Dynamic and structural investigation of capillary suspensions with smooth and rough particles

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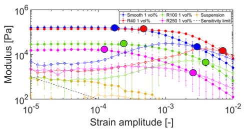
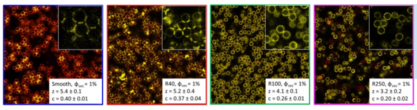
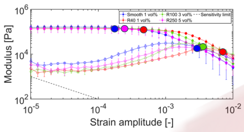
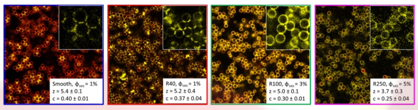
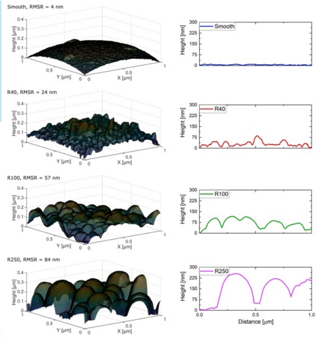





Top row: ϕ_{sec} = 1 vol%
Bottom row: ϕ_{sec} adjusted
All: ϕ_{solids} = 20 vol%

The roughness of raspberry-like particles is varied by electrostatic adsorption of different-sized nanoparticles (40 nm, 100 nm and 250 nm)



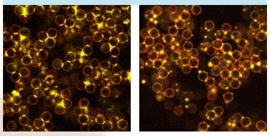
Capillary suspensions

Capillary suspensions consist of particles suspended in a bulk fluid with a small amount of immiscible secondary liquid added to form a percolating network of capillary bridges between the particles and can show a wide range of rheological behavior. We investigate the microstructural changes during interesting rheological transitions, e.g. yield, using confocal microscopy.

Bridge wetting and particle roughness

The bulk rheological properties are inherently related to the strength and number of single capillary bridges. After adjusting the effective bridge volume to compensate for the extra liquid required to fill the asperities, higher particle roughness leads to less clustered networks and a higher yield strain for a matching storage modulus, suggesting an influence from the particle contacts.

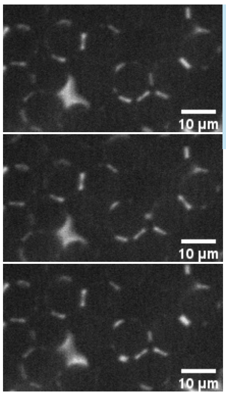
Using a silanization reaction, both the pendular state (θ<90°, left) and the capillary state (θ>90°, right) can be obtained.



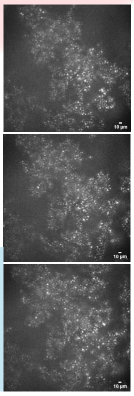
Setup:
- MCR302 WSP rheometer
- VT-HAWK confocal microscope
- Olympus inverted microscope
- Custom built bottom plate with sapphire glass
- Zaber XY-rails to reposition rheometer

Network dynamics

Using a rheometer mounted to a confocal microscope, we are able to directly investigate the yielding of a capillary suspension network subjected to a shear deformation. These experiments show the solid body rotation present in capillary suspension networks where flocs move as single objects, as well as very localized bridge rupture and reformation events.



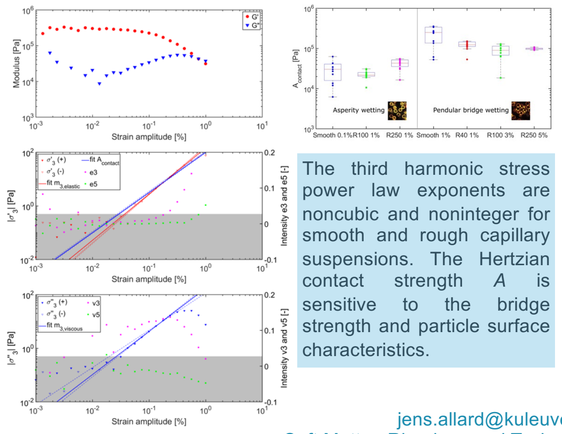
During one oscillation in the nonlinear viscoelastic regime, certain bridges get stretched or compressed, while others do not. Yielding is highly localized and dependent on the local forces between particles!



During the loading of a capillary suspension on the rheometer, rigid body movement of large flocs is observed. Applying a high normal force leads to an increase in effective particle volume fraction by squeezing out the bulk liquid!

Particle contacts

The capillary force of the bridges pulls the particles in contact with each other in the network. We investigated these frictional contacts in the third harmonic stress response using medium amplitude oscillatory shear measurements. Also, we are starting to link these to rheoconfocal observations, for which preliminary results show that the rigid body movement is more pronounced for rough particles.



The third harmonic stress power law exponents are noncubic and noninteger for smooth and rough capillary suspensions. The Hertzian contact strength *A* is sensitive to the bridge strength and particle surface characteristics.

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