



Fracture and Mechanical Properties of Elastomers filled with Soft Particles

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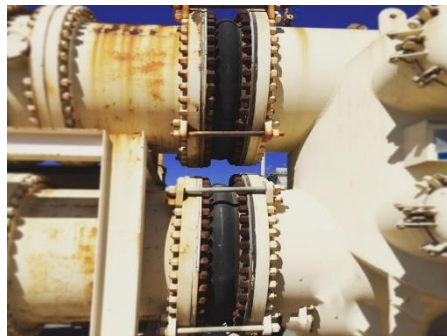


Context

Elastomers are **stretchable** but **soft**



Industrial applications require stronger and tougher stretchable materials.



Pure elastomers suffer from a tradeoff between fracture toughness and stiffness.

composite

hard fillers
particles, fibers

+

soft matrix
elastomers



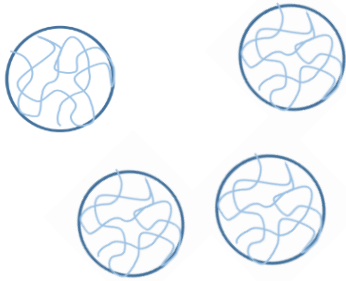
It works



Difficult to process
Change density
Change chemical nature
Not transparent

Soft fillers strategy

Soft elastomeric particles...

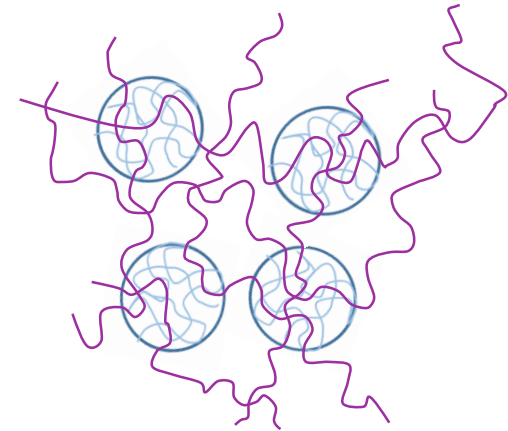


Crosslinked particles of elastomer

Particles of
Poly(Ethyl Acrylate) = PEA



...in a softer matrix

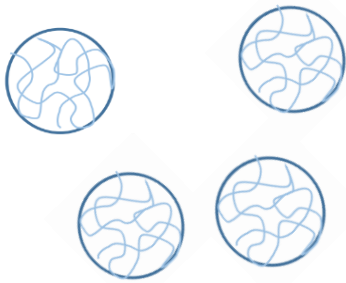


Less crosslinked elastomeric matrix

Matrix of
PEA

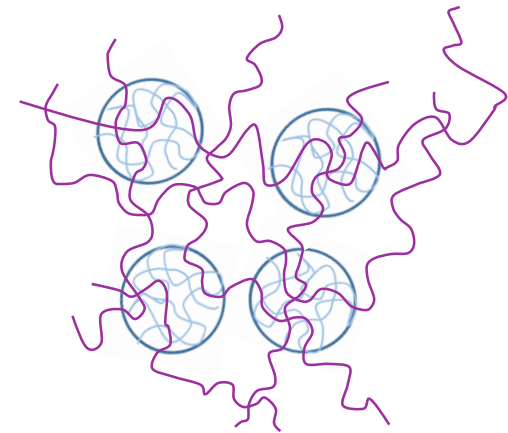
Soft fillers strategy

Soft elastomeric particles...



Crosslinked particles of elastomer

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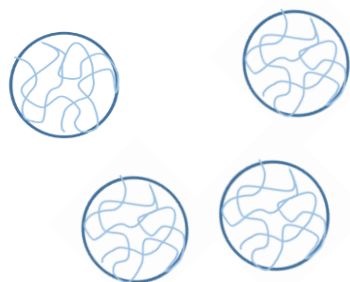


