FOAM EXPO Europe

3 – 5 DECEMBER 2024

MESSE STUTTGART (HALL 1), GERMANY

LATEST FOAMING TECHNOLOGIES & EMERGING FOAM APPLICATIONS

Dr. Miguel Angel Rodriguez- Perez, Dr. Cristina Saiz-Arroyo

CellMat Technologies S.L.

STAND 324

OPENING PANEL: PAVING A PATH FOR THE NEXT DECADE IN FOAM: SUPPLY CHAIN, SUSTAINABILITY, MARKET DEVELOPMENT

ABOUT US

Our strength is the combination of a team of highly qualified scientists and facilities specially designed to develop and validate innovative ideas.

Created more than 10 years ago, in 2012, CellMat Technologies is focused on developing high-quality R&D in all the topics surrounding polymeric foams.

Our main target is to help our industrial partners by applying and transferring our specialized know-how in the field of foams, in their processes and products as a driver to improve their competitiveness.

SOLUTIONS FOR THE INDUSTRY

SERVICES FOR THE WHOLE VALUE CHAIN

Pilot Plants
Small-scale foam production plants

Understanding Foaming
Evaluation and quantification of foaming mechanisms

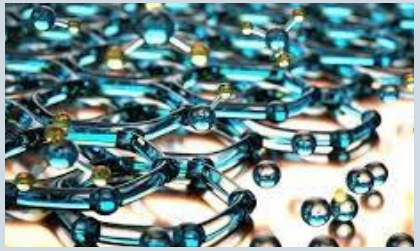
Characterization and Validation
Conventional and advanced characterization techniques

AutoCell
Specific software for advanced foam analysis

Sustainable Solutions
Innovation in materials and processes to drive it

Training Courses
Increasing your competitiveness

On-Site Assessment
We will be wherever you will need us

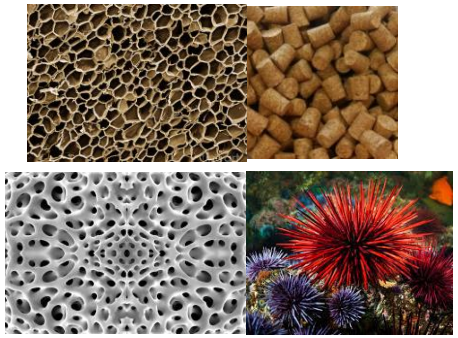


Advanced Products and Processes
Development of novel products and processes. Upscaling.

STAND 324

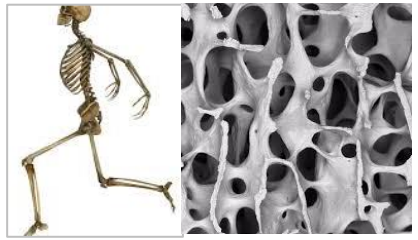
INTRODUCTION

FOAMS, 100 YEARS … OR MORE …



Nature created foams

80 Million Years B.C.



1849 The basis for foam development
Wurtz and Hoffman reported for the first time a reaction between an isocyanate and a hydroxy compound

1920 Otto Bayer and PU Foams
Polyester-based Urethane polymers became essential items during WWII due to the need to replace nylon

1937 Latex Sponge
Precursor of Latex foam made by Dunlop method in 1928

1942 Extruded Polystyrene
With CFCs

1945 Phenolic Foams

1954 Expanded Polystyrene
Suspension Polymerization

1958 Extruded Polyethylene

1961 PolyIsocyanurate Foams

2024 $109 Billion CAGR to 2035: 4.9 %

Sustainability

Montreal Protocol

PCRs

Lightweighting

Reach
(FRs, Blowing Agents, …)

Circular Economy

- Rubbers
- PVC
- PET
- Crosslinked Polyolefins
- …

Microcellular Foams (1980s)

Nanocellular Foams (2000s)

Thermoplastic Elastomers

Biopolymers

INTRODUCTION

FOAMS 100 YEARS…. OR MORE…. AND WHAT IS NEXT?

SUSTAINABILITY

- APPROPRIATE USE OF PCRS
- EFFICIENT RECYCLING OF FOAMS
- MOVING TO THERMOPLASTIC MATERIALS
- SUSTAINABLE BLOWING AGENTS
- USE OF SOLUTIONS BASED ON ONE SINGLE MATERIAL
- USE OF BIOBASED POLYMERS AND ADDITIVES
- MORE SUSTAINABLE FOAMING TECHNOLOGIES

PERFORMANCE

- REDUCING DENSITY
- IMPROVING PHYSICAL PROPERTIES: MECHANICAL, THERMAL INSULATION, FLAME RETARDANCY (HALOGEN FREE), ETC.
- MORE ROBUST FOAMING PROCESSES
- NEW PROPERTIES FOR NEW APPLICATIONS
- TAILOR MADE FOAMS

REGULATIONS

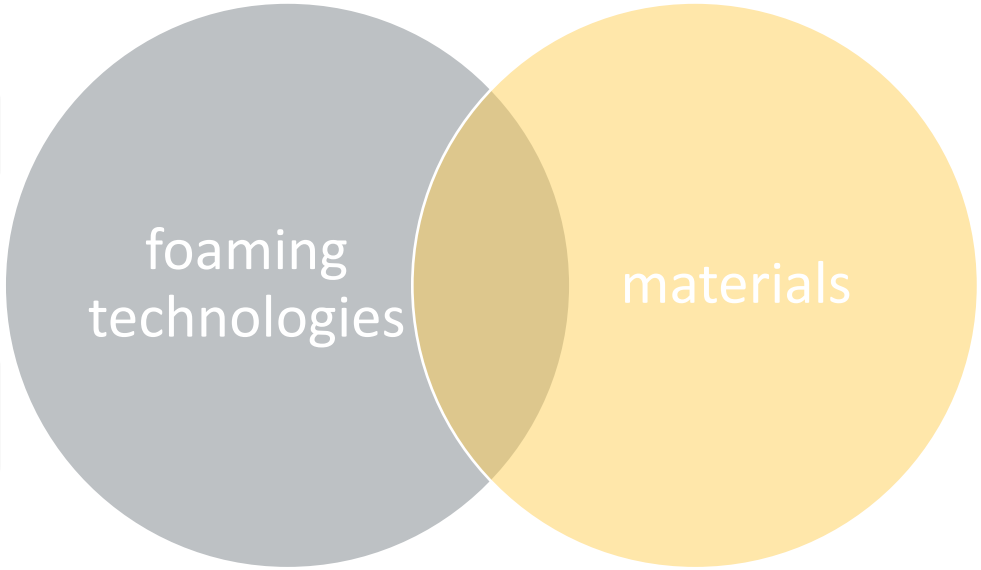
- REGULATIONS ABOUT RAW MATERIALS
- REGULATIONS ABOUT CO_2 EMISSIONS

I WILL SHOW SOME EXAMPLES OF HOW THESE CHALLENGES ARE APPROACHED TODAY

INTRODUCTION

PROCESS/MATERIALS

Sustainability, performance and regulations are triggering innovation in technology and materials



- COMPRESSION MOLDING
- EXTRUSION FOAMING
- REACTIVE FOAMING
- INJECTION MOLDING
- BEAD FOAMING
- GAS DISSOLUTION FOAMING

TRADITIONAL

- POLYETHYLENE
- POLYSTYRENE
- EVA
- POLYPROPYLENE
- PVC
- RIDIG PU
- RUBBERS (NBR, SBR, NR…)
- FLEXIBLE PU
- POLYAMIDE
- POLYETHYLENE TEREPHTHALATE

TECHNICAL

- PVDF
- POLYETHERIMIDE
- POLYCARBONATE
- PMMA

BIO

- STARCH
- POLYLACTIC ACID
- CELLULOSE ACETATE
- POLYHYDROXYALKANOATES
- POLYBUTYLENE ADIPATE TEREPHTHALATE
- POLYBUTILENE SUCCINATE

THERMOPLASTIC ELASTOMERS

- STYRENIC TPES (TPSs)
- THERMOPLASTIC PU (TPUs)
- OLEFINIC TPES (TPOs)
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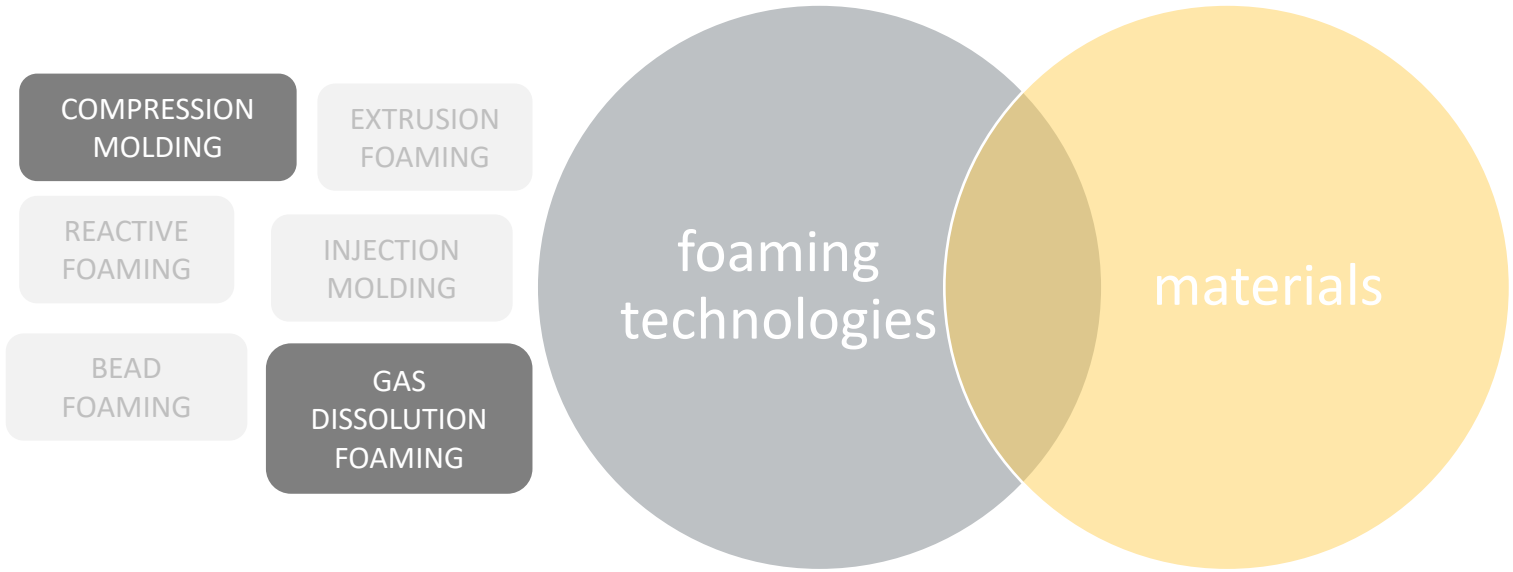

