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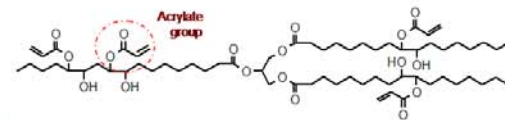
Objective: Plant Oil-Based Foams

Soybean-based polymers are investigated for the replacement of Petroleum-based resins in several foam applications. The main advantage is the use of affordable, renewable resources. The targeted bio-based polymeric foams would have qualities comparable to petroleum based foams, plus potential biodegradability.

Plant oils main constituents are triglycerides, which can be functionalized to enable polymerization.

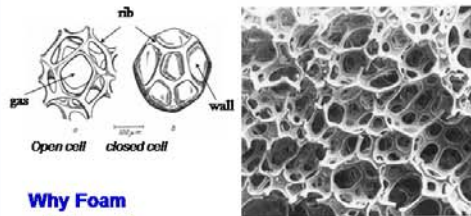
Example of monomer used in this research:

Acrylated Epoxidized Soybean Oil triglyceride (AESO):



Forms a thermosetting resin through free-radical polymerization (with an initiator).

General Foam Structure and Properties



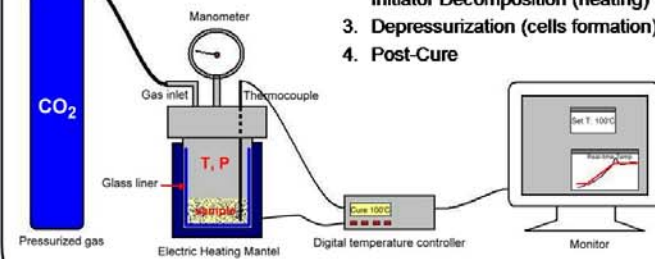
Why Foam a Polymer?

- Density reduction.
- Great weight-to-strength ratio.
- Added flexibility, or rigidity.
- High thermal and electrical insulation properties.
- Large absorption potential (open-cell).
- High impact resistance.
- Sound-dampening property.

Pictures from "Handbook of Polymeric foams"

High-Pressure Foaming Process for Thermosetting Resins

CO₂ or N₂
Gas or Supercritical
50 < T_{crit} < 140°C
20 < P_{crit} < 100 bar



General Process Steps:

1. Dissolution of CO₂ into monomer at high pressure
2. Polymerization triggered by Initiator Decomposition (heating)
3. Depressurization (cells formation)
4. Post-Cure

CO₂ was chosen for its high solubility in organic oils. Non-reactive. Affordable. Environmentally benign.

Creation of Stable Bubbles

The CO₂ cells need to be formed *after* the beginning of the polymerization reaction and *before* the gel point, for an ideal working viscosity μ that allows cells growth and stabilization, or:

- μ too low: coarsening, coalescence, collapse \Rightarrow foam destruction.
- μ too high: no cell formation or foam expansion.

Factors affecting the viscosity:

Polymerization $\Rightarrow \mu \uparrow \uparrow$ with the extent of reaction.
CO₂ Pressure $\uparrow \Rightarrow$ CO₂ Solubility \uparrow .
CO₂ is solvent & plasticizer $\Rightarrow \mu$

\downarrow
Temperature $\uparrow \Rightarrow \mu \downarrow \downarrow$.
but: Faster polymerization $\Rightarrow \mu \uparrow$
Lower CO₂ solubility $\Rightarrow \mu \uparrow$

The right combination of temperature, pressure and reaction time are necessary for the formation of the foam

Process Parameters and Additives

P and T \Rightarrow CO₂ solubility in AESO \Rightarrow Foam Density. Foam mecha. properties best with dense, small cells.

Choice of T for the best foam structure:

Cell size \uparrow when T $\uparrow \Rightarrow$ Low T desired
Cell density $\downarrow \downarrow$ when T $\uparrow \Rightarrow$ Low T desired
Foam density \downarrow when T $\uparrow \Rightarrow$ High T desired

Choose optimal Temp.

Choice of Pressure:

Cells size \downarrow and cells density $\uparrow \uparrow$ when P \uparrow
 \Rightarrow Highest P desired
Low P desired for economical purposes

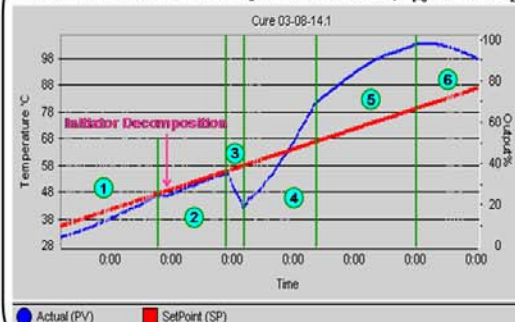
\Rightarrow Choose P as a function of ideal T and desired Foam Density.

Additives:

Nucleating Agent (solid powder) increases cells density.
Surfactant enhances bubbles stability before gelation.
Catalyst allows to trigger the reaction at desired T.

High-Pressure Foaming Experiment

AESO +2% Initiator +0.2% Catalyst +10% Surfactant, P_{in}=60 bar CO₂



This procedure allows triggering both the polymerization and cell formation at the same time, and at low temperature.

The monomer sample is pressurized with CO₂ until saturation. Then the foaming steps are:

- 1 Heating. The presence of catalyst lowers the initiator's decomposition temperature.
- 2 After initiation, the polymerization starts slowly.
- 3 Depressurization at chosen temp. T drops from CO₂ vaporization (endothermic phenomenon). Formation of a liquid foam, stabilized by Surfactant.
- 4 Mixing and concentration of reactives triggers fast polymerization: viscosity increases. +External heat.
- 5 Stop heat: exotherm from Propagation reaction only.
- 6 Termination reaction and cooling of the solid foam.

Future Work

- Control of foam properties: use elastomeric, linear, or highly cross-linked polymers \Rightarrow Wide range of mechanical properties for different foam applications.
- Foam composites with natural fibers.