Same chemical nature
between fillers and matrix
Same density

Matrix of
PEA

Method

Synthesis of the soft elastomeric particles

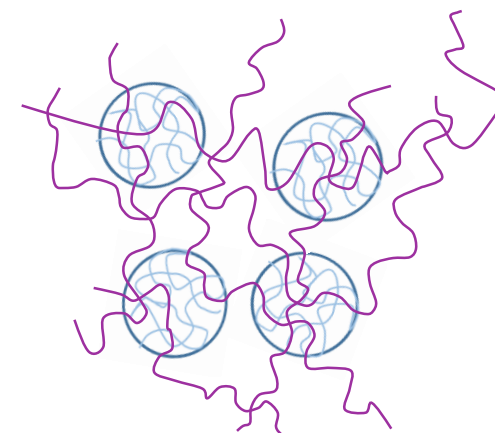


Crosslinked particles of elastomer

Synthesis of the matrix



Final composite

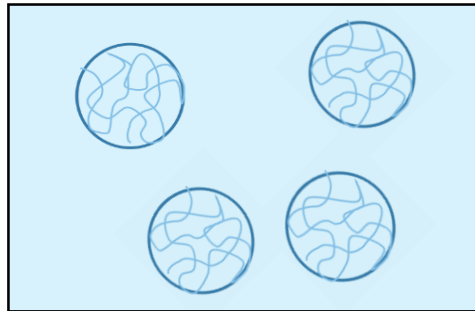


Method

Synthesis of the soft elastomeric particles

Conventional radical emulsion polymerization

in water

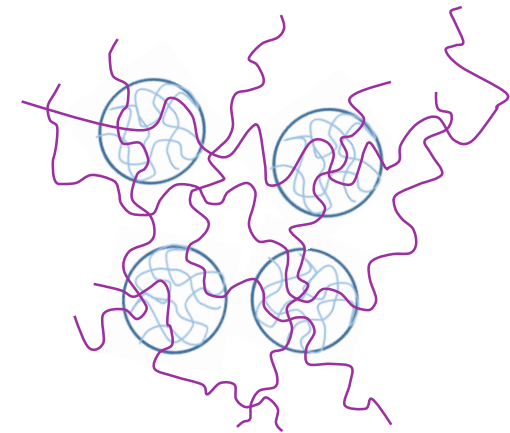


Crosslinked particles of elastomer

Various crosslinker contents



Final composite

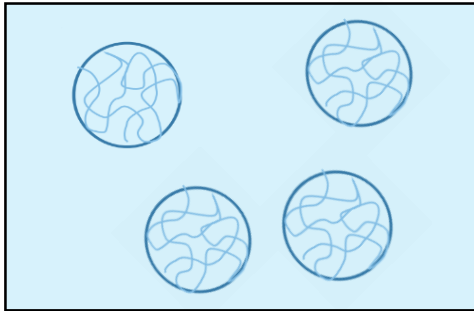


Method

Synthesis of the soft elastomeric particles

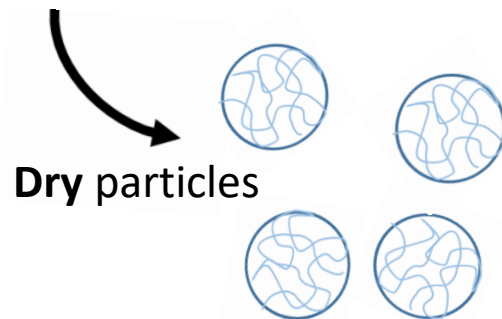
Conventional radical emulsion polymerization

in water



Crosslinked particles of elastomer

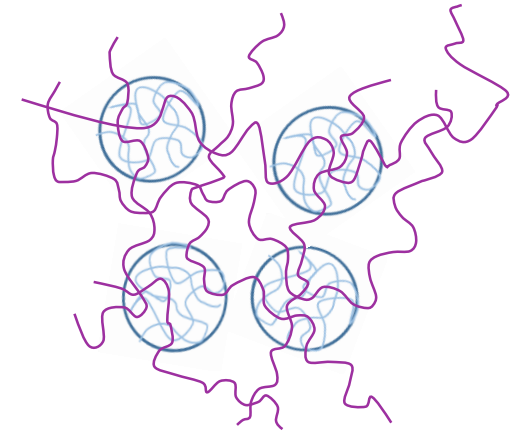
Various crosslinker contents



Dry particles



Final composite

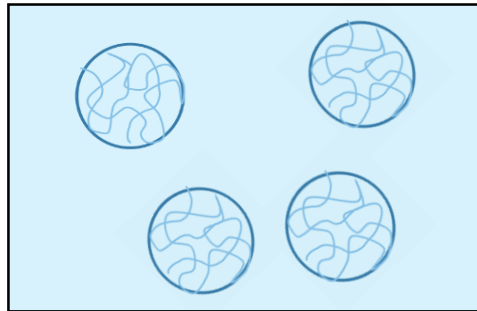


Method

Synthesis of the soft elastomeric particles

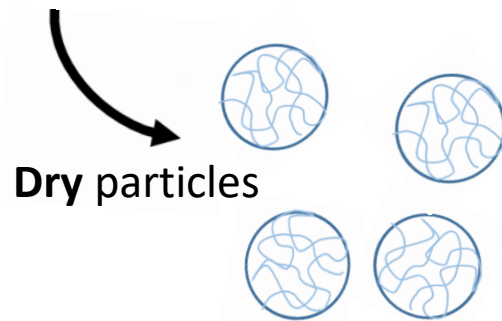
Conventional radical emulsion polymerization

