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Behavior of Nanosilica Filled Epoxies

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Rheological Behavior of Nanosilica Epoxies

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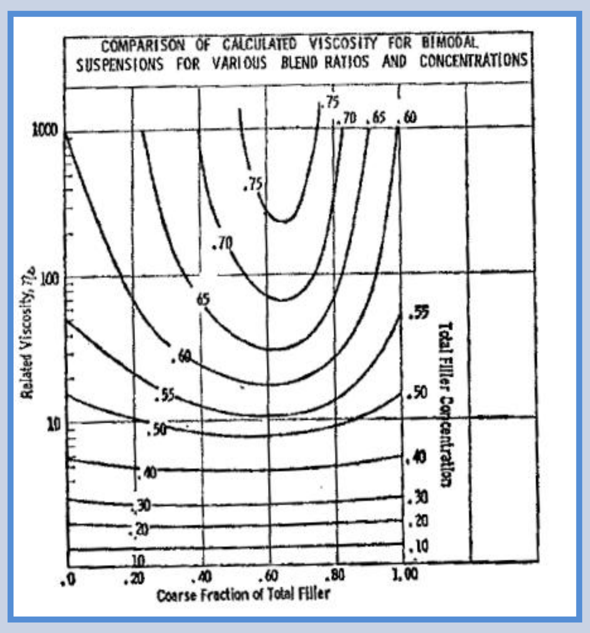
Background



•Einstein's hydrodynamic equation has been used to determine the lower viscosity limit for filled polymers

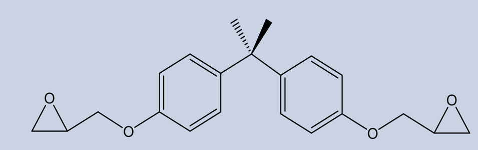
•Based on research by R. J. Farris, bimodal mixtures of nanosilica were explored as a possible means to reduce the viscosity for a given nanosilica content

Objectives

- Demonstrate that viscosity is a function of nanosilica content and particle size
- Determine if flocculation occurs in nanosilica suspensions
- Study particle size influences on thermorheological behavior
- Prepare bimodal mixtures and study effect on viscosity

Experimental

Materials



Diglycidyl ether of bisphenol A

Silica particles
- 22 nm, 47 wt% dispersed in DGEBA
- 168 nm, 52 wt% dispersed in DGEBA

fine to coarse particle ratio of 0.13

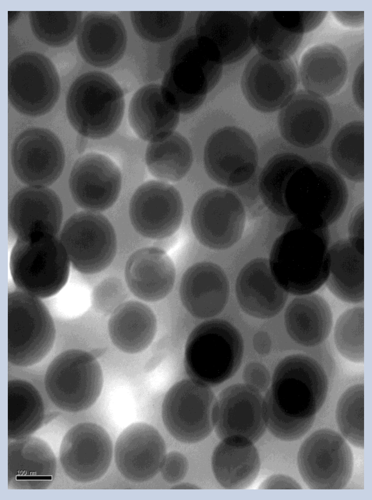
Mix Schedule: 80 ºC for 4 hours

Characterization

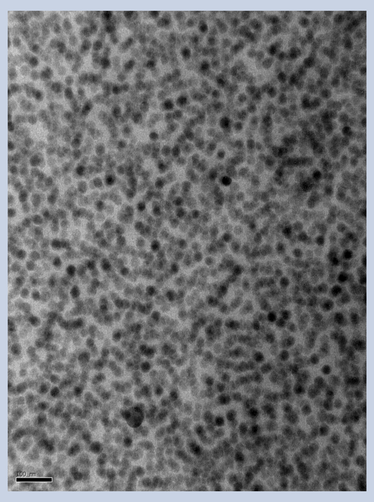
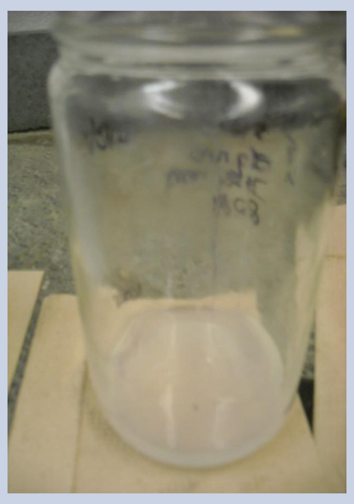
Rheological behavior characterized in steady state shear using a Rheometerics ARES rheometer equipped with a Couette fixture

