UNIVERSITY OF DELAWARE

SYNTHESIS AND CHARACTERIZATION OF CLAY NANOCOMPOSITES FROM PLANT OILS

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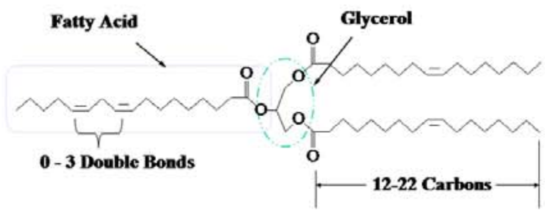
MOTIVATION AND OBJECTIVE

Most of composites matrices are derived from petroleum resources. With the fast depleting of these resources, replacing some or all of these with readily available, renewable and inexpensive natural resources, such as plant oils, becomes important. They offer unlimited resources and potential biodegradability. The formation of nanocomposites with relatively low loading of clay can dramatically increase stiffness, dimensional stability, gas barrier and flame retardancy etc.. These low cost, biodegradable, high performance polymers and composites open a big market on new bio-based materials which would have significant economic advantage and environmental impact.

The objective of this research is to synthesize nanocomposites using functionalized triglycerides and organo-modified clay and study the effect of nano-structure on the final composite properties.

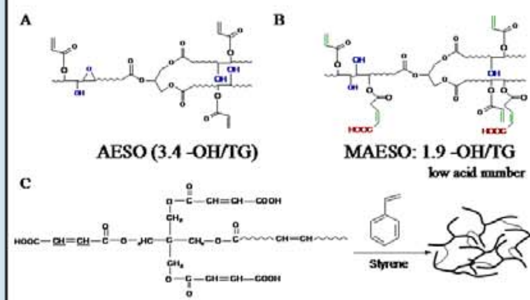
TRIGLYCERIDE STRUCTURE



Common Triglycerides
- 12 - 22 carbons long
- double bond functionality

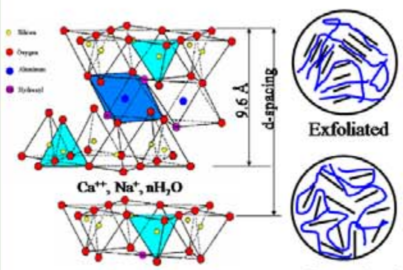
Uncommon Triglycerides
- branched/cyclic fatty acids
- other functionalities
  - fluoro, hydroxy, epoxy

FUNCTIONALIZED TRIGLYCERIDES



SO-PER-MA (acid number > 200 mg KOH/g)

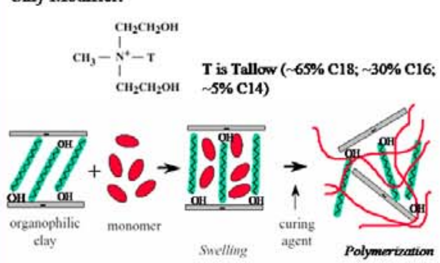
NANOCOMPOSITE STRUCTURE



MMT Structure

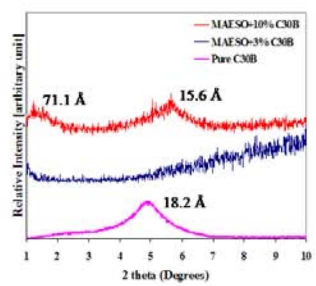
IN SITU BULK POLYMERIZATION

Clay Modifier:



C30B: A natural montmorillonite modified with a ternary ammonium salt (Southern Clay Product, Inc.)

