Synthesis of Highly Porous Polymer Nanocomposite Foams With Graphene Oxide Via Dispersion-based Approach

UNSW SYDNEY

Never Stand Still

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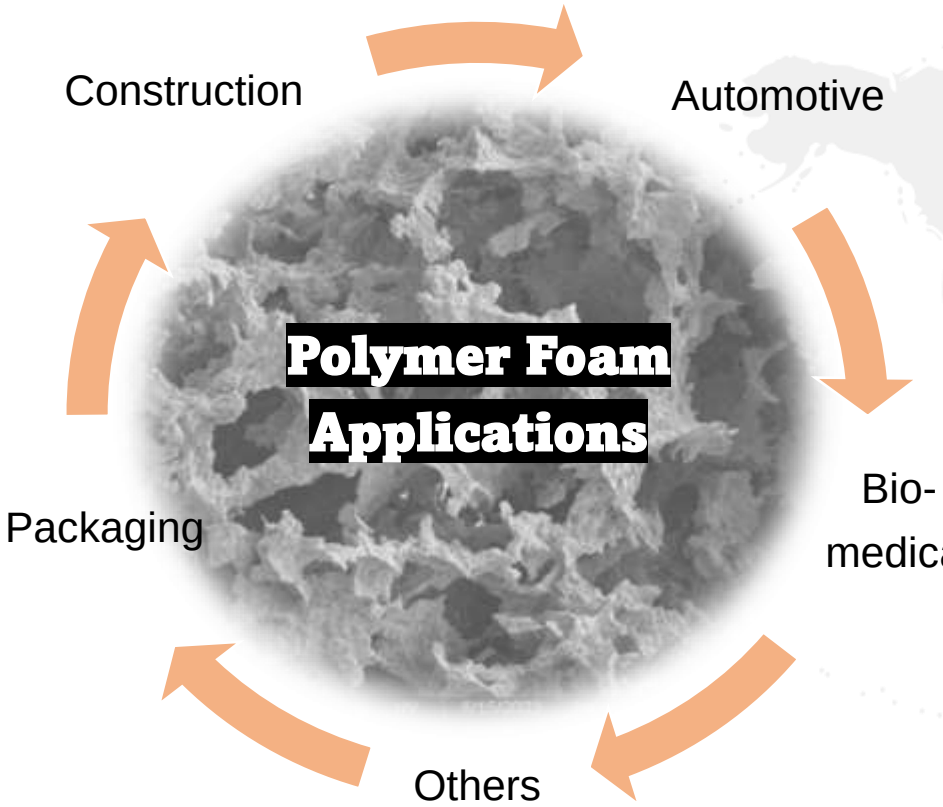
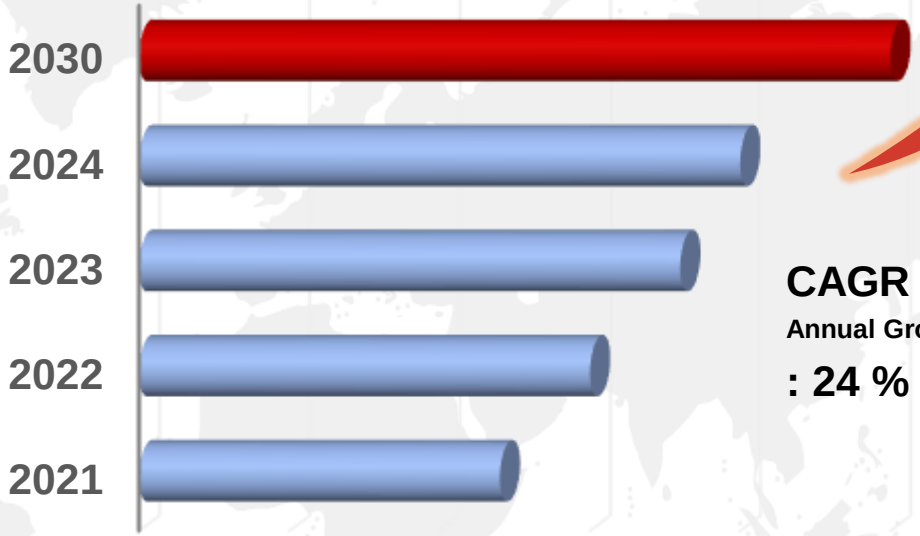
38APS

Polymer Foam



Polyurethane
Polystyrene
Polyolefin
Phenolic
Others…

Market Size



588 Billion USD!

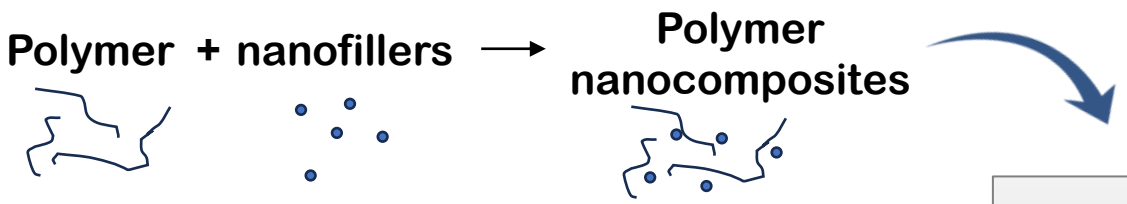
CAGR (Compound Annual Growth Rate) : 24 %

