Effect of Impact Modification on the Foamability of Wood Fiber-Plastic Composites

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Outline

- Introduction
- Objectives
- Experimental
- Results and Discussion
- Conclusions

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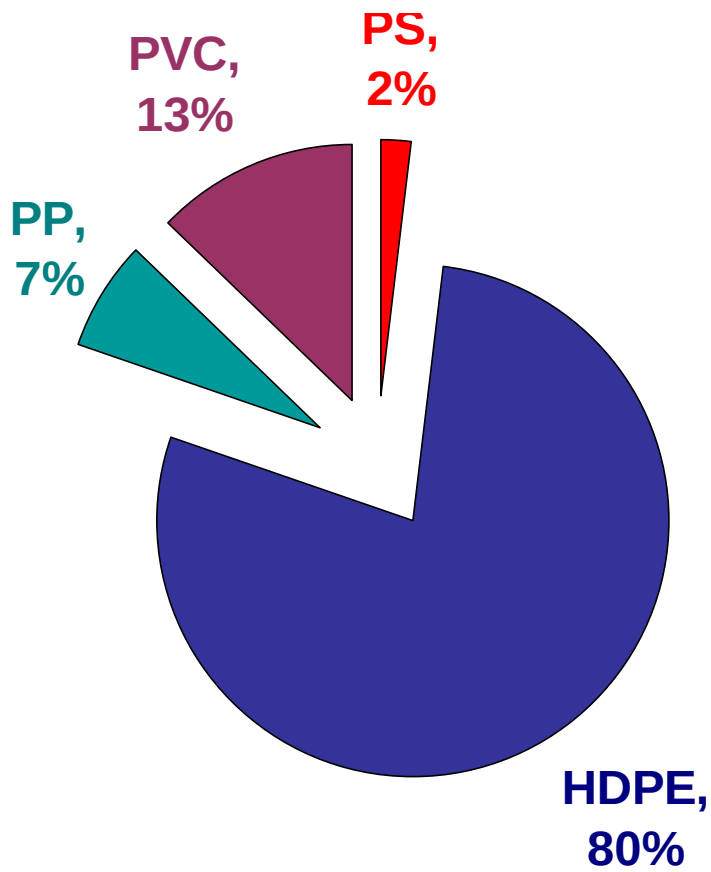
Wood Plastic Composites (WPCs)

- WPCs are already a 1.3-billion-lb market.
- Market growing at 20% annually.



Source: L. Manolis Sherman, www.plasticstechnology.com, July 2004

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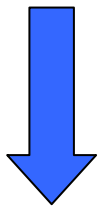
Issues for WPCs

- Have not proven to be “maintenance free” as originally touted.
- splitting, warpage, staining and discoloration, etc. problems have been reported.



Additives are needed

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Issues for WPCs (cont'd)

- Denser than solid wood lumber

Lumber Products	Density (g/cm^3)
WPCs	1 – 1.4
Eastern white pine	0.35
Red maple	0.54

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Foaming Agents in WPCs

- About 20% of all WPCs products (**mostly PVC/wood**) are foamed.
- Reduce weight and material cost.
- Improve surface appearance, processing speed.
- Ease nailing, sawing, screwing, etc.

Typical Formulation for PVC

Ingredients	**Content** (phr)
PVC	100
Heat stabilizer	< 3
CaSt	< 2
Wax	< 2
External lubricant	< 3
Internal lubricant	< 3
Impact modifier	**5 – 20**
CFAs	1.5 – 3.0

Objectives

- Examine the influence of impact modification the foamability of WPCs.

- Study the effects of impact modifier types and contents on the:
  - ***sorption behavior of gas in WPCs.***
  - ***density and cell morphology of foamed WPC samples.***