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FOAMS PRODUCED USING PCR

SUSTAINABILITY OF POLYMERS FOR FOAMING

RECYCLED POLYMERS AS RAW MATERIALS FOR FOAMING

RECYCLED MATERIALS COMING FROM THE SAME PROCESS

ALREADY USED IN SOME TECHNOLOGIES: XPS, EPS, EXTRUDED PE

RECYCLED MATERIALS COMING FROM POST CONSUMER PLASTICS

MORE DIFFICULT TO IMPLEMENT BUT NECESSARY DUE TO REGULATIONS AND END USERS REQUIREMENTS

By 2030, EU plastic packaging must contain 10-35% recycled content, depending on the application. By 2040, the figures rise to 50-65%. Automotive Industry is also promoting similar figures

FOAMS PRODUCED USING PCR

ONE POSSIBLE OPTION IS TO USE
RECYCLED MATERIALS COMING FROM POST CONSUMER PLASTICS

CHALLENGES:

Proper rheological properties of the raw materials (foamability)

Adequate physical properties of the polymer

Compatibility between phases

Homogeneity of each batch of recycled polymer

Reproducibility between batches

EXAMPLE

PRODUCTION OF POLYOLEFIN BASED FOAMS USING POST CONSUMER POLYETHYLENE FILMS COMING FROM THE PACKAGING INDUSTRY

FOAMS PRODUCED USING PCR

Recycled Polyethylene bags

SELECTION OF THE RAW MATERIALS

FOAMABILITY DIAGRAMS

FOAMABILITY DIAGRAMS are useful to **predict** the **foamabilty** of different types of **thermoplastic formulations** without the need of producing and charactering the foams. They are based on the analysis of the **rheological properties** and **thermal properties** of the polymeric formulations.

THEORETICAL BASES

RHEOLOGICAL PROPERTIES

EXTENSIONAL RHEOLOGICAL PROPERTIES:
Strain hardening coefficient: THE HIGHEST, THE BETTER TO FAVOR BUBBLE GROWTH AND AVOID DEGENERATION

INTRINSIC THERMAL PROPERTIES
$\Delta T = T_m - T_c$ (SEMICRYSTALLINE)
$\Delta T = T_f - T_g$ (AMORPHOUS)

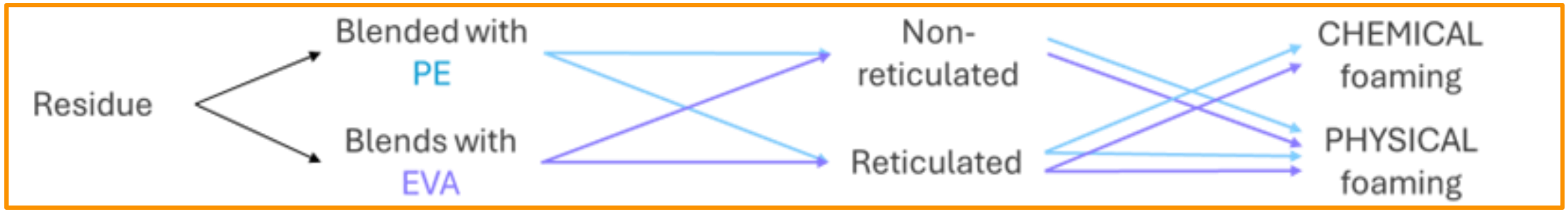
THE LOWEST VALUE OF ΔT TO PROMOTE A FAST STABILIZATION OF THE CELLULAR STRUCTURE

SHEAR RHEOLOGICAL PROPERTIES:
Zero shear viscosity, (Molecular weight): LOW VALUE TO FAVOR EARLY STAGES OF BUBBLE GROWTH

A SPECIFIC RESIDUE WITH 87% CONTENT OF LLDPE, 10% CONTENT OF LDPE AND 2% CONTENT OF OTHER MATERIALS (PP AND INORGANIC FILLERS) WAS SELECTED

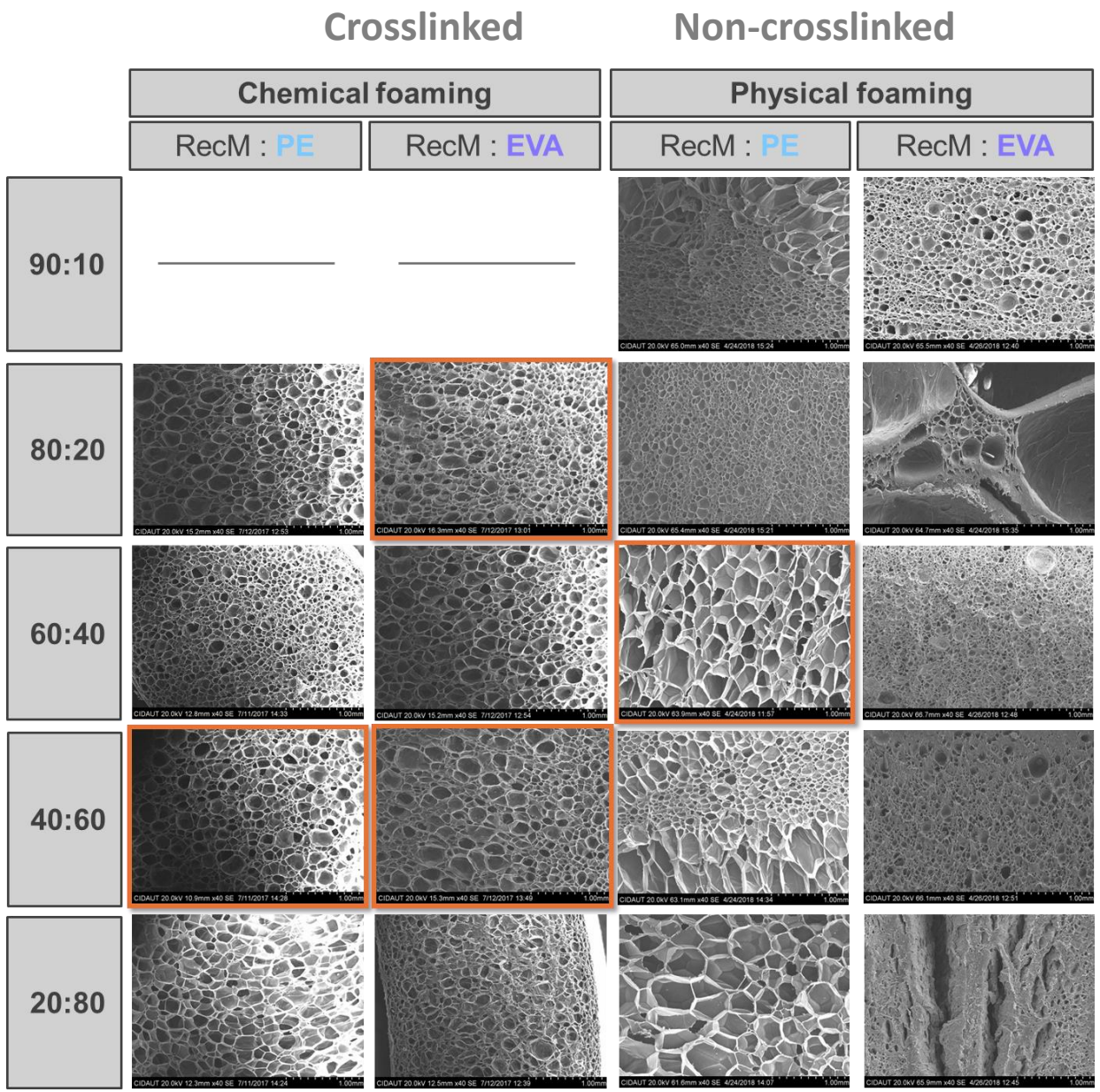
FOAMS PRODUCED USING RECYCLED POLYMERS

PRODUCTION OF FOAMS. CROSSLINKED AND NON-CROSSLINKED FOAMED BY CHEMICAL FOAMING (ONE STEP COMPRESSION MOLDING TECHNOLOGY) AND GAS DISSOLUTION FOAMING



Numerous factors were studied: chemical and rheological compatibility of the polymeric phases between the materials that constitute the recycled material and the virgin materials used in the final blends, types and quantities of additives (Peroxide, carbon black, ADCA and ZnO), foaming processes and experimental parameters used in the processes to obtain the final foams.