Key players

Sealed Air · HUNTSMAN · armacell · ZOTEFOAMS · covestro · kaneka

*** https://www.grandviewresearch.com/industry-analysis/polymer-foam-market**

Polymer Nanocomposites



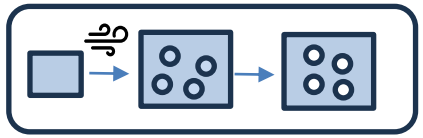
Polymer nanocomposites synthesis

- *In-situ* polymerization
  - Emulsion polymerization
    - **Miniemulsion**
    - **Physical mixing**
    - Sustainable
    - Environmentally friendly
- Solution polymerization
  - ↑ **Solvents**
- Melt mixing / blending
  - ↑ **Temperature, mechanical force**

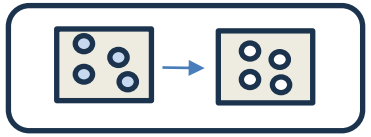
Polymer Foam Fabrication

Foam fabrication strategies

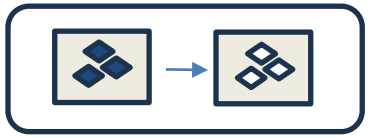
- Blowing agent



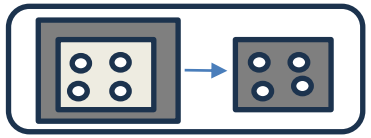
- High internal phase emulsion (HIPE)



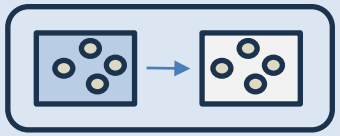
- Porogen leaching



- Dip-coating



- **Our strategy (Dispersion-based) approach**

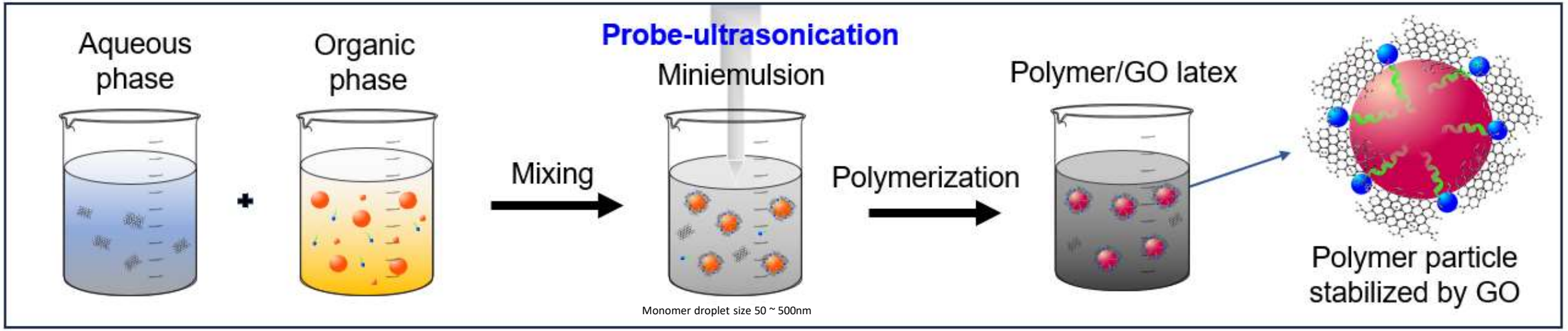


Emulsion polymerization (o/w)
+
Freeze-casting
↓
Polymer foam!

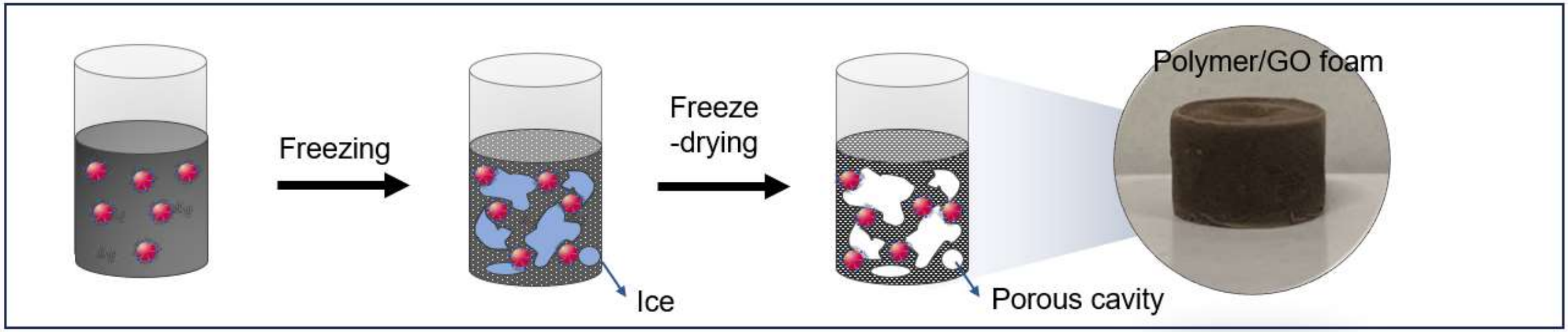
Patent * V. Agarwal, Per B. Zetterlund, R.A. Mat Noor "Polymeric nanocomposite foams", PCT International Application PCT/AU2022/050577'. 2022