Results

TEM: Nanosilica particles are randomly dispersed in epoxy matrix




Coarse Particles: 10 vol% 168 nm

Fine Particles: 10 vol% 22 nm

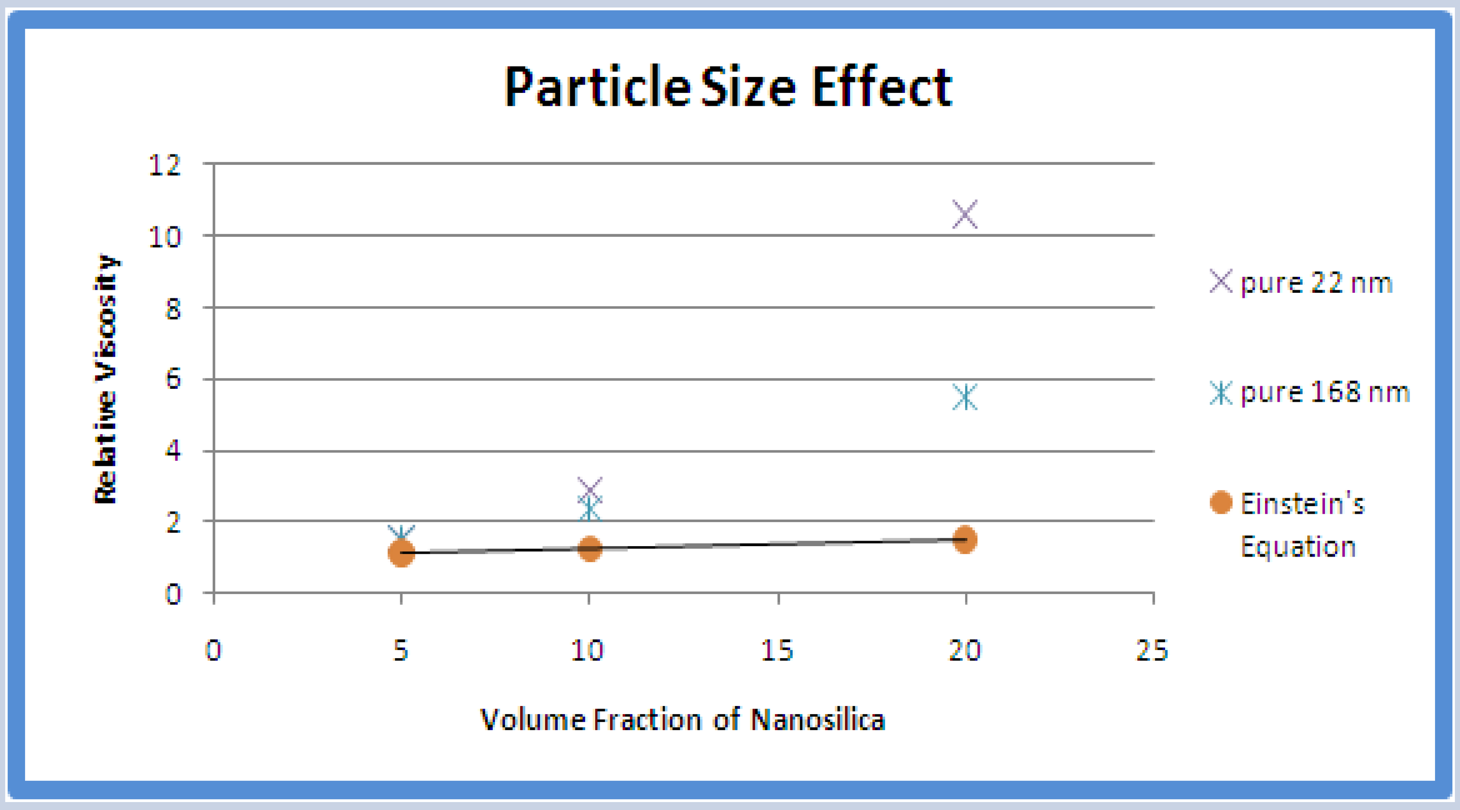
Dilute Suspensions vs. Dilute Solutions

Albert Einstein published a theoretical analysis dealing with viscosity of dilute solutions

$$\text{Relative viscosity} = 1 + 2.5 \cdot (\text{volume fraction})$$

The hydrodynamic equation assumes that there is no interaction between the particle suspensions, and treats dilute suspensions of rigid particles like dilute solutions

