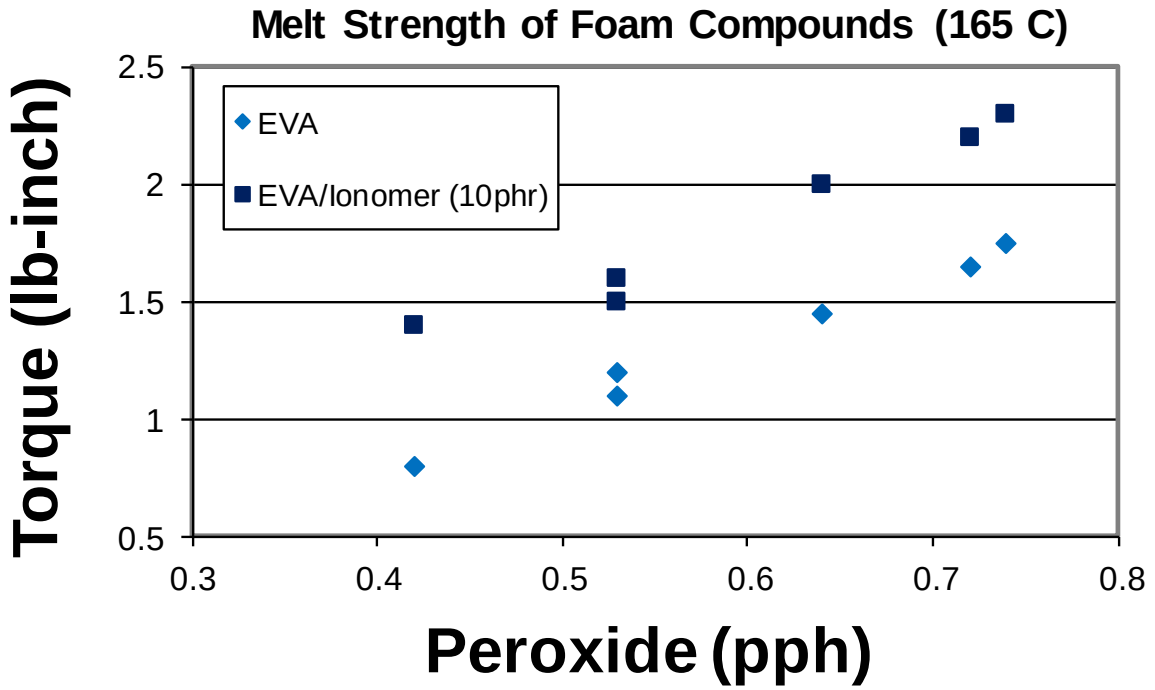
Ionomer Addition for Foaming Control*

Ionomer can be added to introduce secondary ionic crosslinking

Optimizing foaming behavior:

- Enhancing melt strength
- Stabilizing bubble growth
- Controlling the nucleation



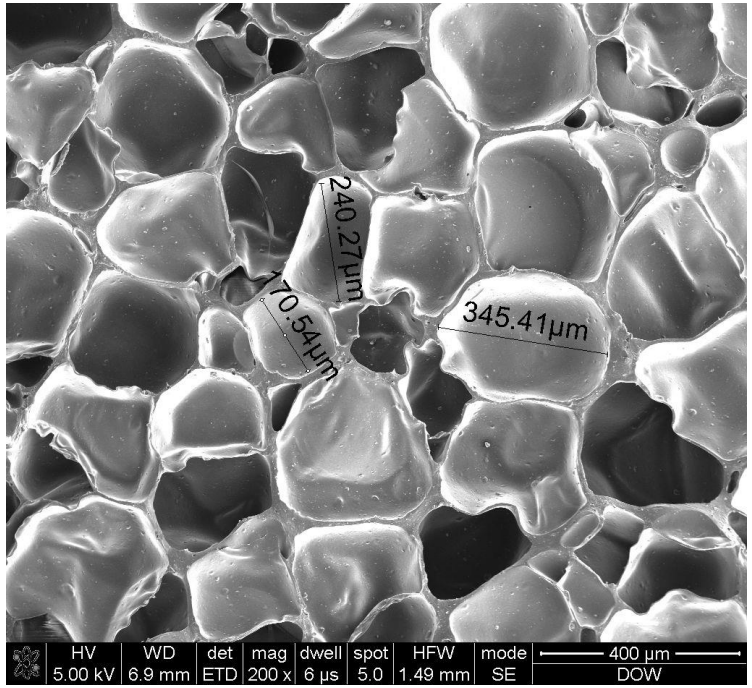


*C.F. Hsu, R. Chou, W. Whelchel, Y.T. Ou, U.S. Patent 6,528,550 (1999).

Ultra Low Density POE/OBC Foam

Low levels of ionomer significantly reduces cell size and improves foam strength.

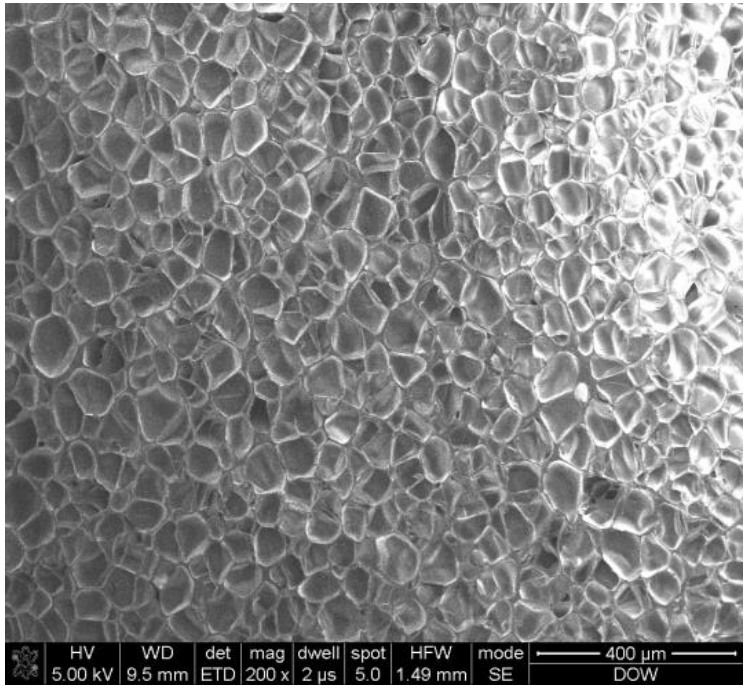
Avg 175µm



Foam Properties

POE/OBC	Foam Properties	With 1 phr ionomer
1.74	Expansion Ratio	1.69
0.14	Av Density, g/cc	0.16
27.5	Shore A	31
60	Rebound, %	61
53	CSET 50%, 50C/6h	53
353	Avg-Strain at Break	383
2.1	Avg-Stress at Break	3.1
11.4	Type C Tear, N/mm	15.5

Avg 52 µm



Polyolefin polymers can be used to make soft, light weight, and resilient foams

Formulation adjustments are needed to account for differences in curing and rheology

- EVA - higher foam tear strength
- POE, OBC - lower density, softer foams
- OBC – excellent dimensional stability and resiliency
- Ionomers – cell size reduction, improved foam strength

Summary of Foam Properties

Thank You

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