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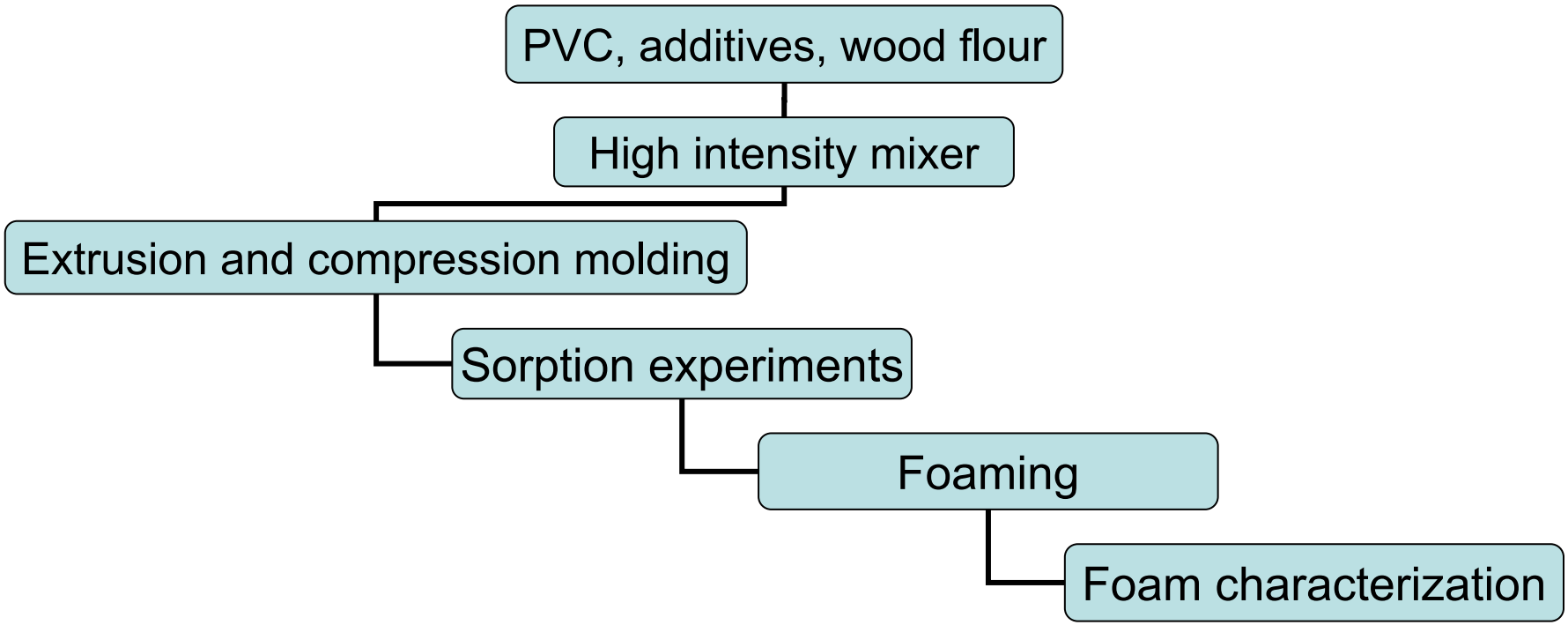
Overall Method



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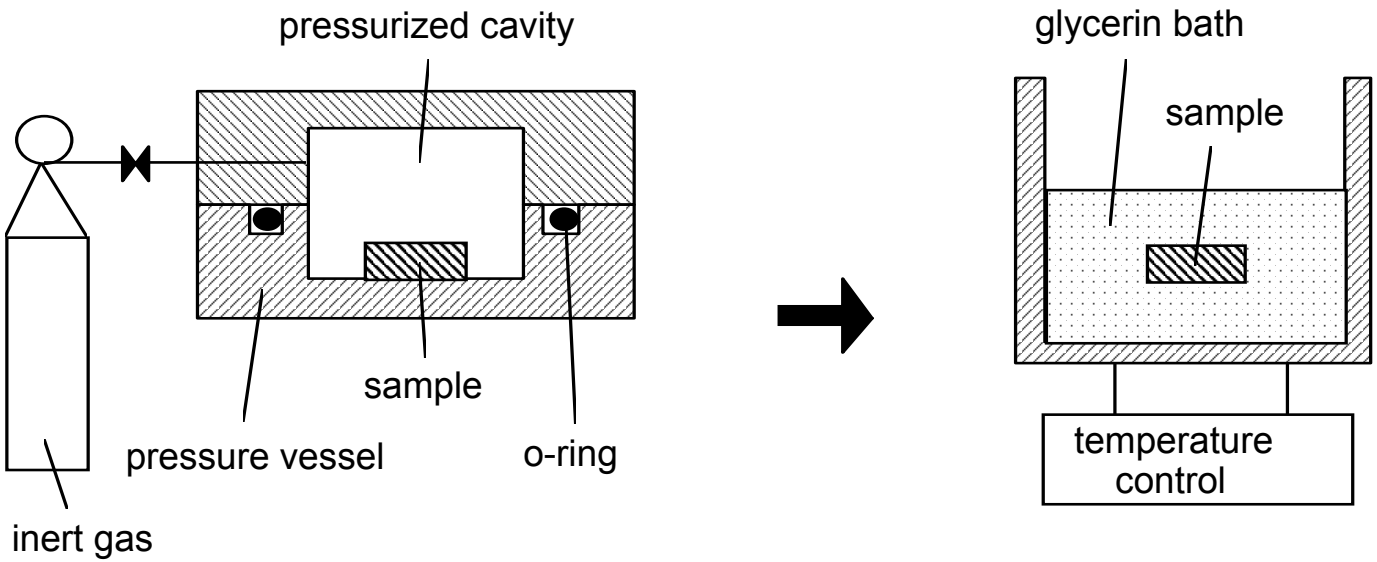
Materials