Polymer Foam Fabrication Via Dispersion-based Approach

Step 1: Latex synthesis via miniemulsion polymerization

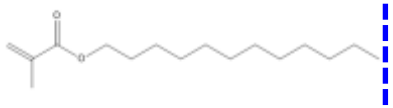
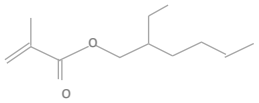
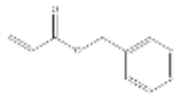
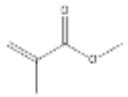


Step 2: Latex freeze-casting



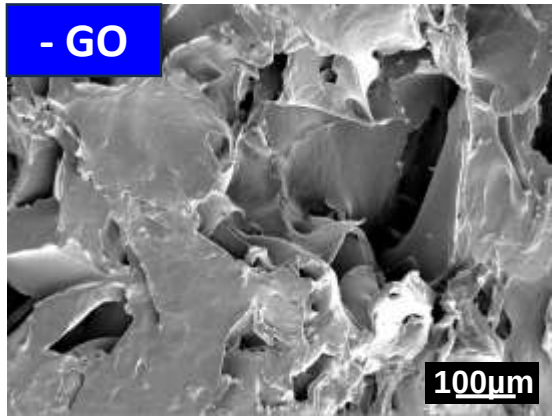
Polymer Foam Fabrication: Effect of T_g and GO

Effect of Glass Transition Temperature, T_g

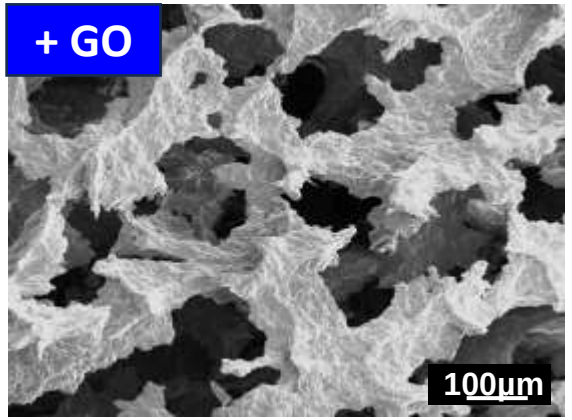
Monomer	Structures	T_g (°C)	Conversion (%)	Foam formation
Lauryl methacrylate (LMA)		-64	91	 ✓
n-Butyl acrylate (*n*-BA)		-49	98	 ✓
2-Ethyl hexyl methacrylate (EHMA)		-10	94	 ✓
Benzyl acrylate (BzA)		7	89	 Fragile and brittle foam
Methyl methacrylate (MMA)		106	96	

Polymer foam formation via dispersion-based method highly affected by polymer T_g

Effect of GO



Dense foam



Better porosity

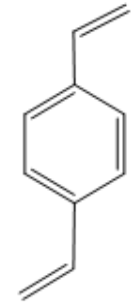
Polymer Foam Fabrication: Effect of Cross-linkers

Synthesis of P(*n*-BA/DVB) and P(*n*-BA/EGDMA) with GO by miniemulsion polymerization

■ Recipes

Exp 1	Composition (%)
n-Butyl acrylate(*n*-BA)	7 wt%
Divinylbenzene (DVB) *	**0 ~ 20 wt%**
Initiator (AIBN)	0.25 M
Surfactant (SDS)	1 wt%
Hydrophobes (HD) *	5 wt%
Nanofiller (GO) *	5 wt %

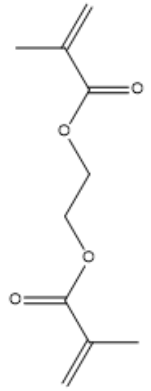
* Relative to monomer



DVB

Exp 2	Composition (%)
n-Butyl acrylate(*n*-BA)	7 wt%
Ethylene glycol dimethacrylate (EGDMA) *	**0 ~ 20 wt%**
Initiator (AIBN)	0.25 M
Surfactant (SDS)	1 wt%
Hydrophobes (HD) *	5 wt%
Nanofiller (GO) *	5 wt %