FOAMS PRODUCED USING PCR



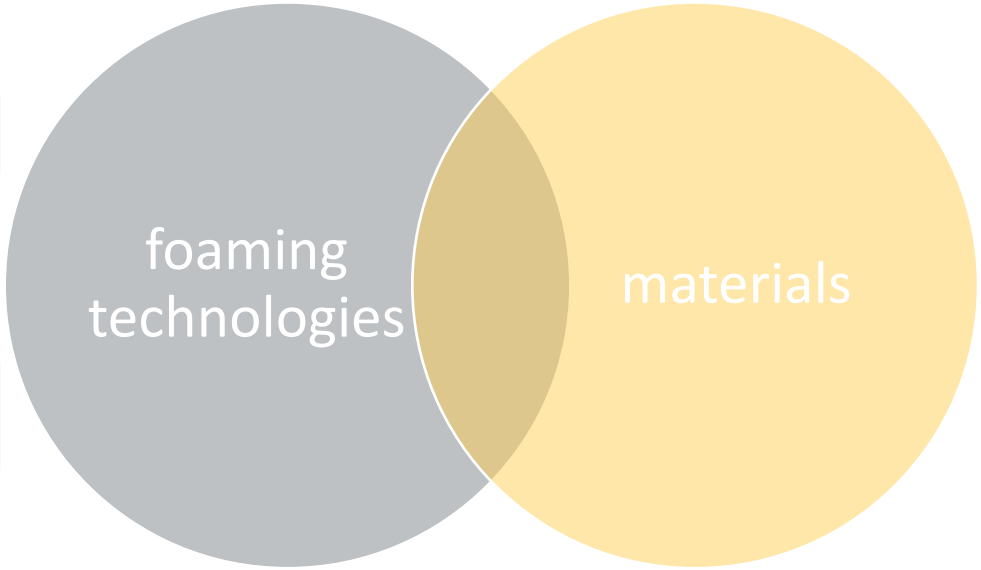
90:10 means 90 % that the polymeric matrix is 90% virgin material (LDPE or EVA) -10% recycled material

IT HAS BEEN POSSIBLE TO PRODUCE MATERIALS WITH UP TO 80% OF RECYCLED MATERIAL AND HOMOGENEOUS CELLULAR STRUCTURES, SOME OF THEM WITH DENSITIES IN THE RANGE OF SOME COMMERCIAL PRODUCTS.

INTRODUCTION

PROCESS/MATERIALS

Sustainability, performance and regulations are triggering innovation in technology and materials



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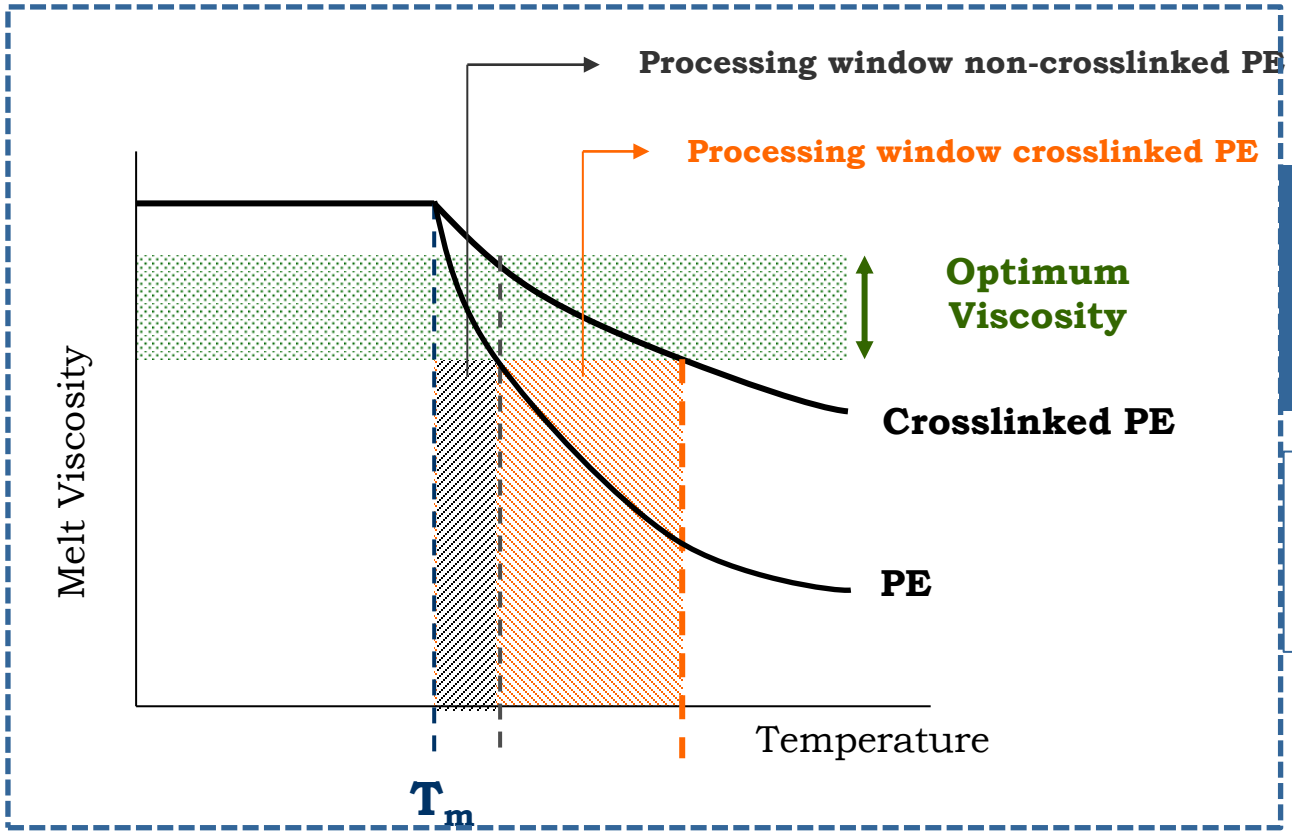
DYNAMIC CROSSLINKING IN POLYOLEFIN FOAMS

THE MECHANISM TO STABILIZE THE SYSTEM & PROVIDE THE DESIRED PROPERTIES

Crosslinking stabilizes the expanding bubbles by sharply increasing the extensional viscosity of the polymer, thereby preventing the cell walls from draining.
In addition, the produced foams have improved thermal stability among other properties



Crosslinking extends the rubbery plateau of the polymer melt -> widening of the temperature range in which a stable foam can be produced.

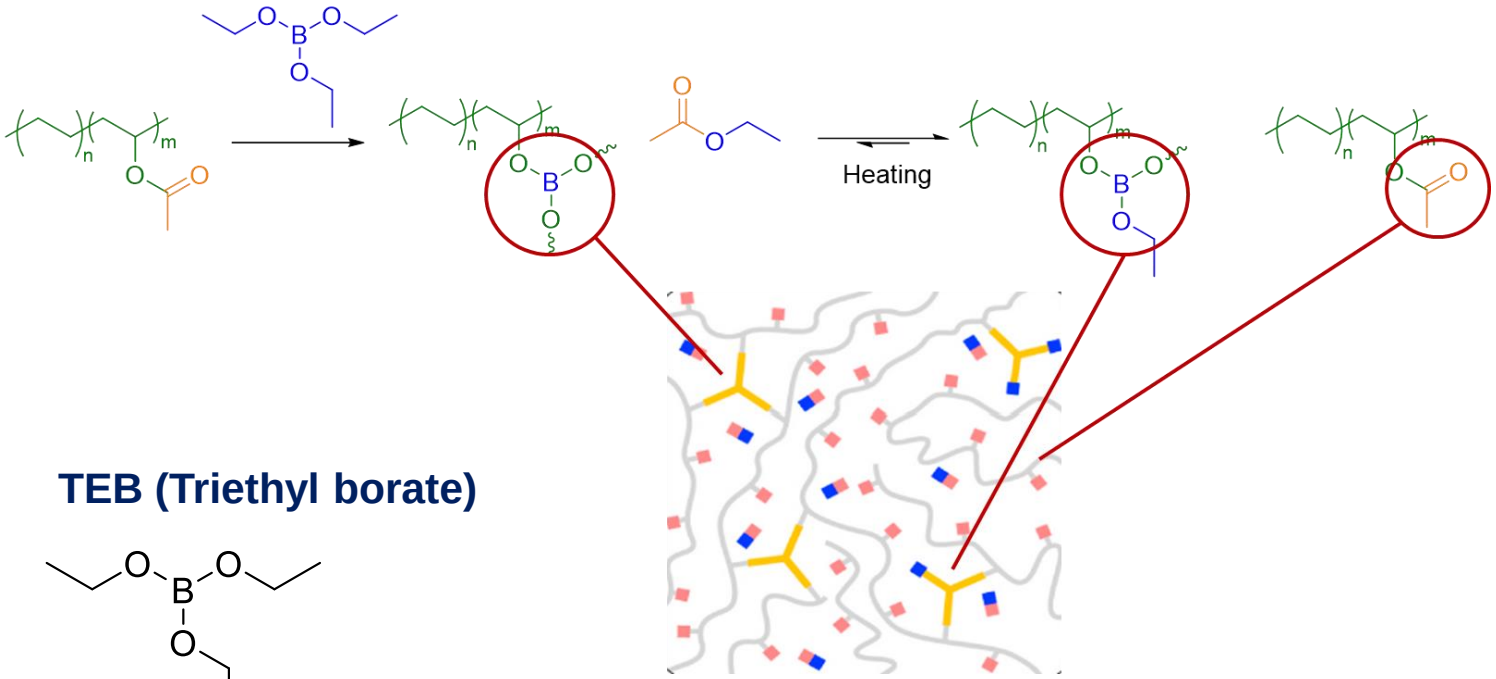
But also … Enhances the resistance of the foam to thermal collapse which is critical for example in thermoforming

RECYCLING BY THE CONVENTIONAL MECHANICAL METHODS IS NOT POSSIBLE

PRODUCTS CANNOT BE RECYCLED AND THE SCRAP IN FACTORIES CAN NOT BE REUSED.

DYNAMIC CROSSLINKING IN POLYOLEFIN FOAMS

IS IT POSSIBLE TO PROCUCE HIGH QUALITY POLYOLEFIN FOAMS USING THE CONCEPT OF DYNAMIC CROSSLINKING?