- Rigid PVC (proprietary formulation)
- 45 phr maple wood flour (100 mesh size)
- 0.75 phr amino-silane coupling agent
- 0-30 phr impact modifiers:
  - All-acrylic (ACR): crosslinked (core-shell)
  - Chlorinated PE (CPE): uncrosslinked with 36% of chlorine

Batch Microcellular Foaming Process



1. Gas saturation process

2. Foaming process

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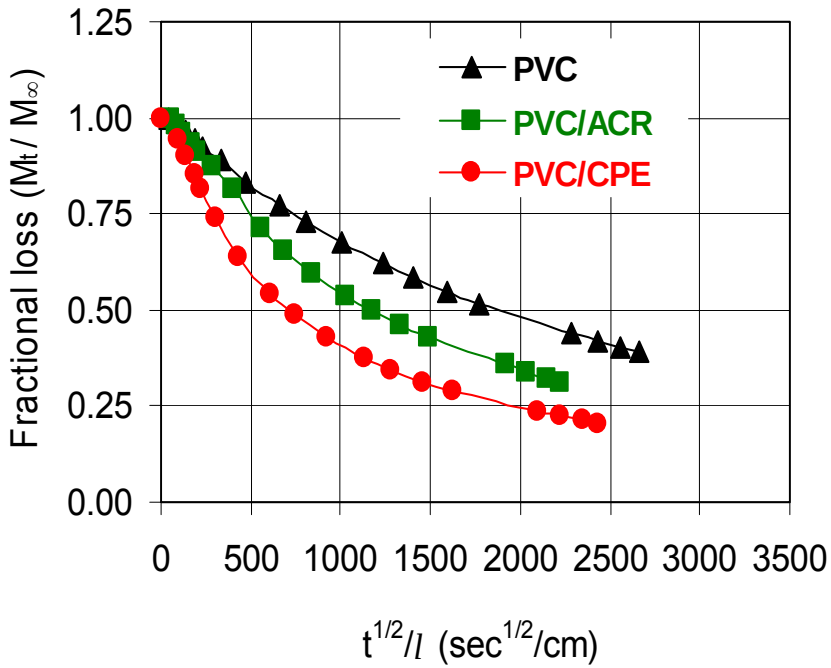
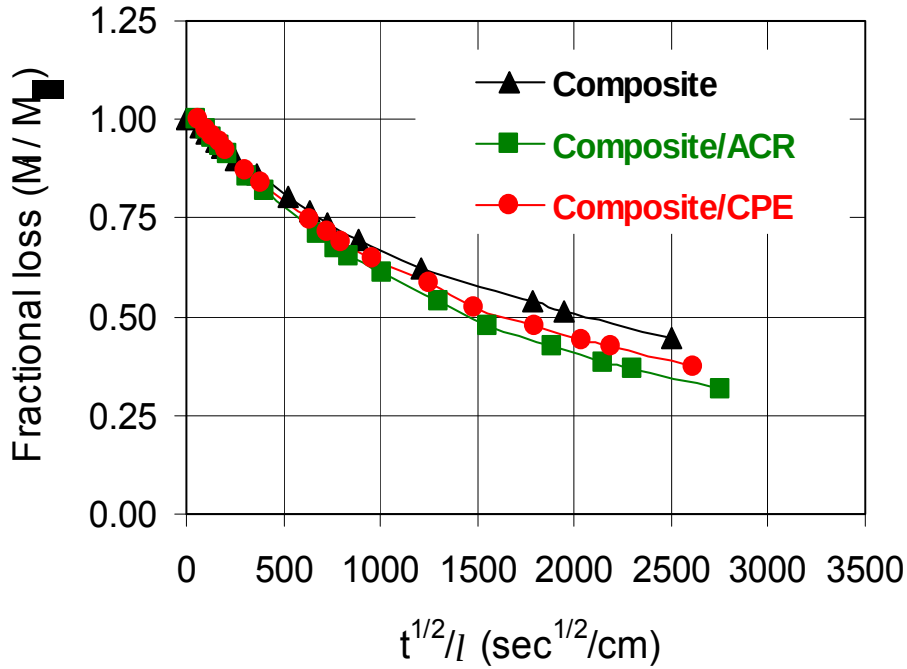
Desorption Curves

Neat PVC samples



PVC/wood-flour composites



- **12 phr ACR and CPE impact modifiers**

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Diffusion Theory

$$D = \frac{\pi}{16}\left[\frac{d\left(\frac{M_t}{M_\infty}\right)}{d\left(\frac{\sqrt{t}}{l}\right)}\right] \quad \text{(absorption)} \qquad D = \frac{0.049}{\sqrt{t/l}} \quad \text{(desorption)}$$

