Review of Reinforcement of Poly(propylene) with Minerals

Zhiyong Xia

Plastics Applications R&D

Specialty Minerals Inc

Bethlehem , PA 18017

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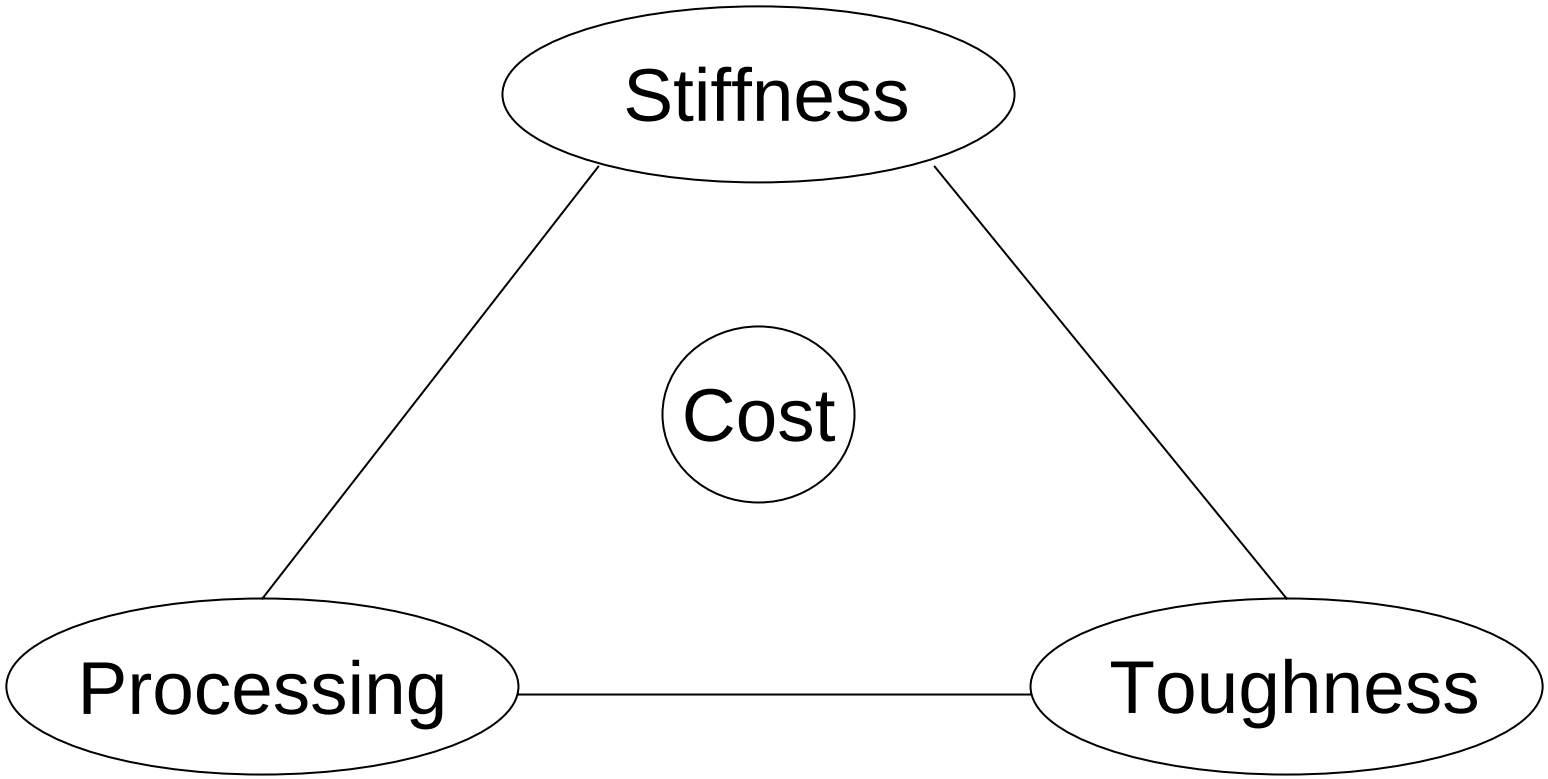

Stiffness
Cost
Processing
Toughness

Surface treatment of fillers

- Non-reactive
- reactive

Non-reactive

- Amphiphilic surfactant
  - CaCO3 treatment with stearic acid.
  - Adsorption of the polar group of the surfactant on to the surface of fillers.
  - Forming ionic bonding between CaCO3 and acid [1].