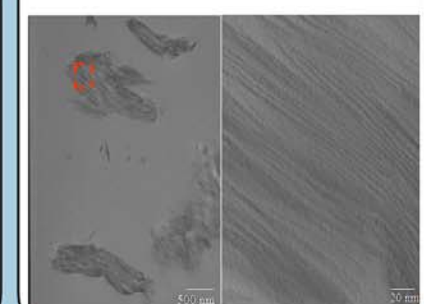
MORPHOLOGY - XRD



Bragg Law:

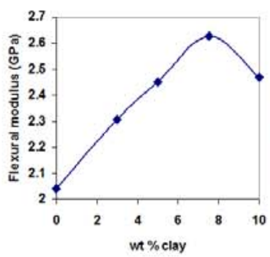
$\lambda = 2d \sin\theta$

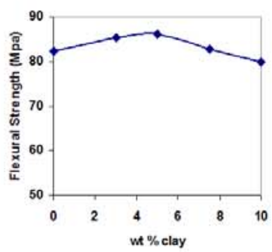
MORPHOLOGY - TEM



MAESO+8wt%C30B

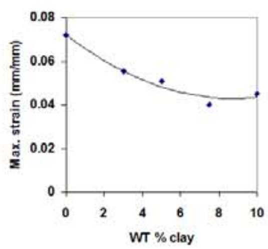
FLEXURAL PROPERTIES

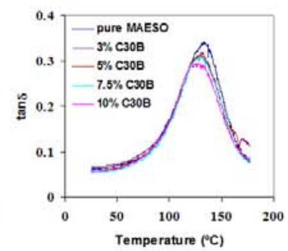




- Flexural modulus significantly increases with increasing clay content up to 7.5 wt%, then decreases.
- Flexural strength slightly increases at low clay loads, then decreases.

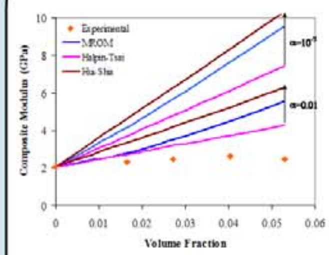
MORE PROPERTIES





- Flexural strain decreases with increasing clay concentration because the formation of nano-structure restricts the flexibility of polymer chains.
- Glass transition temperature slightly decreases with increasing clay concentration.

THEORETICAL PREDICTION



Halpin-Tsai Model

$$E = E_0 \frac{1+ABc}{1-B\psi c}$$

$$A = 1.33\alpha^{-0.045} \qquad B = \frac{E_1/E_0 - 1}{E_1/E_0 + A}$$

Hui-Shia Model

$$E = \frac{E_0}{1-\frac{c}{4}\left[\frac{1}{\xi}+\frac{3}{\xi+\Lambda}\right]} \qquad g = \frac{\pi}{2}\alpha$$

$$\xi = c + \frac{E_0}{E_1 - E_0} + 3(1-c)\left[\frac{(1-g)\alpha^2 - (g/2)}{\alpha^2 - 1}\right]$$

Modified Rule of Mixtures relation(MROM)

$$E = cE_1(MRF) + (1-C)E_0$$

$$(MRF) = 1 - \frac{\ln(u+1)}{u} \qquad u = \frac{1}{\alpha}\sqrt{\frac{cG_0}{E_1(1-c)}}$$

Aspect ratio $\alpha = t/a$ (a=30~2000 nm)

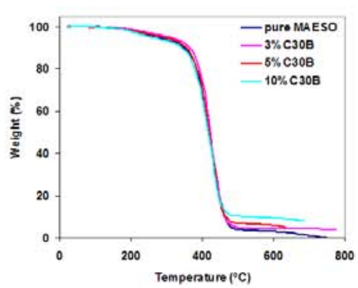
Modulus of clay: 178 GPa

- The modulus increase is not consistent with the models for conventional composites with flake-like inclusions.

MORE TEM PICTURES

3 wt% C30B

THERMAL DEGRADATION



CONCLUSIONS

- Nanocomposites were formed by in situ polymerization.
  - Mainly intercalated and partially exfoliated structure.
  - Great increase in flexural modulus but no significant effect on flexural strength and glass transition temperature.
  - Measured modulus does not follow the predictions of the theoretical models, which work well for conventional composite systems.
  - The thermal degradation is hastened slightly.

FUTURE WORK

- Detailed Study of the Formation of Nanocomposites:
  - Effect of chemical functionality
  - Effect of mixing
  - Effect of polymerization

ACKNOWLEDGEMENTS

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