D: diffusivity of the gas

M_t: mass uptake at time t

M_∞: mass uptake at infinite time

t: time

l: thickness of the sample

$\sqrt{t}/l$ is the value at which $\frac{M_t}{M_\infty} = 0.50$

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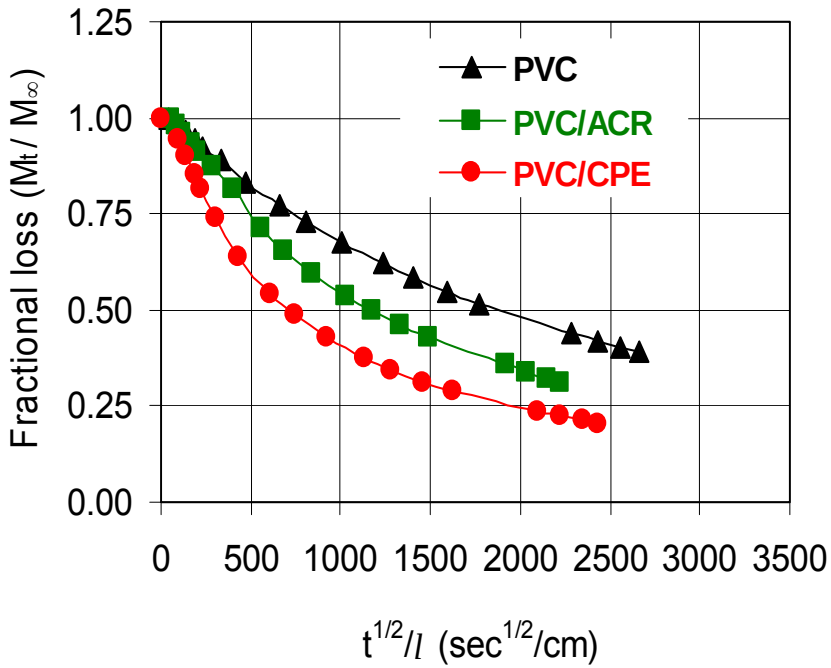
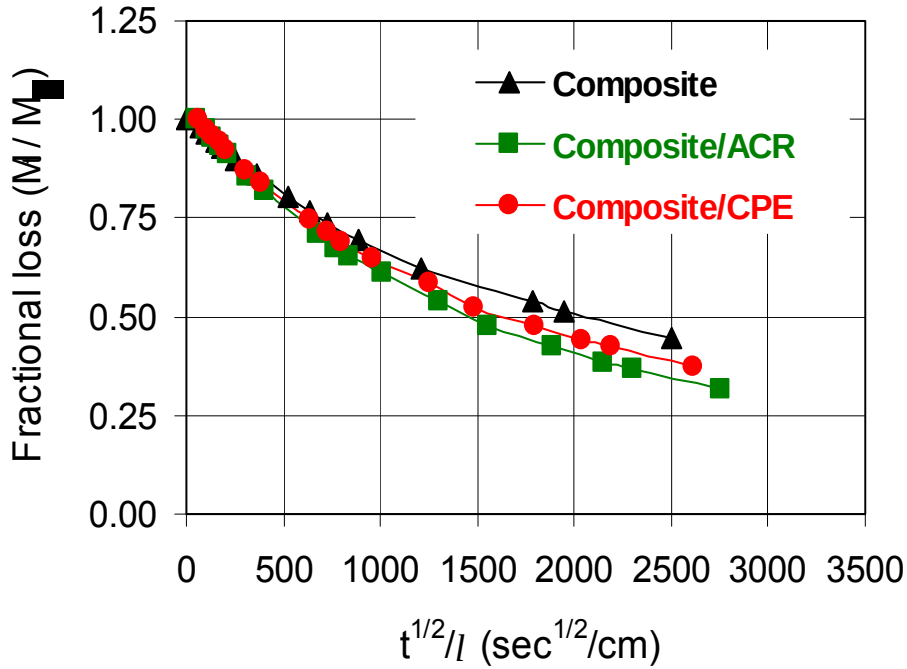
Desorption Curves