Effect of Particle Size on Suspension Viscosity

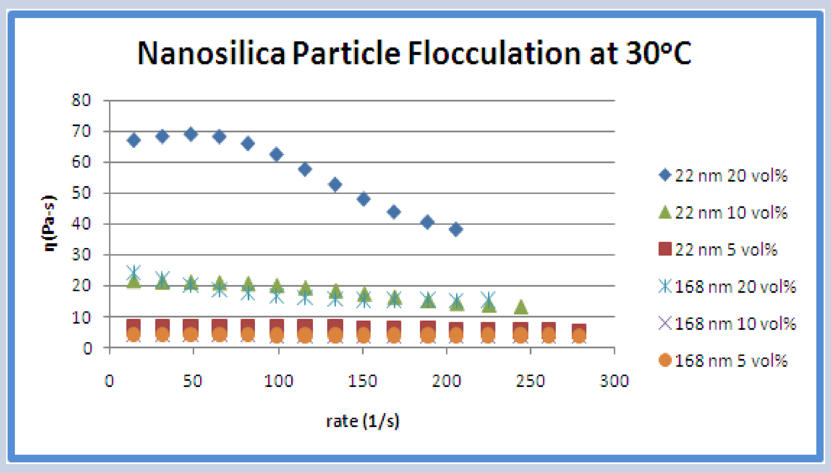


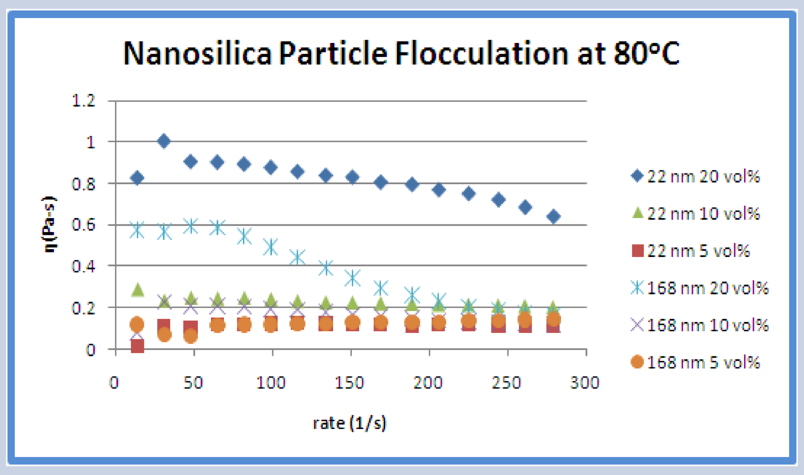
Viscosity measured at a shear rate of 100 s-1

•The smaller nanosilica particles (22 nm) are more viscous than the larger (168 nm) nanosilica particles.
•As the concentration of particles increase, so does this viscosity
•This increase in viscosity indicates that there is particle interaction
•Dilute suspensions of rigid particles cannot be treated like dilute solutions