TEB (Triethyl borate)

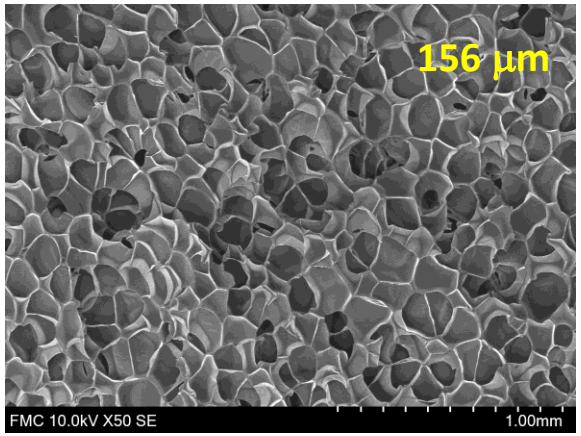
HYPOTHESIS:

THE BONDS CREATED BY THE TEB COULD INCREASE THE VISCOSITY ALLOWING THE PRODUCTION OF THE FOAM BUT KEEPING THE POSSIBILITY OF RECYCLING BY THERMOMECHANICAL METHODS.

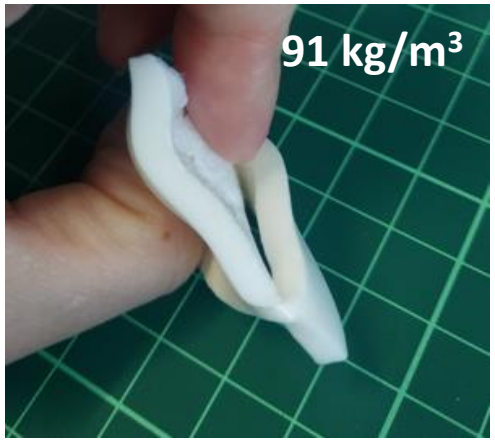
DYNAMIC CROSSLINKING IN POLYOLEFIN FOAMS

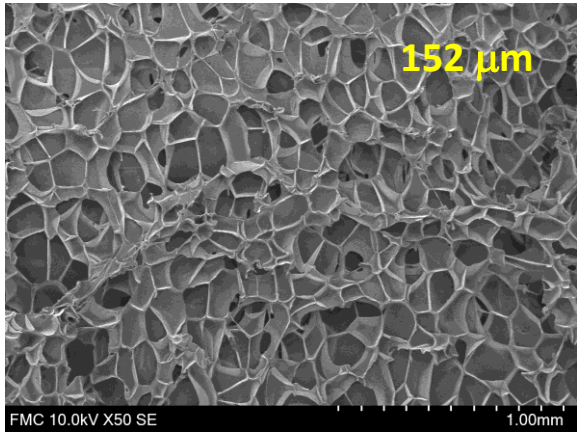
COMPARSION ORIGINAL VERSUS REPROCESSED FOAM

FOAM PRODUCED FROM THE DYNAMIIC CROSSLINKED POLYMER (Compression molding Technology)



FOAM PRODUCED FROM THE RECYCLED (by mechanical means)
DYNAMIC CROSSLINKED POLYMER (Compression molding Technology)





MECHANIICAL RECYCLING IS POSSIBLE.
FOAMS WITH VERY SIMILAR CHARACTERISTICS ARE OBTAINED.

SCRAP COMING FROM THESE FOAMS WILL BE ELIMINATED

INJECTION MOLDING

PROCESS/MATERIALS

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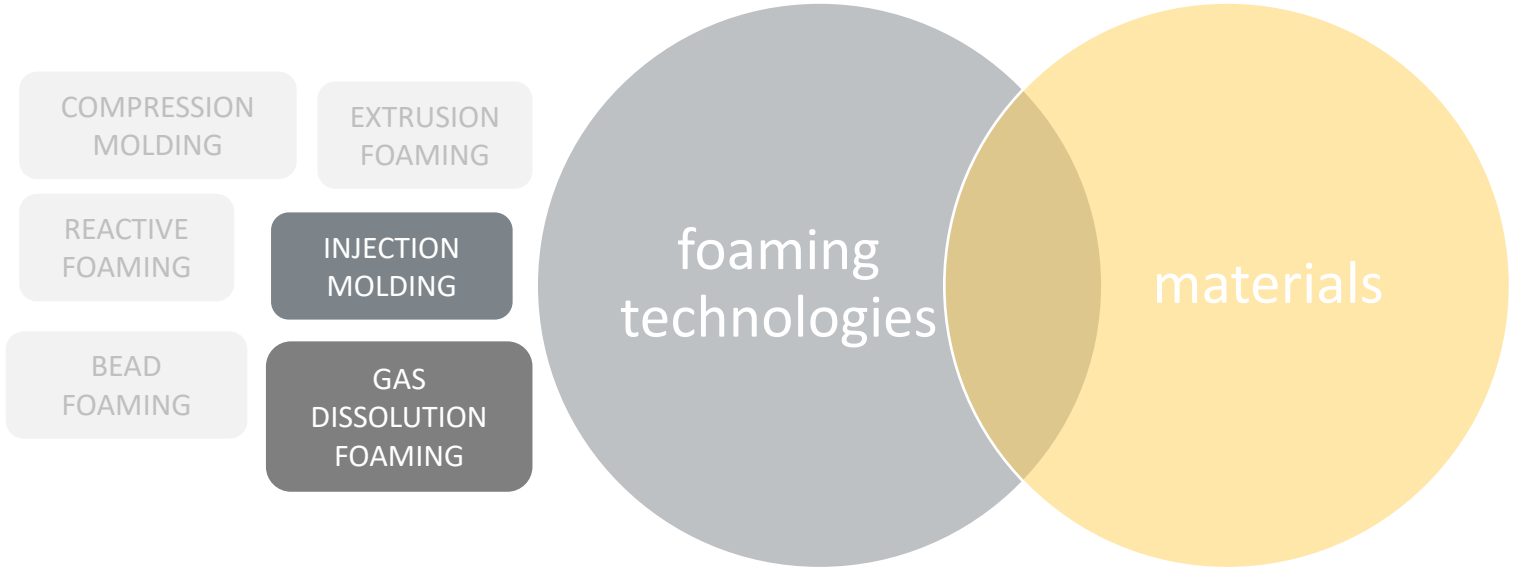

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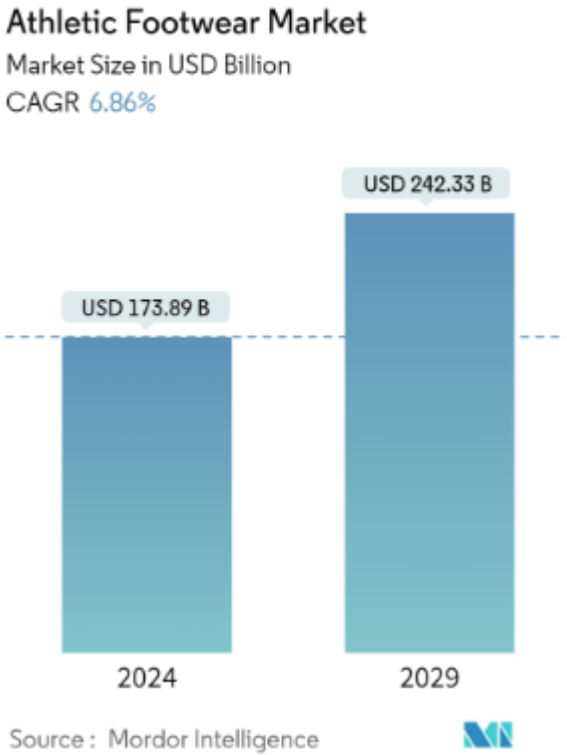
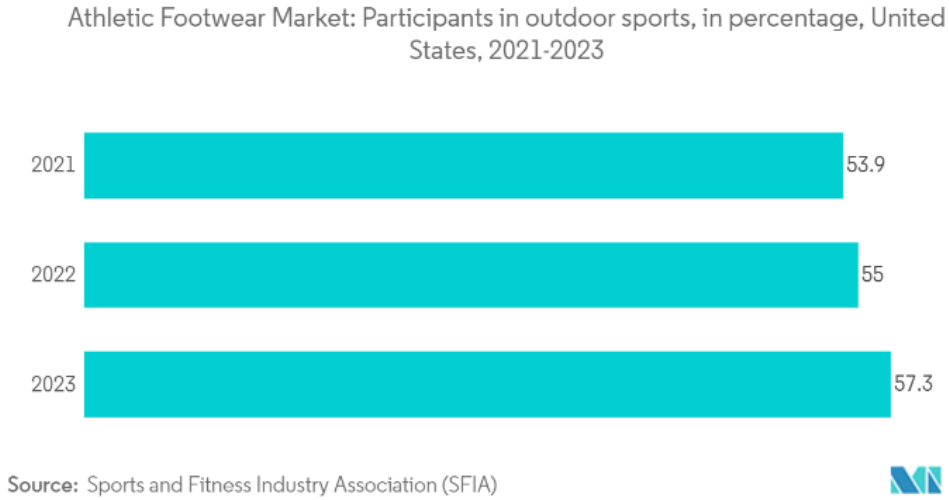
INJECTION MOLDING

REVISITING A CLASSIC, BY THE SPORTS SHOE INDUSTRY



Fastest Growing Market – Asia Pacific
Largest Market – North America

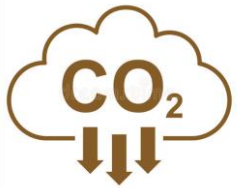


INJECTION MOLDING

THE TRADITIONAL SCENARIO FOR MIDSOLES PRODUCTION

The Formula

Components – Traditional Formula Midsole
Polymer(s) (EVA, POE, LLDPE)
Crosslinking agent (BIPB, DCP)
Blowing agent (Azodicarbonamide)
Catalyst BA (ZnO, ZnSt, Urea)
Catalyst XL agent (TAC, TAIC)
Processing aids
Pigments
TiO2
Fillers (CaCO3)