in water



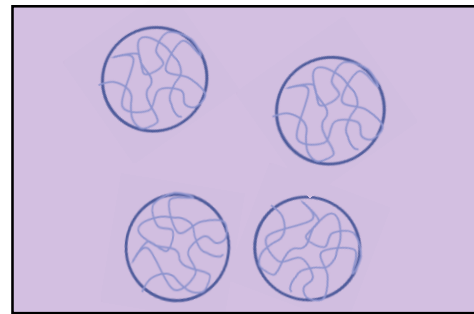
Crosslinked particles of elastomer

Various crosslinker contents



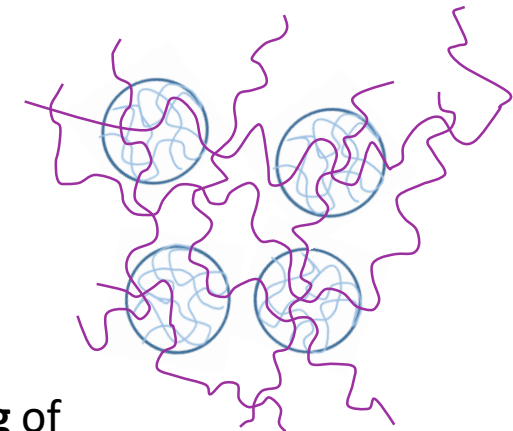
Dry particles

Dispersion and swelling of the dry particles in monomer



Various particle contents

Final composite



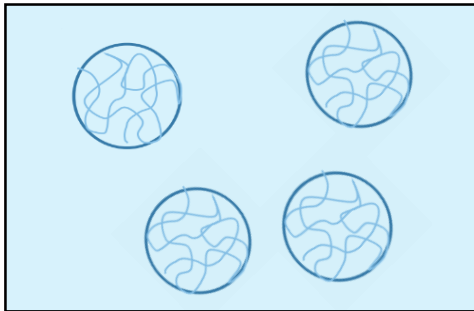
Easy dispersion of the fillers

Method

Synthesis of the soft elastomeric particles

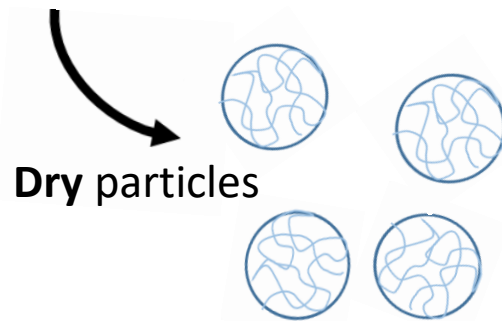
Conventional radical emulsion polymerization

in water



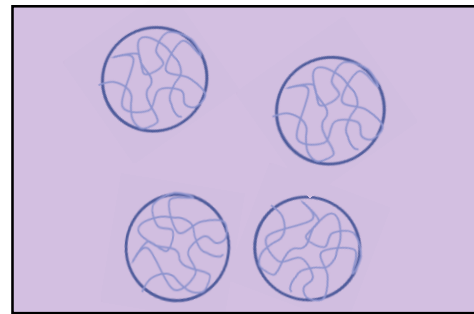
Crosslinked particles of elastomer

Various crosslinker contents



Dry particles

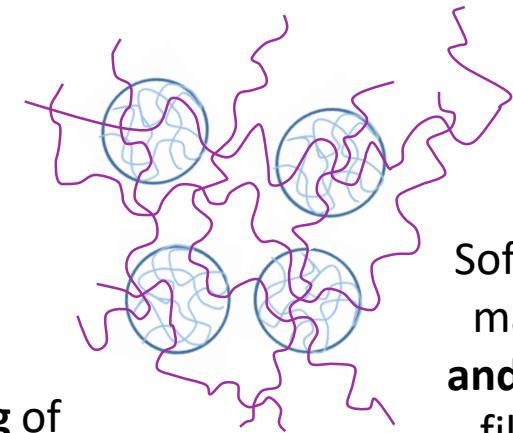
Dispersion and swelling of the dry particles in monomer