Analysis

Shear Rate Tests of Nanosilica Epoxy Suspensions

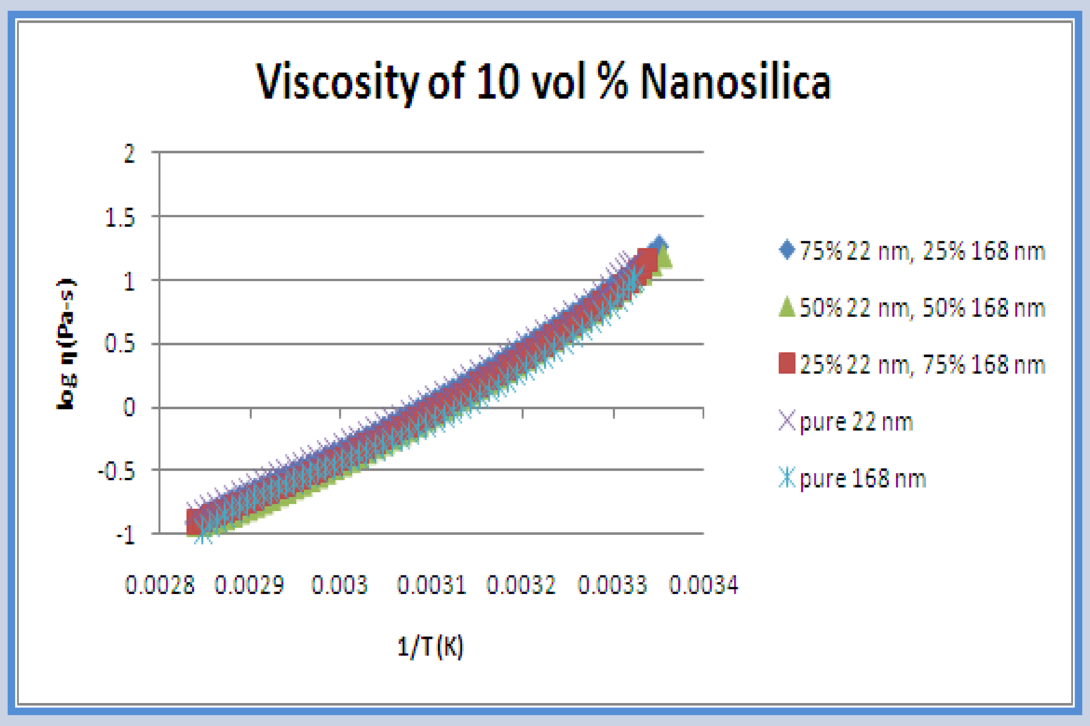




•In the 5 vol% and 10 vol% suspensions, the viscosity behavior is fairly Newtonian (no shear rate dependence)
•The 20 vol% suspensions demonstrate significant non-Newtonian behavior, suggesting particle aggregation

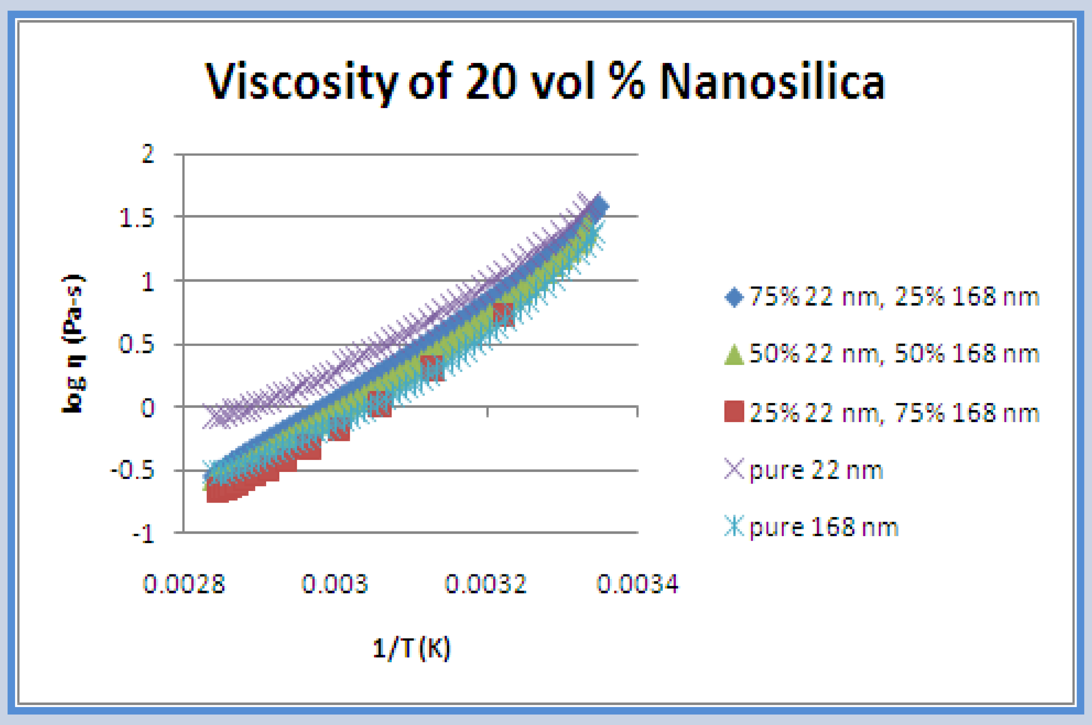
Thermorheological Behavior of Suspensions

•The constant slope in the 10 vol% suspension proves that the addition of particles does not influence thermorheological behavior



•As the concentration of the suspension increases from 10 vol% to 20 vol%, the influence of the bimodal distribution becomes more evident (greater particle interaction)

•At higher temperatures, the viscosity of the 75% 168 nm suspension has a lower viscosity than the pure 168 mixture



Conclusions

•As expected, viscosity is a function of nanosilica particle concentration
•Interestingly, viscosity was found to be influenced by nanosilica particle size, suggesting significant particle-particle interactions
•Shear rate studies confirmed the presence of particle-particle interactions, which were highest for the 20 vol% suspensions
•Constant slopes prove that the addition of particles does not influence thermorheological behavior, except for 20 vol% suspensions
•Bimodal mixtures of nanosilica particles can be used to reduce viscosity

Future Work

- Determine whether multi-modal particle distributions will lower the viscosity even more (seen from micron size suspension)

Acknowledgements

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