[1] Polypropylene Structure, blends and composites edited by J.Karger-Kocsis Chapman & Hill 1995.

Non-reactive surface modification

- Decrease surface energy of fillers
- Lead to less filler-filler interaction
  - better dispersion
  - improved processability
- Lead to weak filler-polymer interaction as well
  - Decrease yield stress

Reactive treatment

- Silane
  - One end has a hydrolyzable group, the other end (organo-functional group, e.g. epoxy, methacrylate, amine, vinyl.
  - For PP vinyl silane can be used. Vinyl group can react with PP via free radical reaction) can entangle with polymer molecules.
  - Used when –OH presents in fillers (glass fiber, mica)
  - Not efficient with CaCO3

Stiffness of polymer/filler composites

- Filler
  - Concentration
  - Modulus
  - Size
  - Aspect ratio
  - Orientation
- Polymer
  - Modulus
  - Poisson's ratio
- Polymer-filler interaction
  - Interfacial adhesion
  - Polymer-filler interlayer thickness
  - Filler dispersion

Tensile Strength

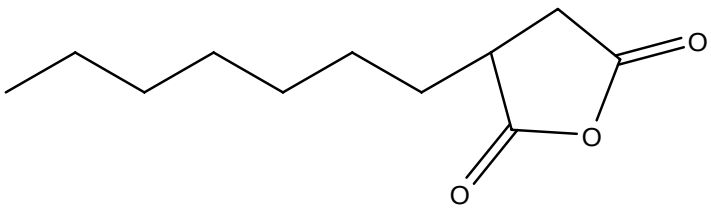
- Tensile strength of filler and polymer
- Filler concentration
- Filler dispersion
- Interfacial adhesion (poor bonding lead to debonding earlier than plastic deformation, i.e., lower yield stress)

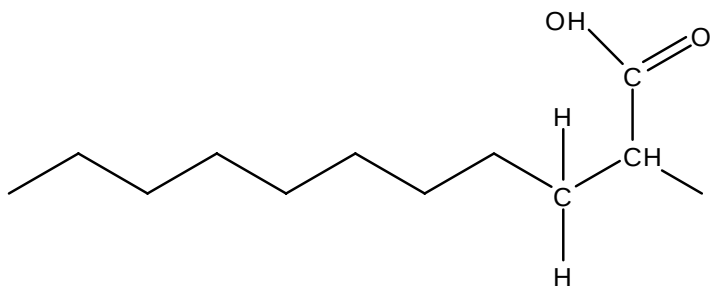
Other benefits from mineral fillers

- Improved dimensional stability
- Improved processability
- Improved heat deflection temperature
- Good scratch/mar resistance
- Improved crystallization kinetics (both from melt and from glass)

Compatiblizers for PP

- Maleic anhydride modifield PP (MAH-g-PP)
  - Yield stress increase with Mw of MAPP
- Acrylic acid modified PP (AA-g-PP)
  - <220°C recommended for processing
  - Less effective than MAH





Halpin-Tsai Predictions

$$\frac{E_{11}}{E_m} = \frac{1+2\zeta\eta\varphi}{1-\eta\nu_f} \qquad \eta = \frac{\left(E_f / E_m\right)-1}{\left(E_f / E_m\right)+2\zeta}$$