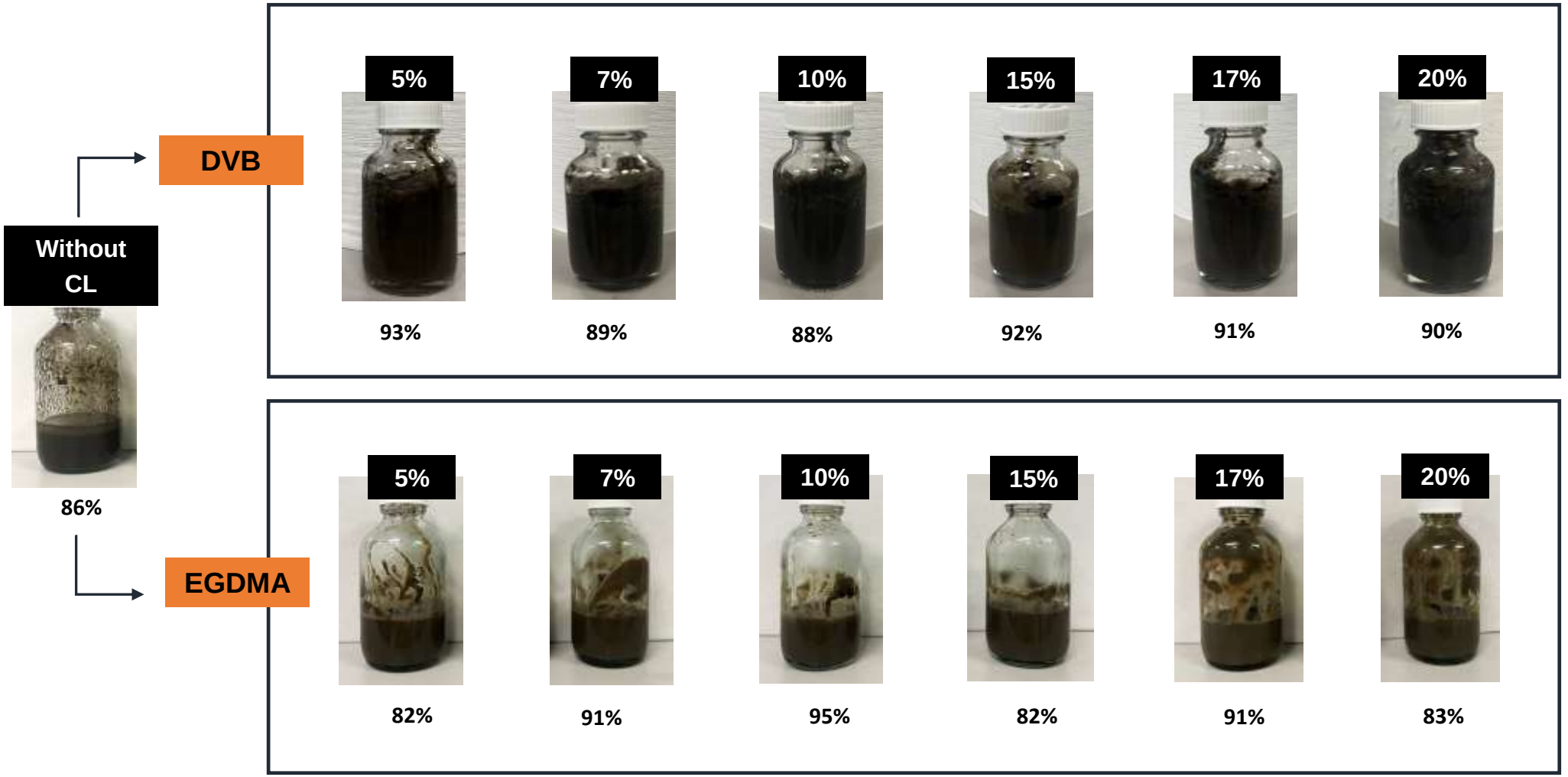
* Relative to monomer



EGDMA

Polymer Foam Fabrication: Effect of Cross-linkers

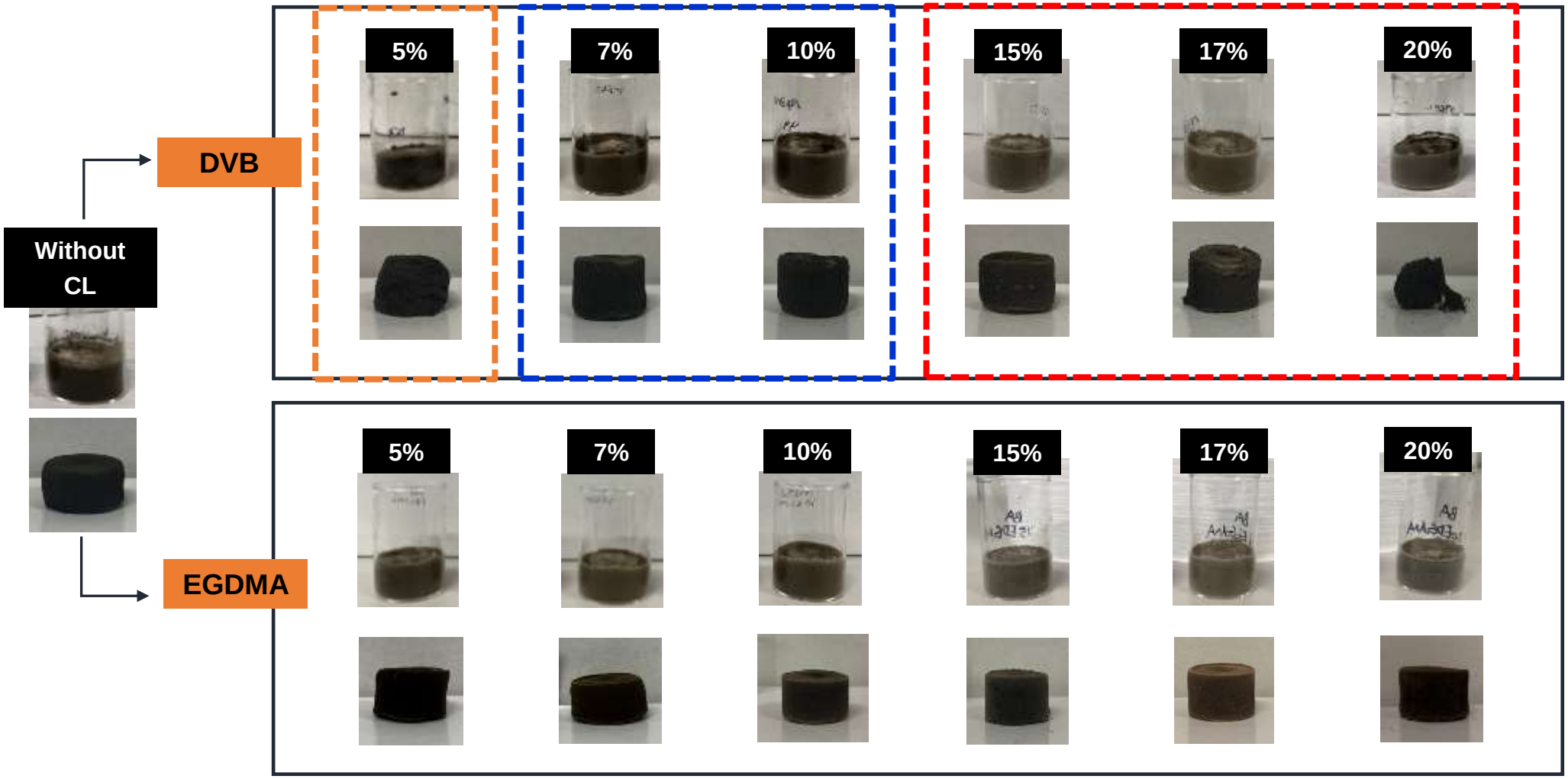
■ P(*n*-BA/crosslinker with 5% GO) latexes after miniemulsion polymerization



All compositions produce homogenous latex