Neat PVC samples



PVC/wood-flour composites



- **12 phr ACR and CPE impact modifiers**

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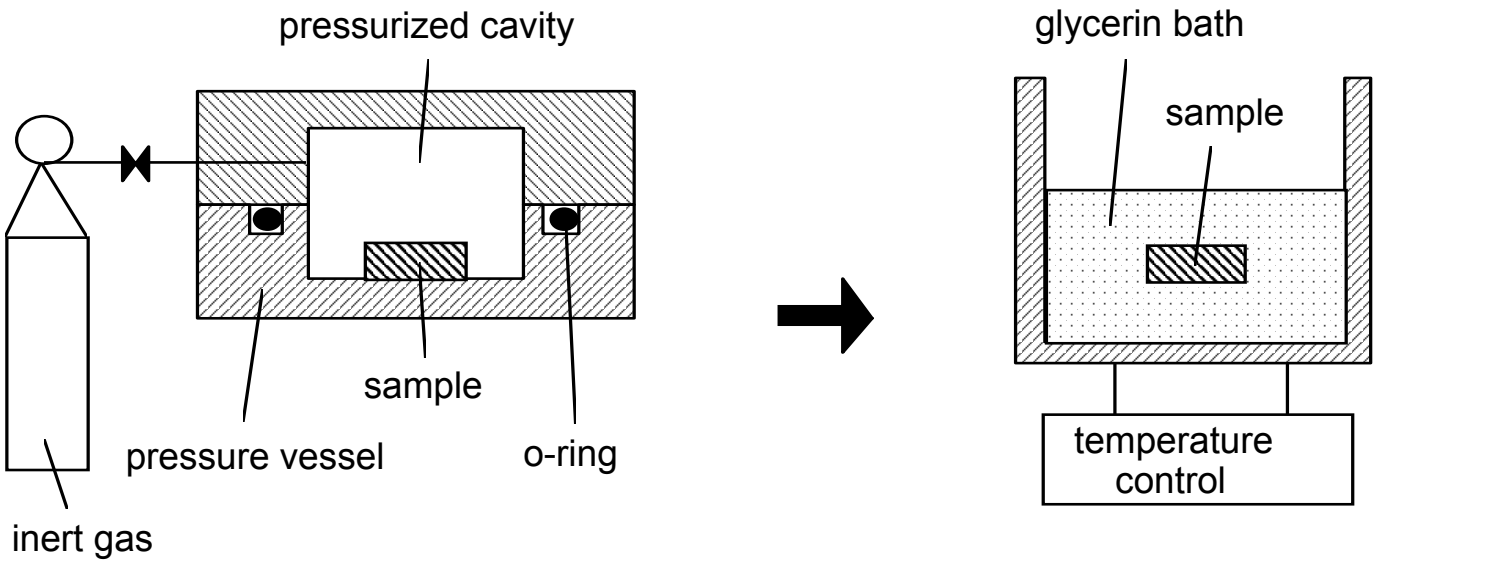
Batch Microcellular Foaming Process

100°C

20 sec



1. Gas saturation process

2. Foaming process

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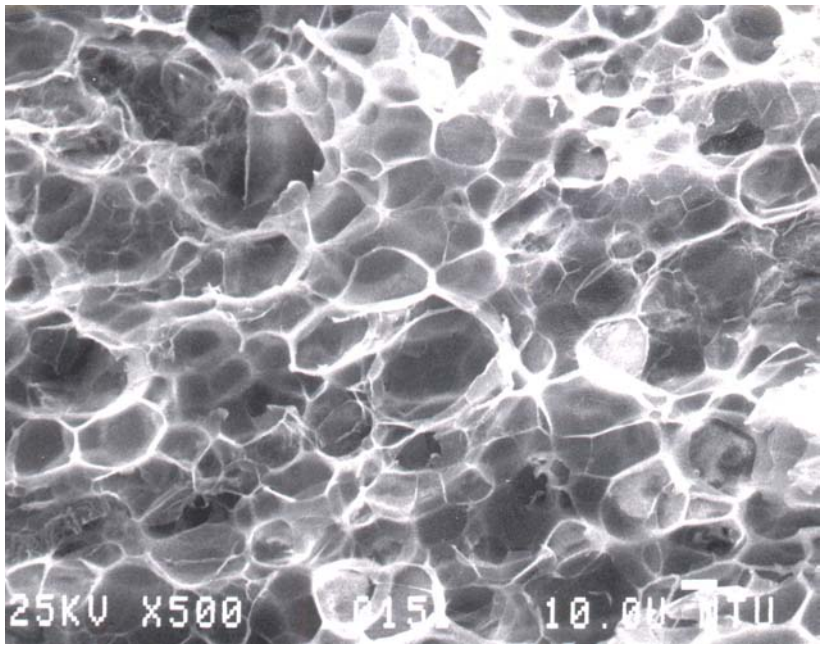
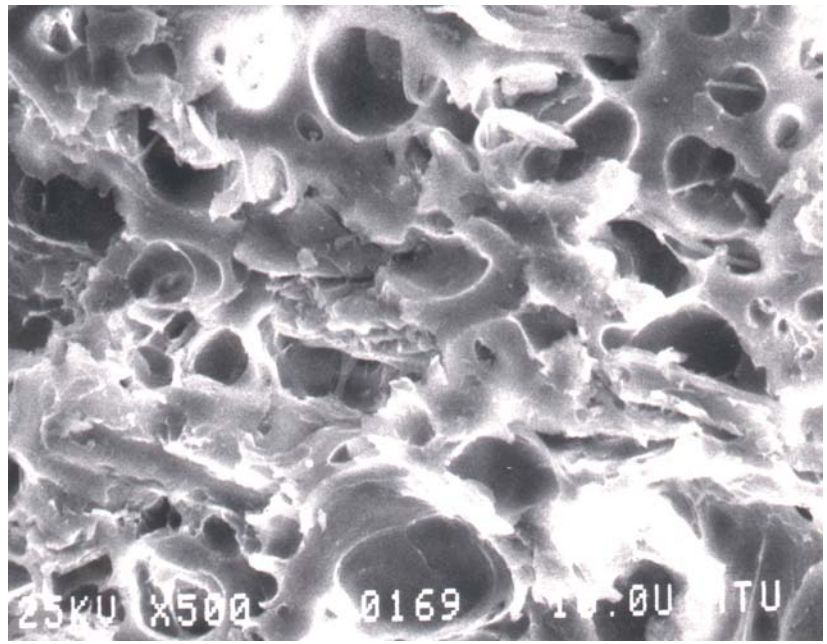
Microcellular Foamed Samples