$$\zeta = \frac{l}{t}$$

E_{11} : composite modulus

E_f : fiber modulus

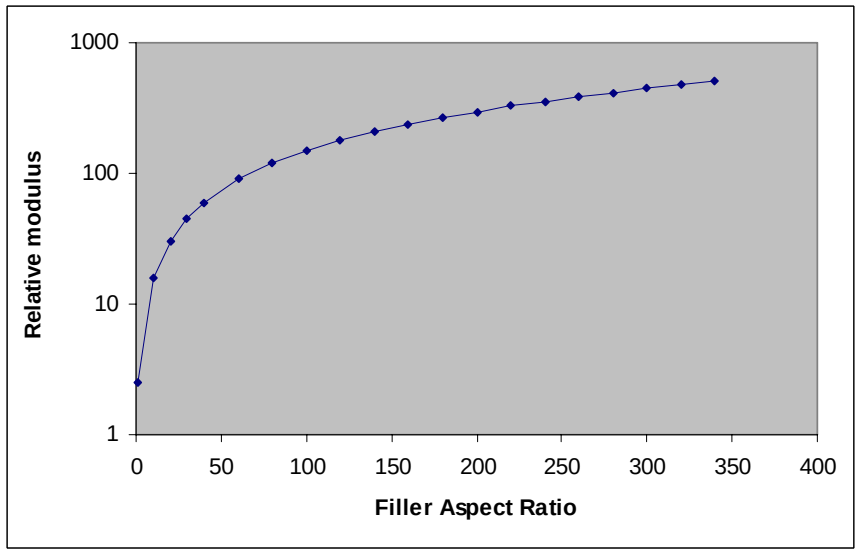
E_m : matrix modulus

φ : fiber volume fraction

l : fiber lengh

t : fiber thickness

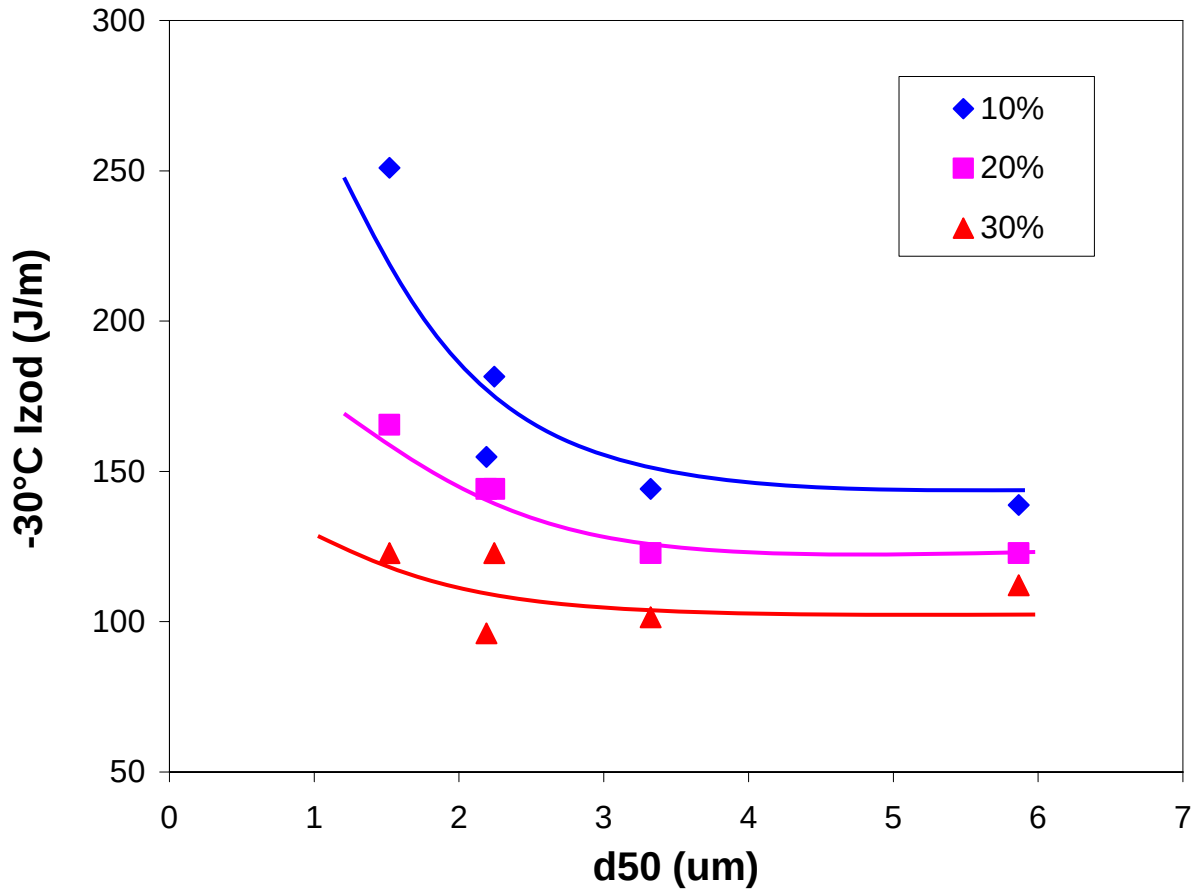
ζ : geometric factor



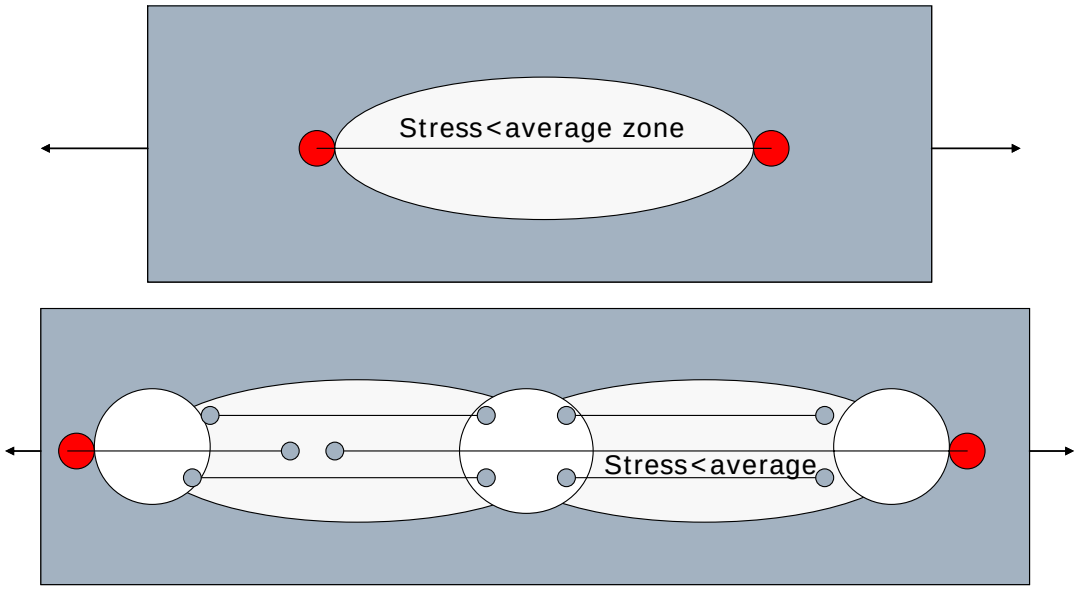
Toughness

- Filler size
- Filler size distribution
- Filler aspect ratio
- Filler orientation
- Good filler dispersion to avoid crack imitation agglomerates
- Interface bonding
  - Debonding must occur to allow plastic deformation around fillers