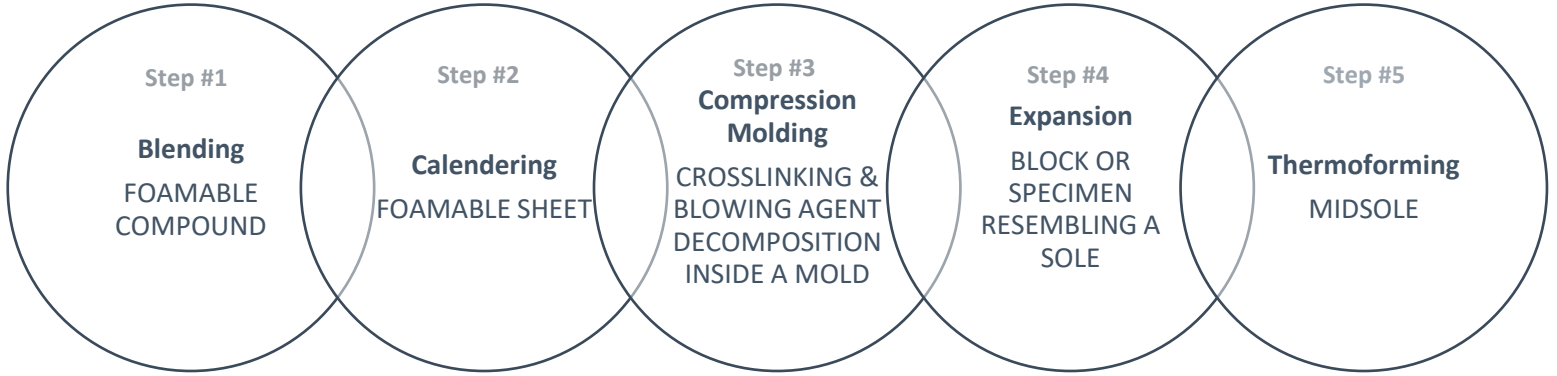


- Raw materials
- Crosslinked solutions (poor, challenging, expensive recyclability)
- Large amount of residues

- Limited design/properties

The Production Routes

COMPRESSION MOLDING + THERMOFORMING



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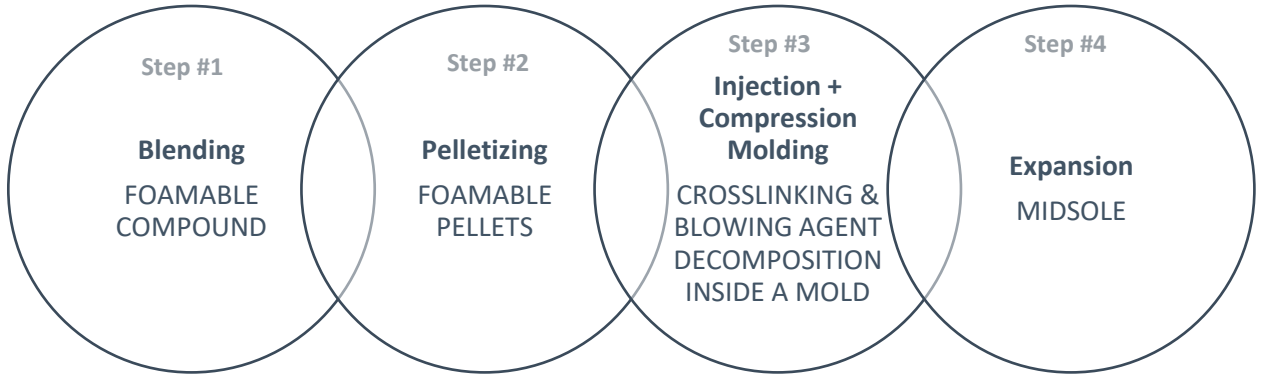


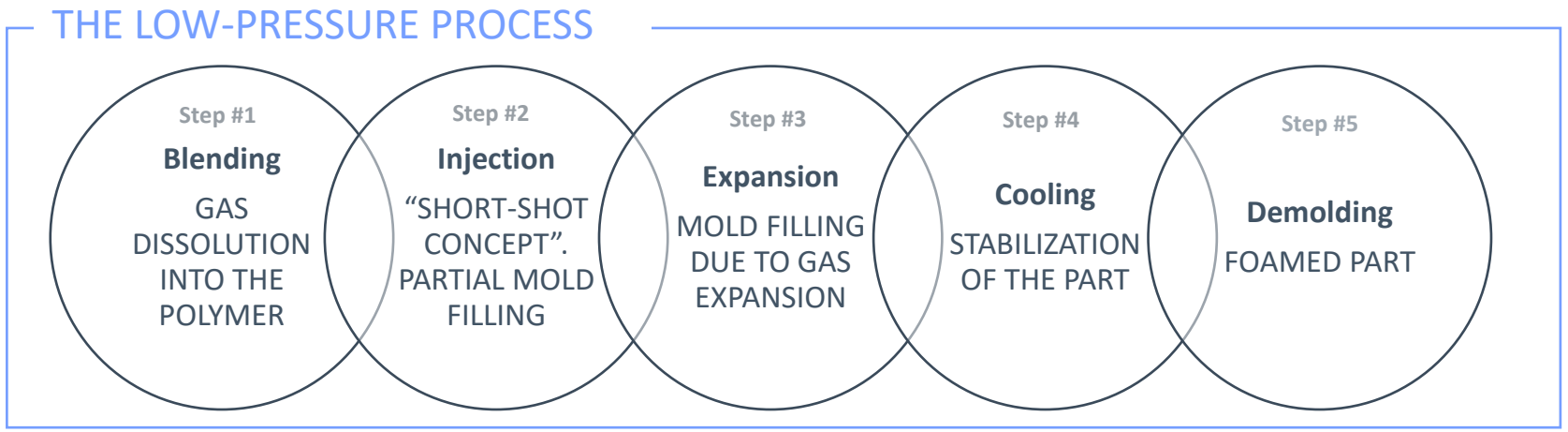
INJECTION MOLDING

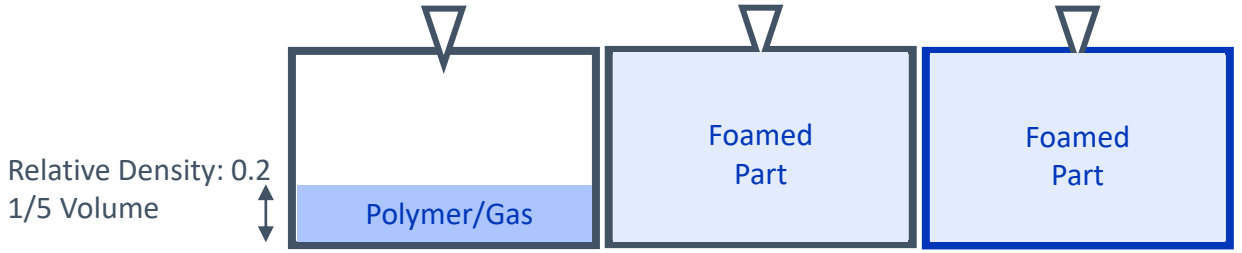
THE NEW PARADIGM: INJECTION MOLDING WITH SUPERCRITICAL BLOWING AGENTS

The Formula

Components – Traditional Formula Injected Part
Polymer(s) – THERMOPLASTIC ELASTOMERS
Blowing agent – Supercritical PBA (CO2, N2)

The Production Routes





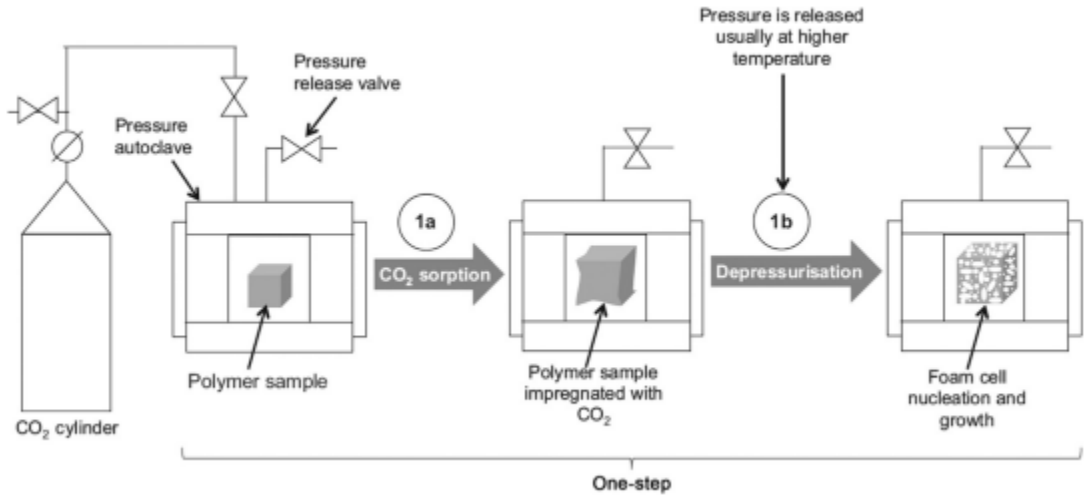
Highly dependent on the characteristics of the polymeric matrix

- Quality of the cellular structure and minimum density DEPENDING ON THE FOAMABILITY (AT HIGH TEMPERATURE) OF THE POLYMERIC MATRIX
- Stabilization means: MOLD TEMPERATURE AND FOAMABILITY
- Low-pressure process – Density gradients, cell morphology gradients. Effects on properties?
- Surface quality

GAS DISSOLUTION FOAMING

ANOTHER OPTION: GAS DISSOLUTION FOAMING OF TPE

PRESSURE INDUCED BATCH FOAMING (PRESSURE QUENCHING)



- Saturation done close to Tg/Tm (softened polymer)
- Expansion takes place inside the autoclave
- Foamability can be controlled by adjusting the temperature before depressurization

- Massive technology in the scientific literature
- Until less than 5 years ago, it only occurred at an industrial scale in one company!