unfilled rigid PVC sample



rigid PVC/wood-flour composite



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Foam Characterization

$$V_F = 1 - \left(\frac{\rho_F}{\rho} \right)$$

VF: void fraction or density reduction

ρ_F: density of foamed samples

ρF: density of unfoamed samples

Effect of Impact Modification on the absorbed CO_2 content

Impact modifier contents (phr)	Measured CO_2 contents (%)			
	PVC		Composites	
	ACR	CPE	ACR	CPE
0	8.6	8.6	6.6	6.6
12	10.2	8.7	8.1	5.8
30	14.6	8.5	12.2	7.7

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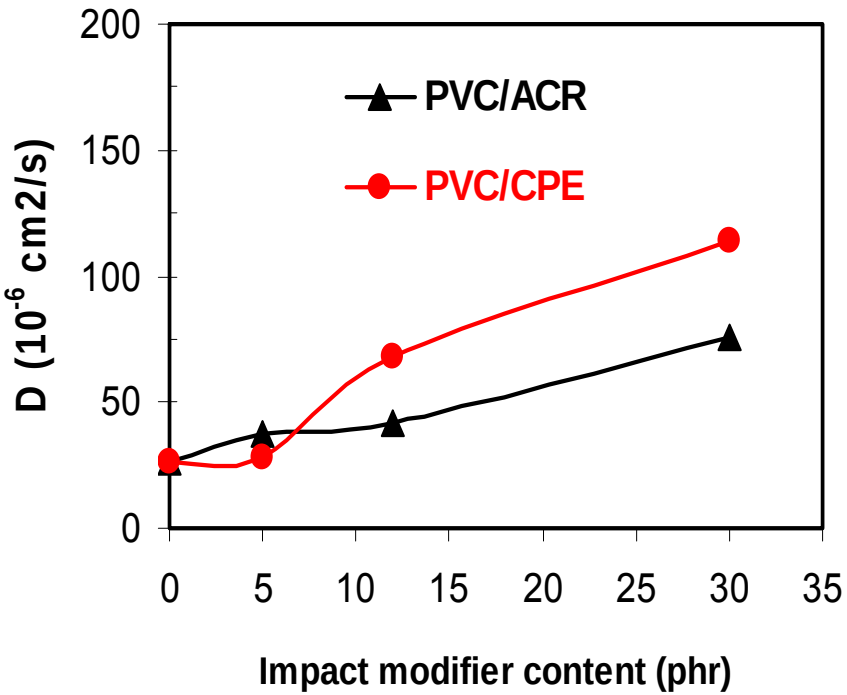
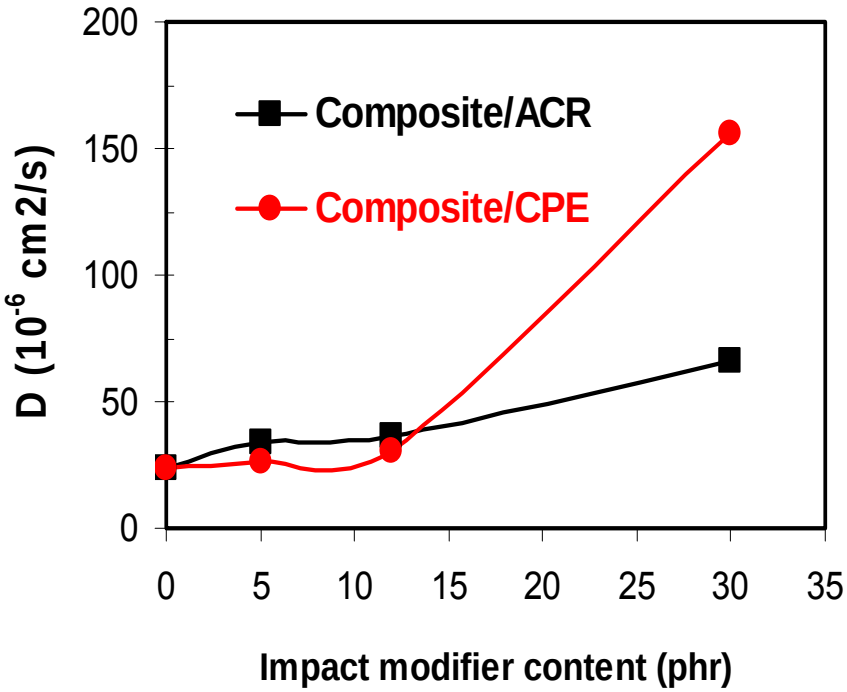
Effect of impact modification on the diffusivity of CO_2 in the samples