Polymer Foam Fabrication: Effect of Cross-linkers

■ P(*n*-BA/crosslinker with 5% GO) foam formation after freeze-casting



5%: Dense foam

7~10% : Good foam

> 15% : Brittle foam

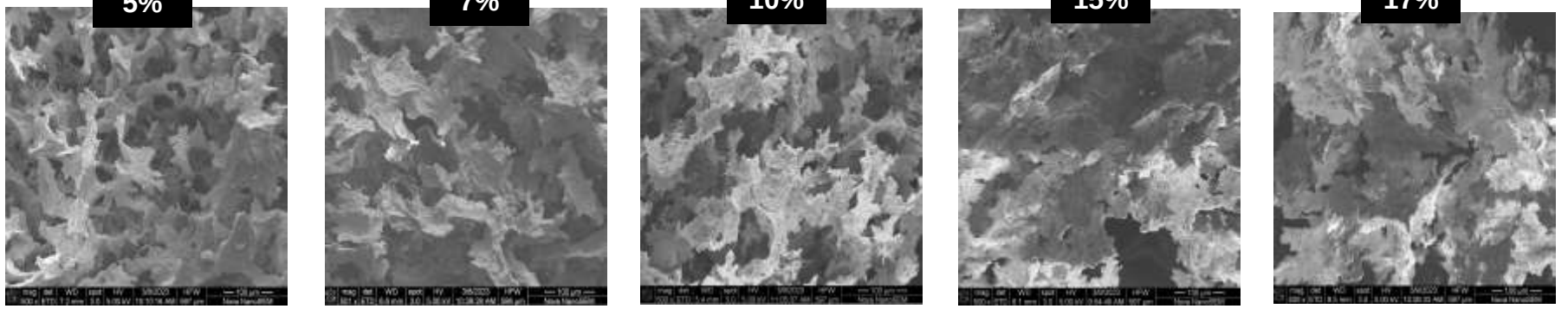
All EGDMA latex compositions produce better foam structure compared to DVB system