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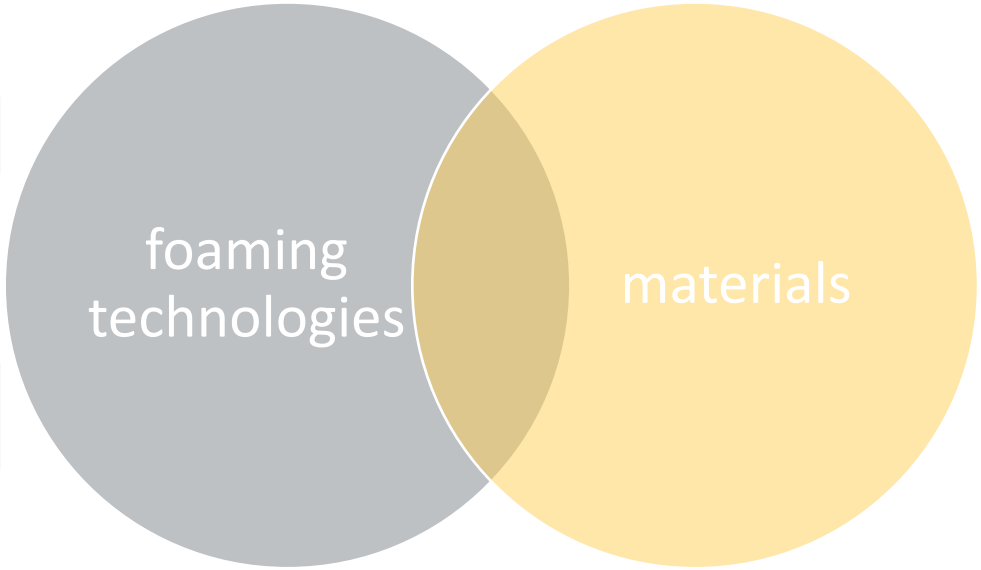

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HALOGEN FREE PU FOAMS

HALOGEN FREE FLAME RETARDANCY IN A FLEXIBLE PU FOAM FOR EXTREMELY HIGH DEMANDS

WATER BLOWN FORMULATION FOR THE
PRODUCTION OF FLEXIBLE PU FOAM

+

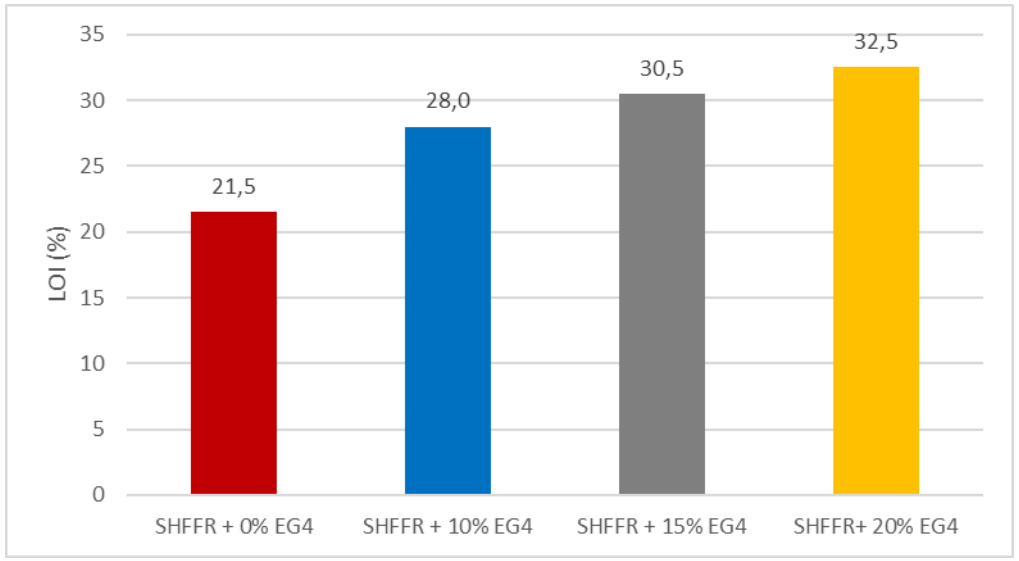
Name of the EG	Volume expansion (cm^3/g)	Starting Temperature (ºC)	Particle Size (microns)
EXPANDABLE GRAPHITE	240	180	300

+

SINERGETIC HALOGEN FREE FLAME RETARDANT (SHFFR)

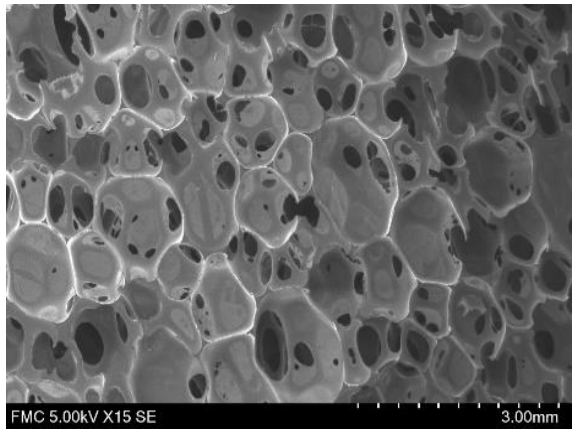
HALOGEN FREE PU FOAMS

EFFECT OF DIFFERENT EG CONTENTS

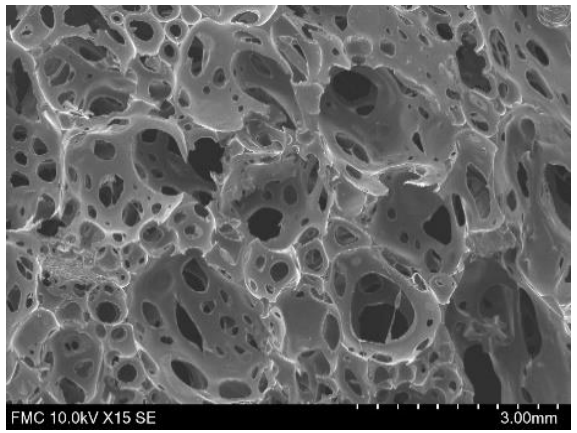


- Very large values of LOI can be obtained
- The ignitibility test show a good performance for EG contents above 10%

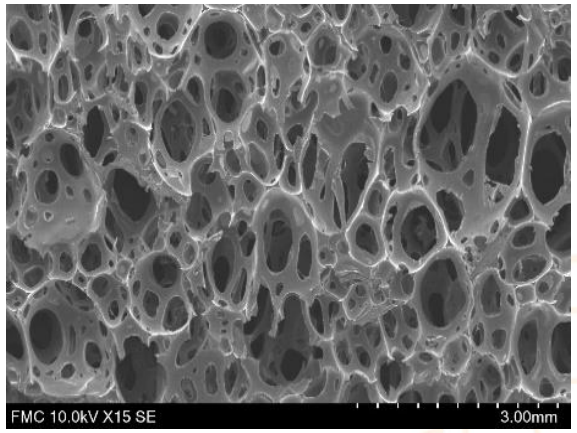
SHFFR+ 0% EG4



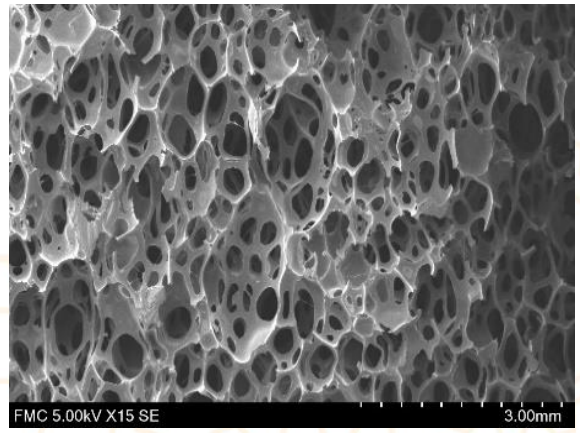
SHFFR + 10% EG4



SHFFR+ 15% EG4



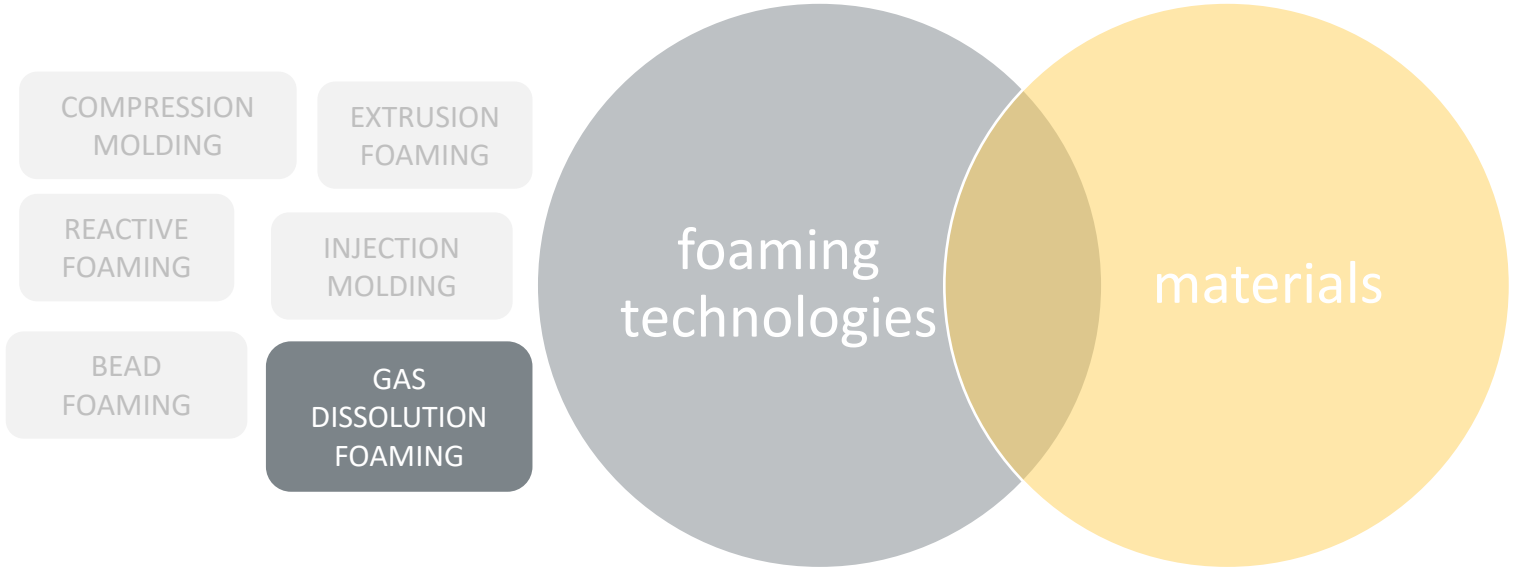
SHFFR + 20% EG4



INTRODUCTION

PROCESS/MATERIALS

Sustainability, **performance** and regulations are triggering innovation in technology and materials