Various particle contents

Synthesis of the matrix

Conventional radical bulk polymerization



Soft elastomeric matrix **around and inside** of the filler particles



Transparent

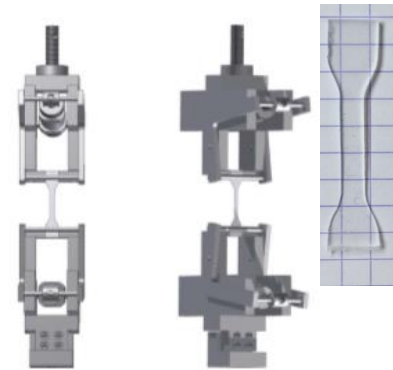


Same chemical nature
between fillers and matrix
Same density
Easy dispersion of the fillers
Transparent

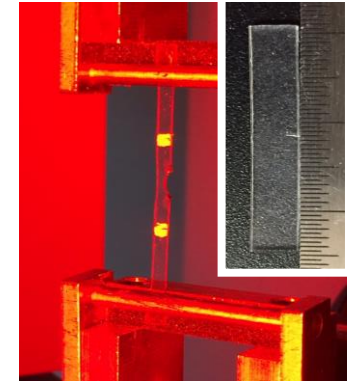
Does it work



Mechanical tests



- **Uniaxial extension**
Young's modulus, stress at break
- **Cyclic loading**
Viscoelastic energy dissipation or irreversible damage



- **Fracture propagation**
Toughness

What will happen to the mechanical properties of the material ?

How does the soft fillers change the mechanical behavior of the matrix ?

Will elastomers resist fracture propagation better with soft fillers ?

Fracture and Mechanical Properties of Elastomers filled with Soft Particles

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Introduction

Nano-fillers are widely used to strengthen and toughen rubbers. This reinforcement depends on a variety of factors (nature of the filler, distribution, interactions filler/matrix). Hard fillers affect the transparency, density and chemical nature of the material.

What happens if the nano-fillers and the matrix are of the same type?

Objectives

Develop and study transparent elastomeric nanocomposites filled with soft and penetrable particles of the same polymer.

In order to:

- get better understandings of the dissipative mechanisms in this new soft system
- control strain-hardening and Young's modulus independently

1 Particles

Free Radical Emulsion Polymerization

Surfactant: CH3(CH2)10CH2OCH2CH2OH

Monomers: Ethyl Acrylate, BDA Cross-Linker, Initiator

Conditions: $\Delta 80^{\circ}\text{C}$, Drying at room conditions

Result: Soft polymeric NP in water

2 Composite

Free Radical Polymerization

Matrix alone: Ethyl Acrylate, Initiator

Conditions: UV 10W/cm², 3h, N₂, atmosphere

Result: Elastomer filled with soft NP

Sample	Radius in water (nm)	Radius in EA (nm)	Q _s	mol% _{BDA}
L_EA1.5	70	114	4.5	0.38
L_EA1.5	73	117	4.1	1.47
L_EA3	78	116	3.3	3
L_EA6	81	108	2.4	4.45
L_EA12	76	85	1.4	12.85

$Q_s = \left(\frac{R_{EA}}{R_w}\right)^3$

The swelling factor Q_s decreases as the amount of cross-linker increases.

4 Fracture propagation

Variation of wt%_{NP} 3 mol%_{BDA} NP

Variation of mol%_{BDA} Constant volume fraction 30%

Experimentally determined by Greensmith: $G = \sigma \cdot \epsilon \cdot W(T, \lambda_c)$

No or low effects of the filler particles on the fracture energy of the materials.

Slight increase of the fracture energy for higher $\lambda_{m0.05}$ in the filler NP.

3 Mechanical properties

Variation of wt%_{NP} 3 mol%_{BDA} NP

Variation of mol%_{BDA} Constant volume fraction 30%

Tunable strain-hardening

Cyclic loading

Low hysteresis

Moderate increase of modulus and decrease of strain at break.

Hysteresis increases with wt% and mol%_{BDA} but remains limited compared to hard filler systems.

Low variation of modulus, calculated after each cycle, meaning that a low amount of elastic chains broke during the cyclic test.

Conclusion

Soft particles reinforce the matrix at large strains.

The dissipative mechanisms in our system are different from the ones in hard fillers elastomers.

Acknowledgements

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References

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