- Interparticle distance

Impact toughness vs. particle size



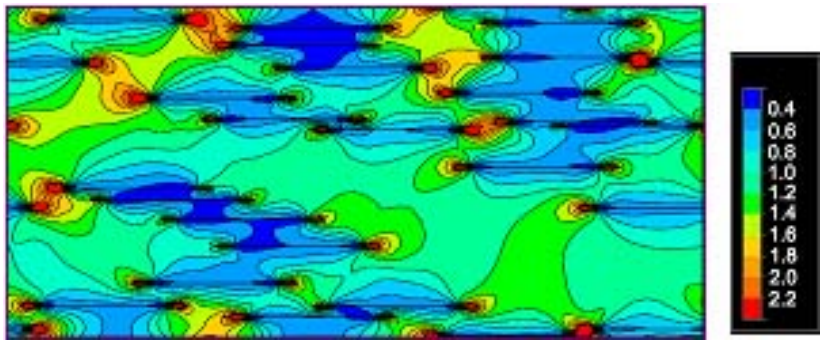
Schematic of Stress/Strain Lobe Around Fillers



The high stress area (at the ends fibers) are reduced when fall within the low stress lobes near the center of adjacent fibers

FEM Simulation Results

Strain contour around nano-clay particles (e11 = 0.005, L/t = 100, f = 2%)
(N. Sheng and M. Boyce MIT ACS-PMSE, Spring Meeting, 2002)



Summary

Good processing-property-cost balance can be achieved with the proper selection of mineral fillers