SEM Analysis

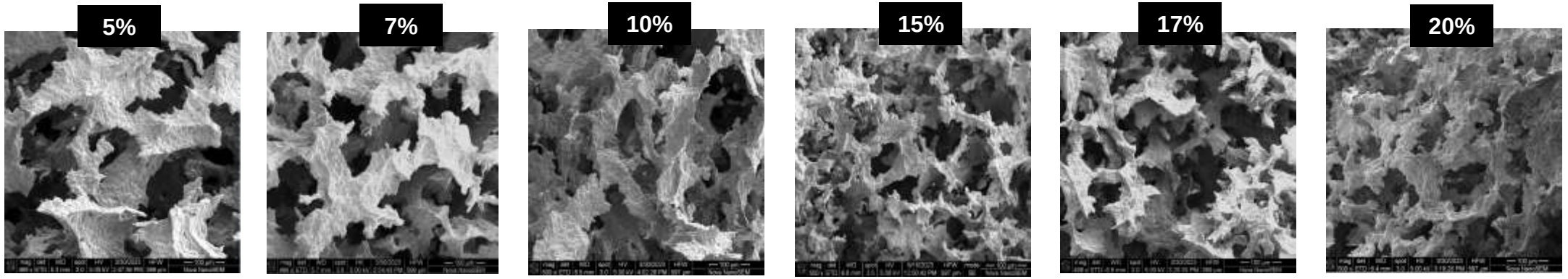
Foam microstructures

Scale : 100 µm

DVB

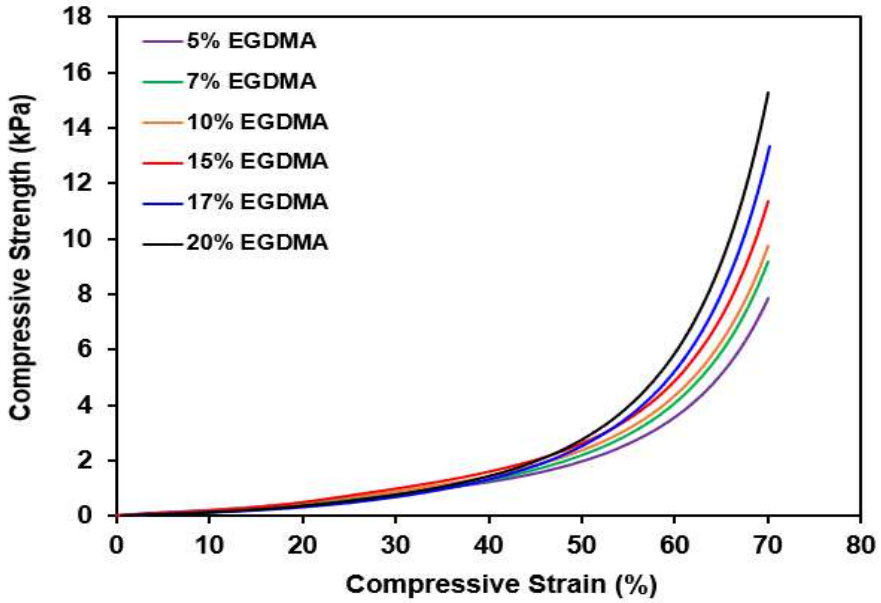


EGDMA



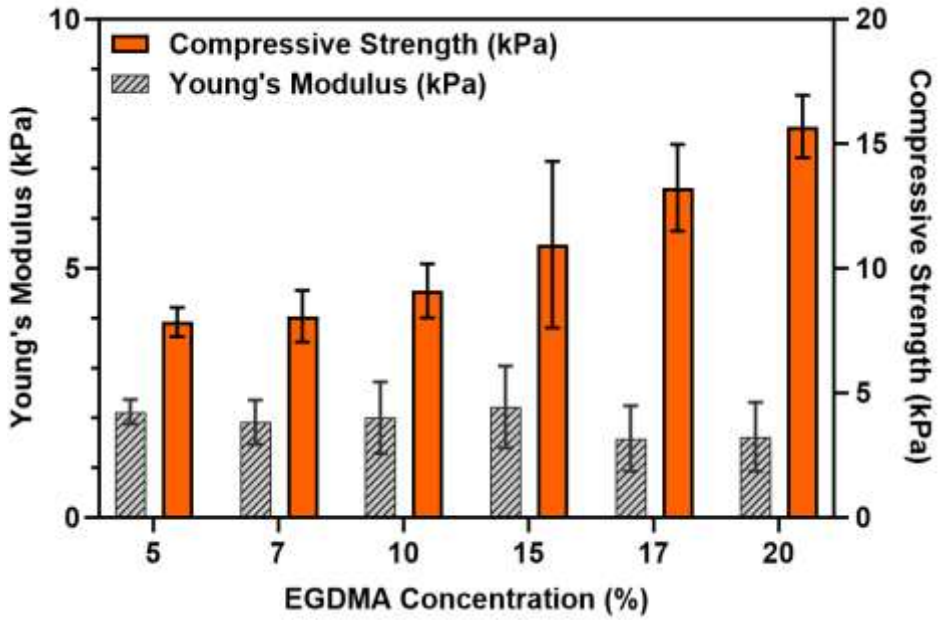
Dynamic Mechanical Analysis (Compression)

~Compressive Strength :
Maximum strength at 70% strain
~Young's Modulus:
Stiffness/ slope of stress/strain up to 10% strain