TRADITIONAL

- POLYETHYLENE
- POLYSTYRENE
- EVA
- POLYPROPYLENE
- PVC
- RIDIG PU
- RUBBERS (NBR, SBR, NR...)
- FLEXIBLE PU
- POLYAMIDE
- POLYETHYLENE TEREPHTHALATE

TECHNICAL

- PVDF
- POLYETHERIMIDE
- POLYCARBONATE
- PMMA

BIO

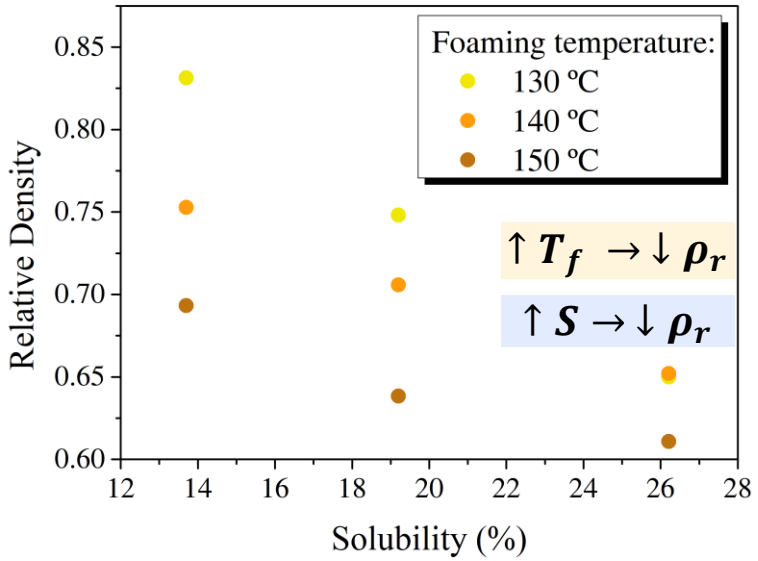
- STARCH
- POLYLACTIC ACID
- CELLULOSE ACETATE
- POLYHYDROXYALKANOATES
- POLYBUTYLENE ADIPATE TEREPHTHALATE
- POLYBUTILENE SUCCINATE

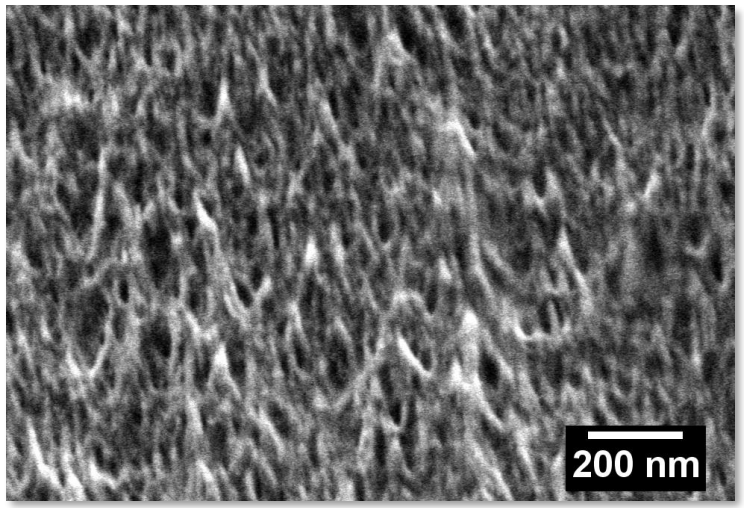
THERMOPLASTIC ELASTOMERS

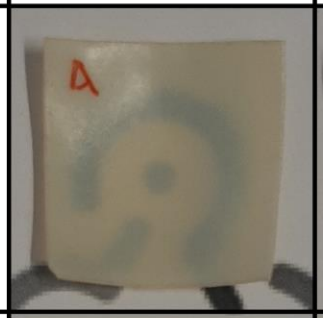
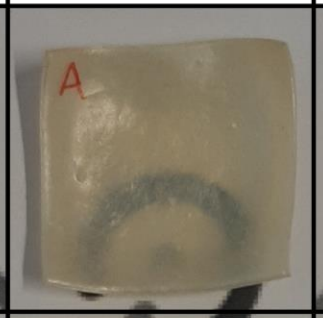
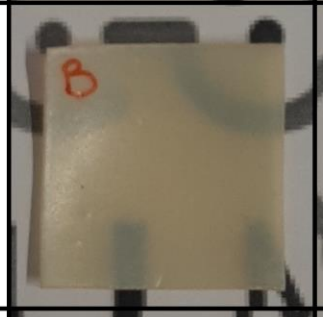
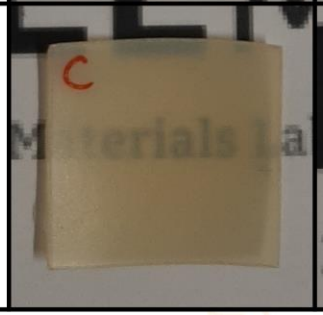
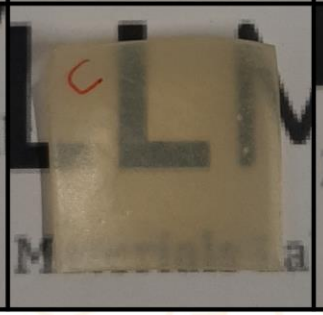
- STYRENIC TPES (TPSs)
- THERMOPLASTIC PU (TPUs)
- OLEFINIC TPES (TPOs)
- THERMOPLASTIC RUBBER VULCANIZATES (TPVS)
- POLYAMIDE TPES (TPAs)
- COPOLYESTER TPES (TPCs)

NANOCELLULAR FOAMS: nCell Technology

POLYETHERIMIDE (PEI)