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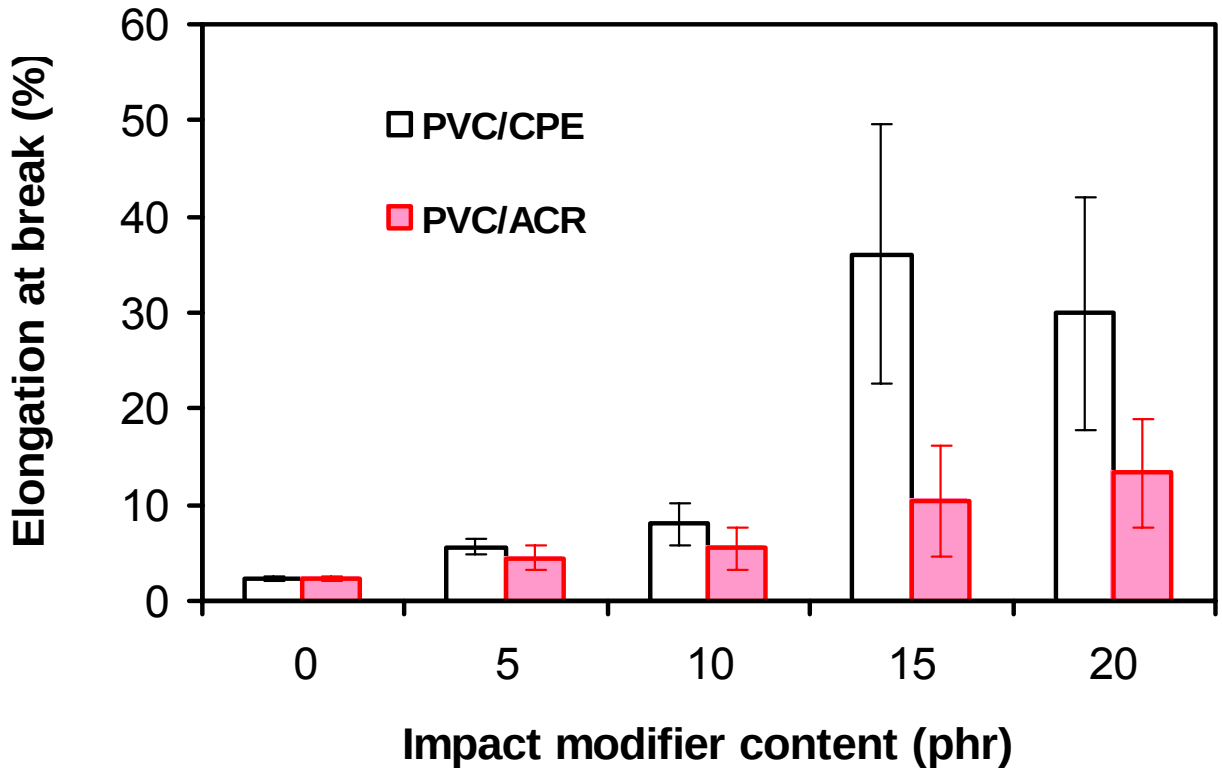
Effects of impact modification on the elongation at break of neat rigid PVC samples