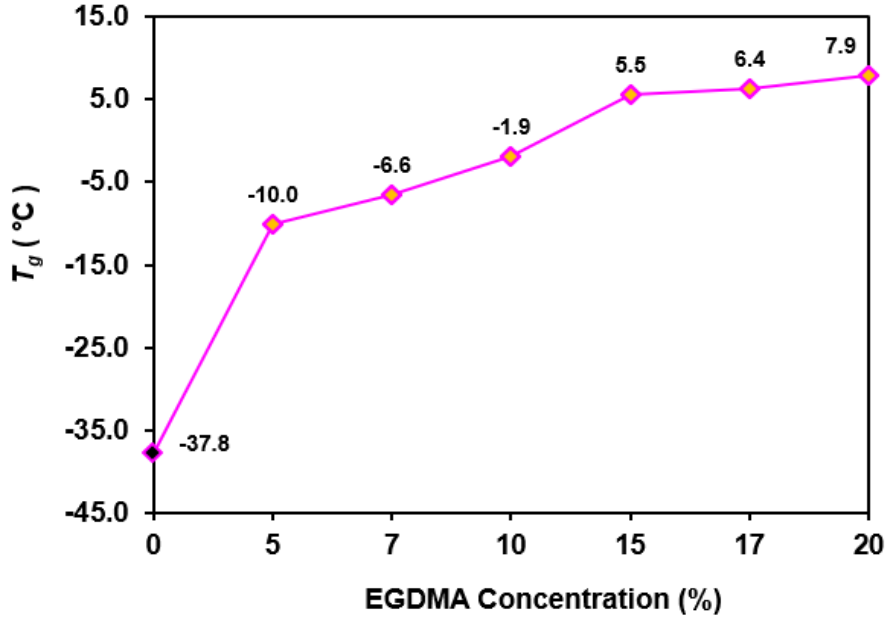


- **Compressive Strength ↑ with increasing EGDMA %**

- **Young's Modulus between 1.59 ~ 2.22 kPa**



Foam T_g : Peak of Tan delta curve obtained from DMA temperature ramp test

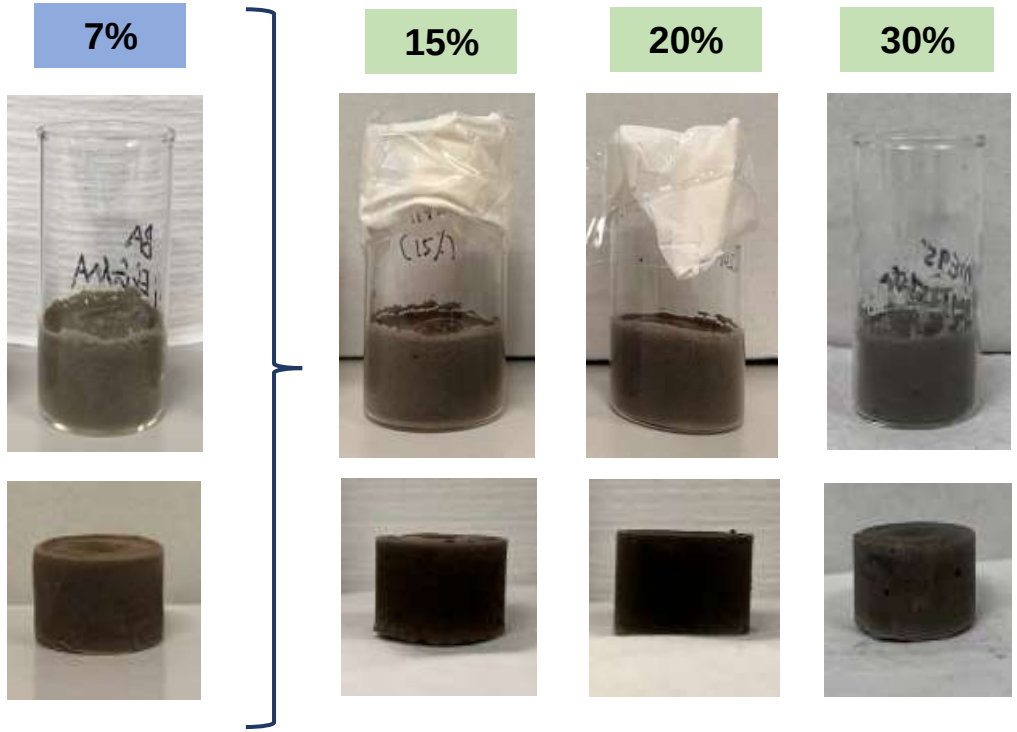


Foam T_g (°C) range is between -38 °C ~ 8°C

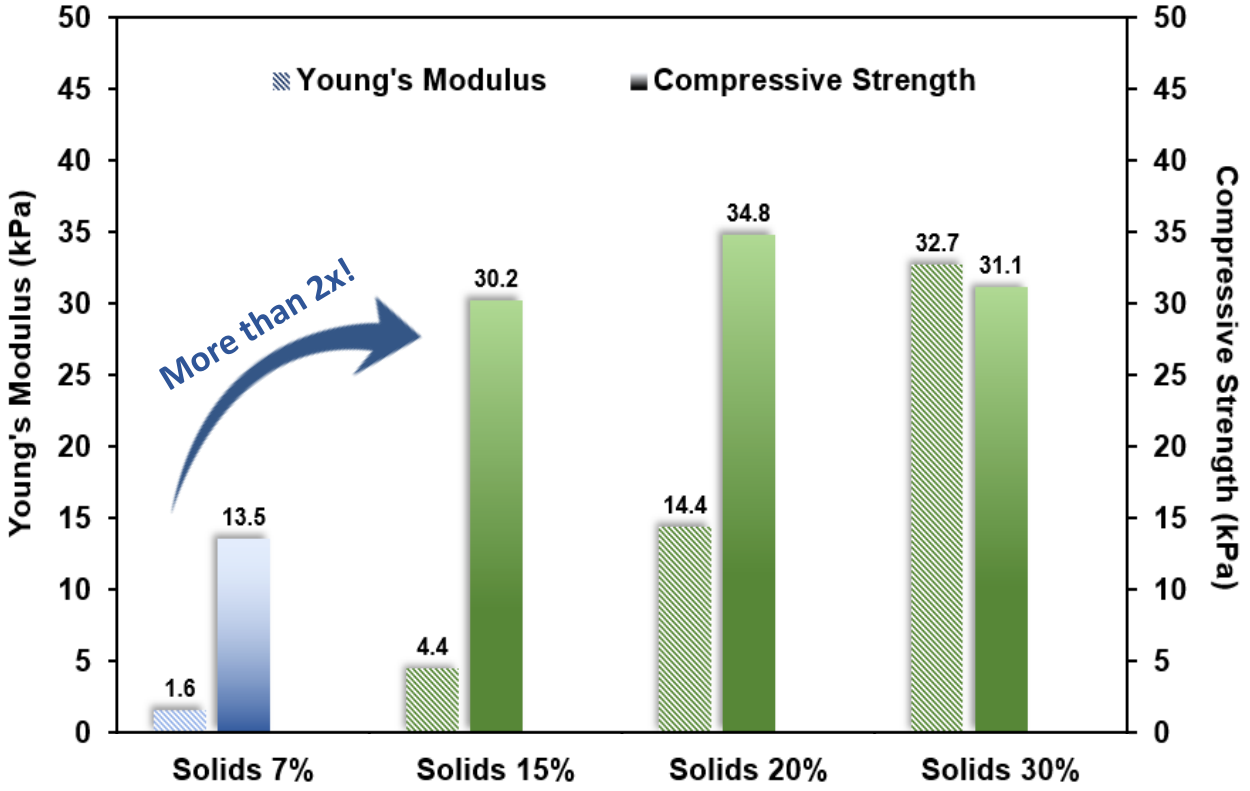
Polymer Foam Fabrication: Effect of Solids Content

Synthesis of P(*n*-BA/EGDMA) with 5% GO by miniemulsion

Solids content ↑ from 7% → **15, 20, 30%**



Highly durable and robust foam

