

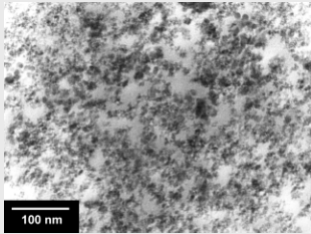
## Objectives

### Investigation of fumed silica/epoxy nanocomposites:

- Dispersion and manufacturing process
- Chemical surface-modification
- Influence of surface modification on manufacturing and mechanical properties

## Materials and Manufacturing

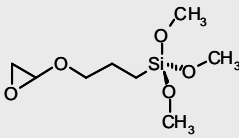
- Aerosil®**
  - Spherical SiO<sub>2</sub>-particles
  - Diameter ~ 7nm
  - Young's Modulus E = 68GPa
  - Highly hydrophilic



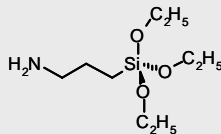
- High shear mixing with mini-calander: Efficient and up-scalable method [1]

### Surface modification with silanes

- 3-Glycidyloxypropyltrimethoxysilane (DYNASILAN GLYMO®)
- 3-Aminopropyltriethoxysilane (DYNASILAN AMEO®)



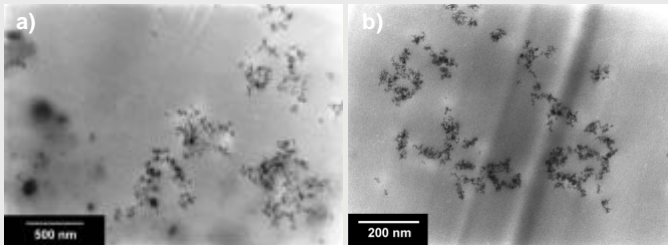
3-Glycidyloxypropyltrimethoxysilane



3-Aminopropyltriethoxysilane

- Introduction of epoxy- and amino-groups on the particle surface
- Covalent bonding to epoxy system possible

## Dispersion – TEM investigations



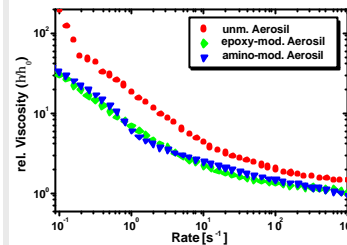
### TEM-Images (Philips EM 400):

Observed dispersion of

- unmodified fumed silica
- epoxy-modified fumed silica
- amino-modified fumed silica

- Matrix-compatible surface functionalisation stabilises suspension
- Functionalisation improves dispersibility
- Best results with epoxy-functionalisation

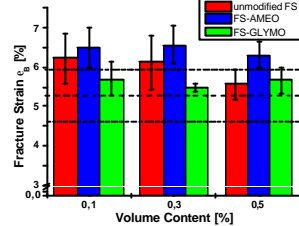
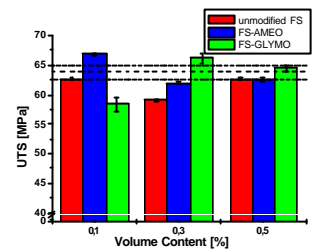
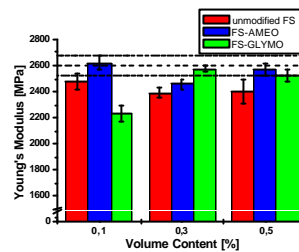
## Rheological Analysis



Epoxy Resin/0.5 vol.% fumed silica: relative viscosity vs. shear rate.

- 0.5 vol.% of fumed silica increase viscosity ( $\eta/\eta_0 \sim 200$ )
- Surface-functionalisation reduces viscosity-increase ( $\eta/\eta_0 \sim 30$ )
- Particle-Particleinteractions reduced
- Suspension stabilised
- Control of viscosity important for applications (e.g. FRPs)

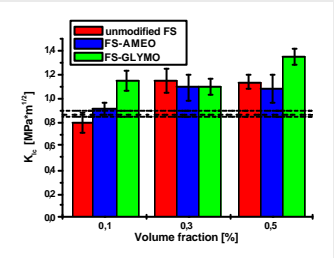
## Tensile Tests



- Slight reduction of Young's Modulus observed [2]
- No influence on ultimate tensile strength
- Strain-to-failure increased for all composites (up to + 25%)
- Conventional composite models not applicable
- Formation of ductile interphase suspected

## Fracture Toughness

- Significant increase in K<sub>1c</sub> for all composites [2]
- Highest improvement +54% for 0.5 vol.% of epoxy-modified particles
- Toughening via off-fracture plane processes (e.g.void nucleation, matrix deformation)
- Superproportional increase in K<sub>1c</sub> – further investigations needed (inter-phase formation)



## Summary

- Effective dispersion of fumed silica using a mini-calander
- Surface modification enables
  - control of viscosity
  - improved dispersion stability
  - particle-matrix bonding
- Fracture toughness and ductility were significantly improved

## Acknowledgements

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## References

- Gojny FH, Wichmann MHG, Köpke U, Fiedler B, Schulte K. Carbon Nanotube-reinforced epoxy-composites – Enhanced Stiffness and Fracture Toughness at low Nanotube Contents. Composite Science & Technology 64 (2004), p. 2363-2371.
- Wichmann MHG, Cascione M, Fiedler B, Quaresimin M, Schulte K. Influence of Surface Treatment on the mechanical Behaviour of Fumed Silica / Epoxy Resin Composites. Composite Interfaces (2005) accepted.