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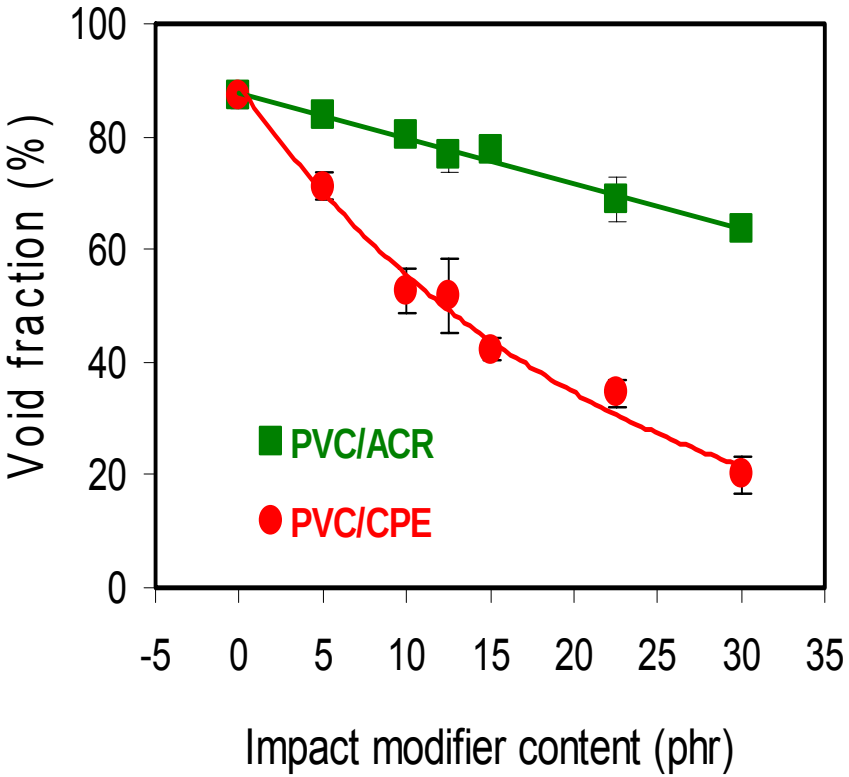
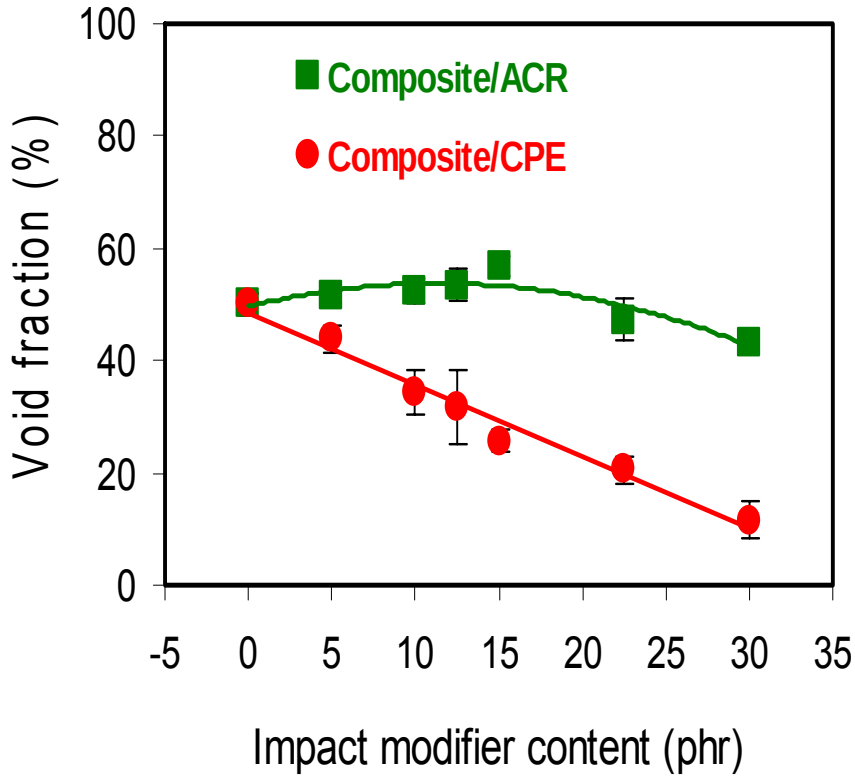
Effect of impact modification on the void fraction





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Percentage of gas loss during foaming experiments

Samples	*Measured CO_2 content (%) in the samples*		
	Before Foaming	*After 5 sec Foaming*	*Percent gas loss*
Neat PVC			
Unmodified	7.8	6.8	**12.1**
Modified with 12 phr ACR	9.2	7.0	**24.0**
Modified with 12 phr CPE	7.6	1.5	**80.7**
PVC/wood-flour composites			
Unmodified	4.3	2.3	**47.1**
Modified with 12 phr ACR	6.5	3.9	**40.1**
Modified with 12 phr CPE	4.7	1.4	**70.2**

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Conclusions

- Impact modification accelerates the rate of gas loss during foaming process, which impedes the growth of nucleated cells.
- Due to this accelerated gas loss, impact modification inhibits the potential of producing foamed samples with void fractions similar to those achieved in unmodified samples.

Acknowledgments

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