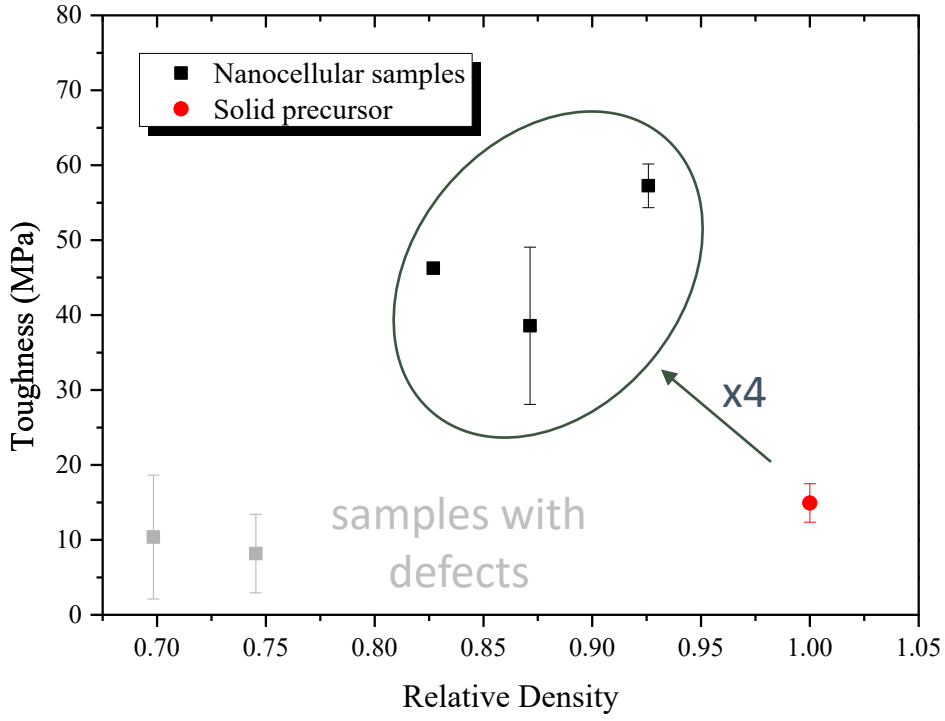


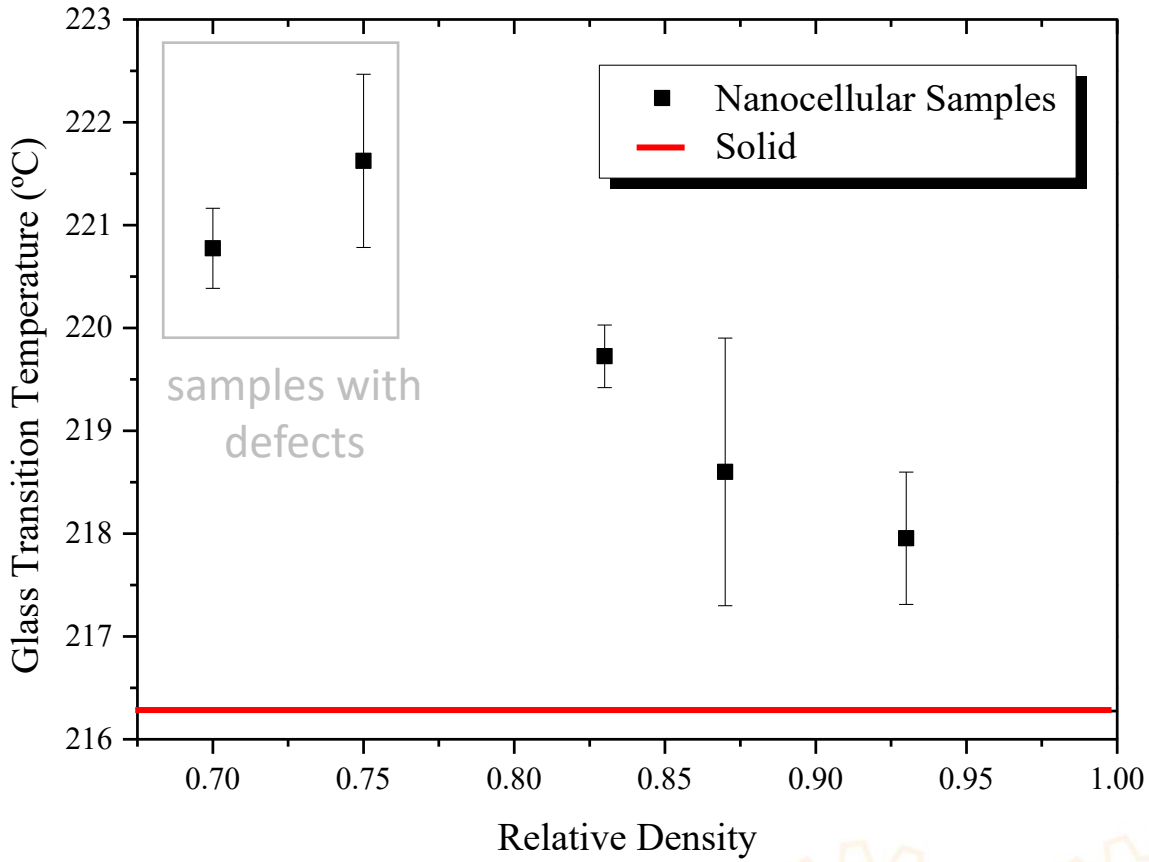


Saturation conditions →		6 MPa 24 ºC	20 MPa -10 ºC	20 MPa -32 ºC
Solubility →		Low	Medium	High
Nanocellular Samples 2 cm	Foaming Temperature: 150 °C			
	Foaming Temperature: 140 °C			
	Foaming Temperature: 130 °C			

NANOCELLULAR FOAMS: nCell Technology

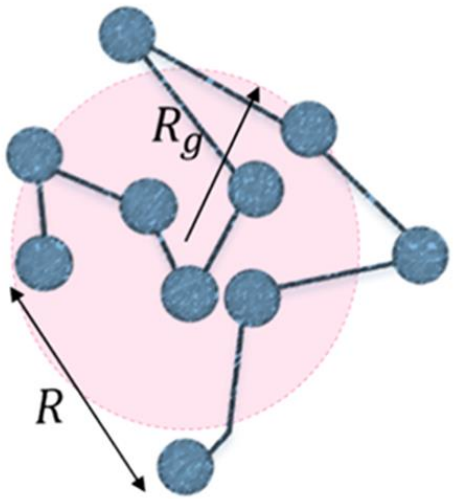
POLYETHERIMIDE (PEI)





FOAMS WITH BETTER PROPERTIES THAN THE SOLIDS ….!!

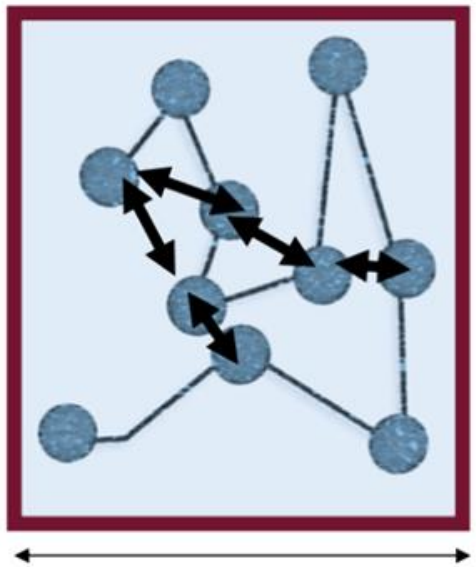
NANOCELLULAR FOAMS



polymer chain in the bulk

R: End-to-end distance of polymer chain

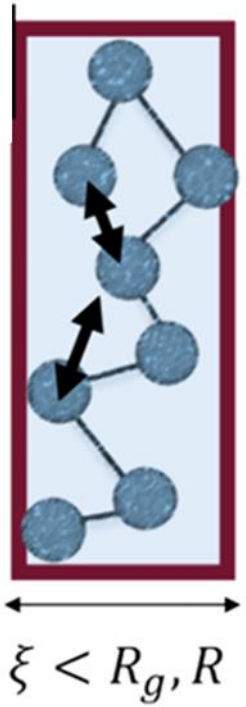
Rg: Radius of gyration



$\xi > R_g, \mathrm{R}$

polymer chains in cell wall (ξ) thicker than Rg and R

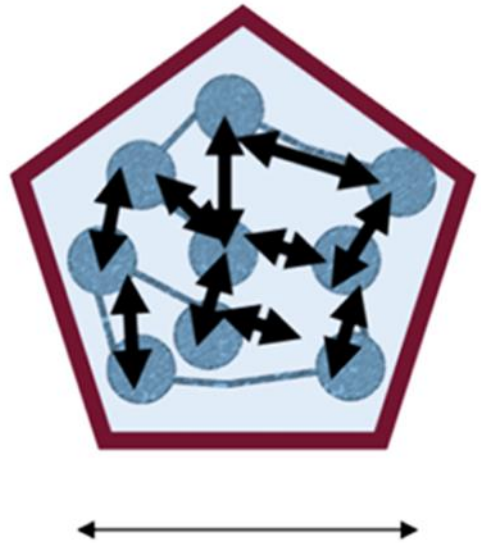
polymer chain in a cell wall (ξ) thinner than Rg and R



$\xi < R_g, R$

2D confinement

polymer chain confined within 3D nanopore wall smaller than Rg

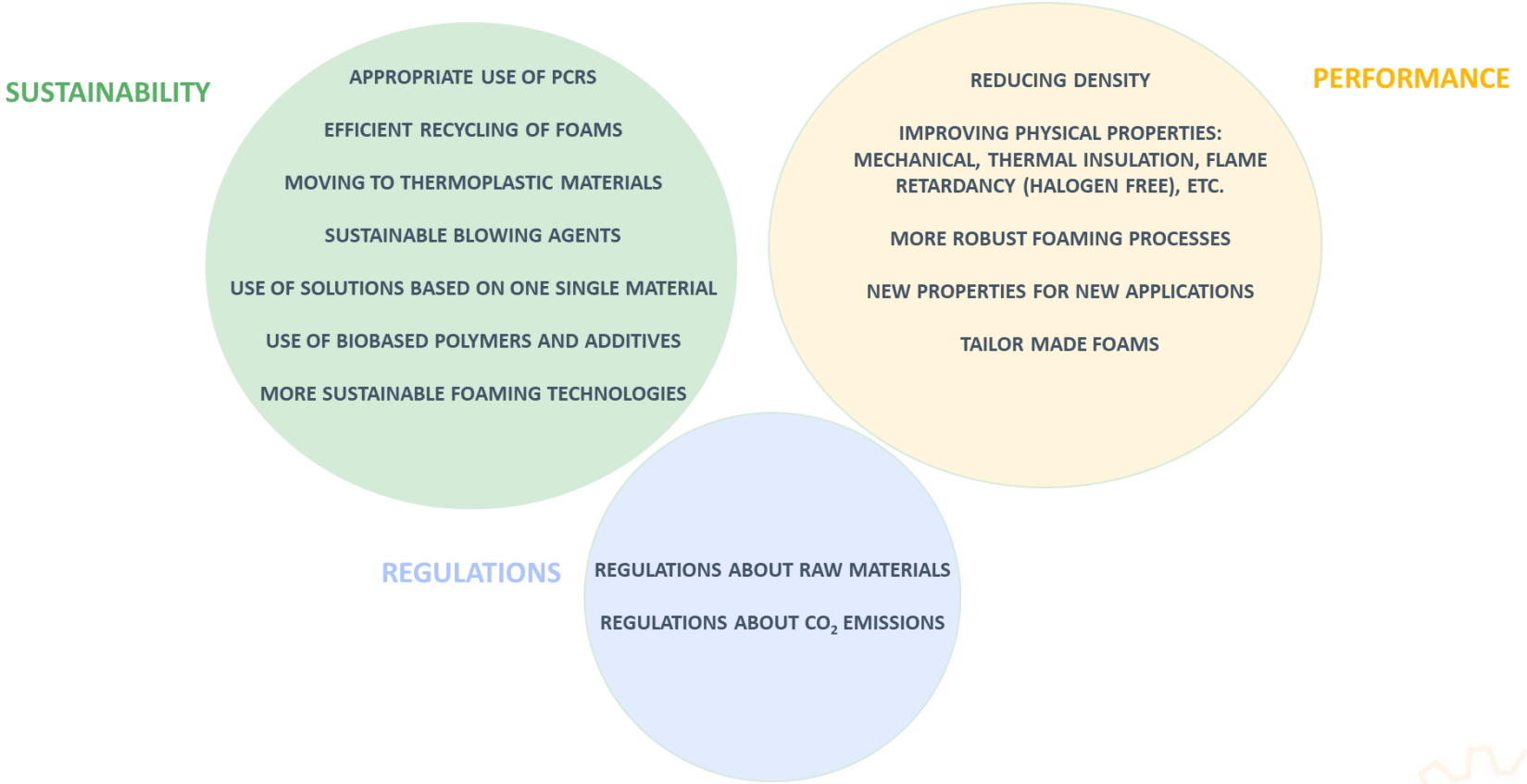


$\phi < R_g, R$

3D confinement

CONFINEMENT

SUMMARY



SEVERAL TECHNICAL APPROACHES ARE CURRENTLY UNDER STUDY TO ACCOMMODATE FOAMS TO THE DEMANDS OF SUSTAINABILITY, PERFORMANCE AND REGULATIONS. NO DOUBT WILL CONTINUE PLAYING A KEY ROLE FOR SEVERAL DECADES

THANK YOU SO MUCH FOR YOUR ATTENTION!

YOU CAN FIND MORE INFORMATION ABOUT OUR ACTIVITIES IN OUR WEBSITE:
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