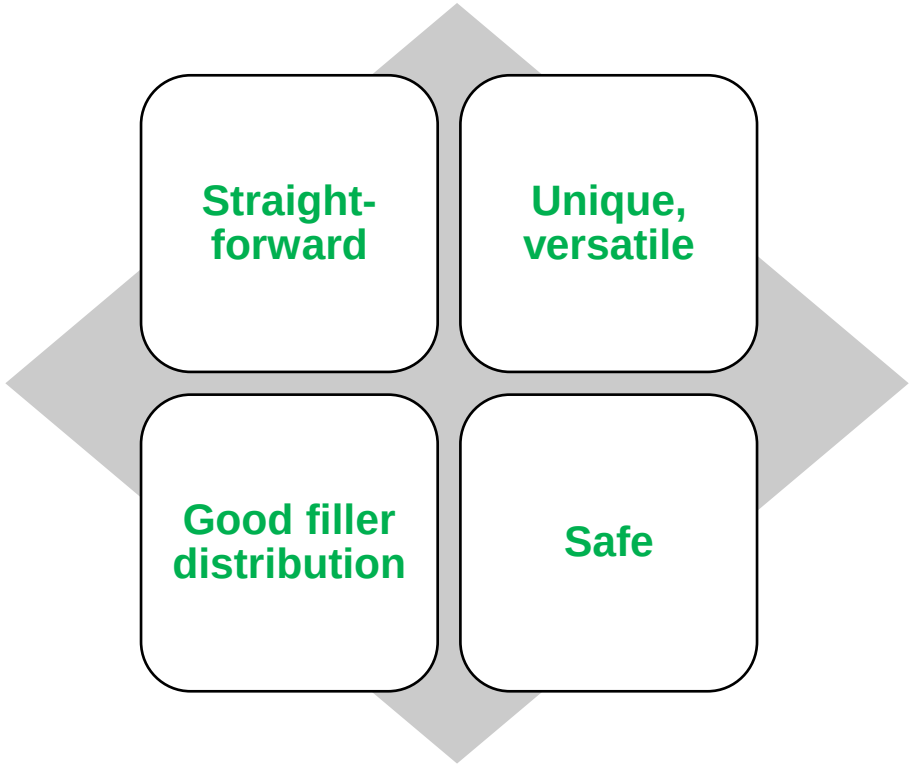


Young's Modulus and Compression Strength significantly ↑ with higher solids contents

Summary

1

Polymer foam formation via our aqueous dispersion-based method is……



2

- **Cross-linker types**
- **Solids content**

……affects overall foam formation and its mechanical properties

Acknowledgments

Supervisors

- Per Zetterlund

- Vipul Agarwal

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38th APS Organizers

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THANK YOU