Investigation of capillary (nano)suspensions

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SMaRT SOFT MATTER, RHEOLOGY and TECHNOLOGY

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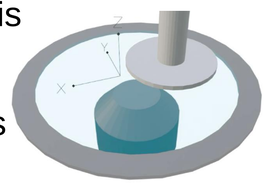
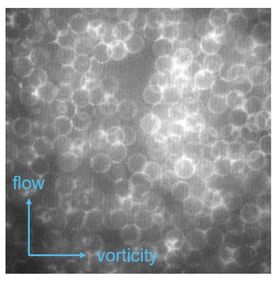
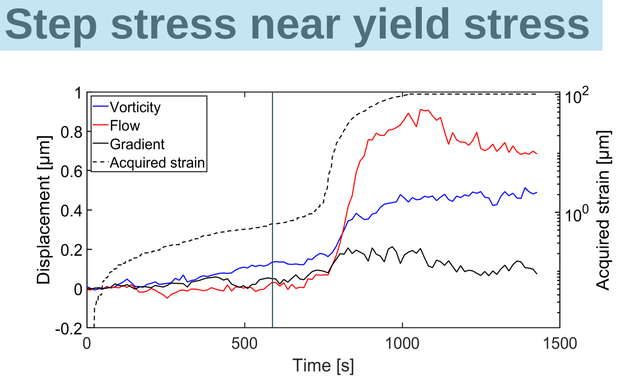
Mechanisms of yielding

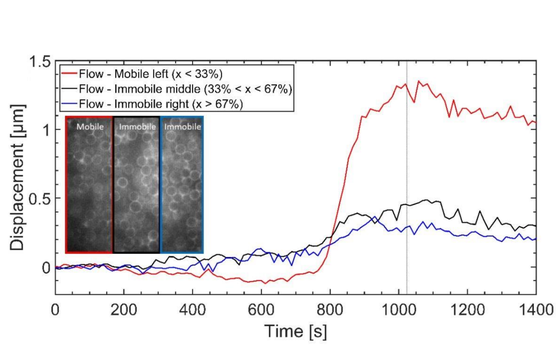
- Bridge (particle) & cluster tracking analysis
- In-situ rheology
- Sequence of Physical Processes analysis (SPP)





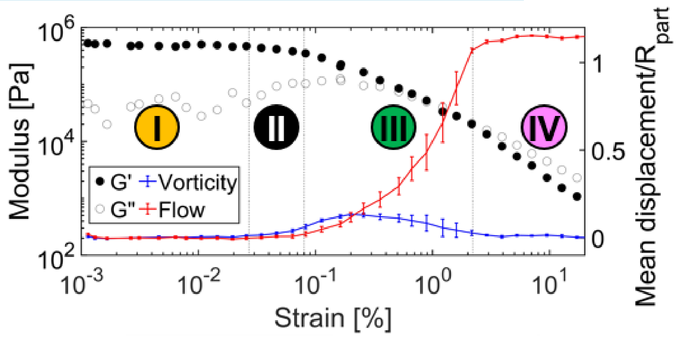
Step stress near yield stress

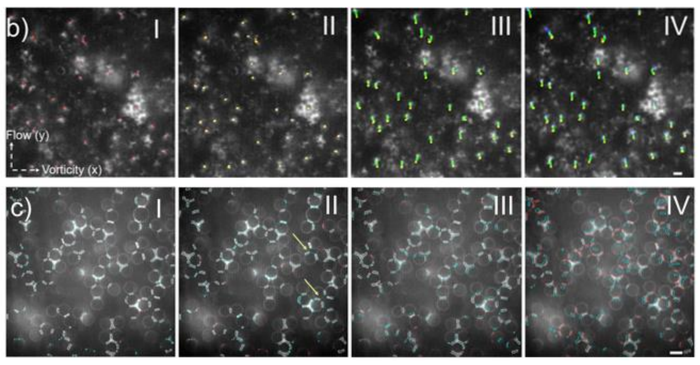




- Displacement localized primarily to mobile region
- Vorticity displacement precedes flow

Full amplitude sweep





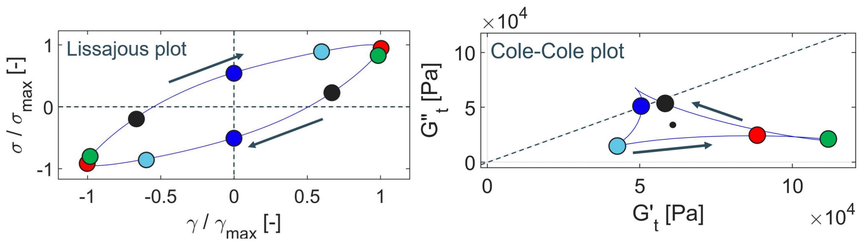
I LVE (constant G' and G''), very little displacement, some bridge merging

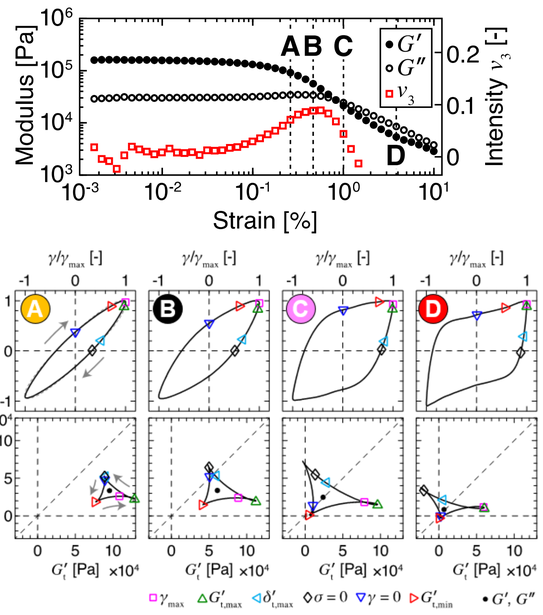
II End of LVE but still reversible yielding, movement in vorticity direction, rotation of floppy connections

III Large movement in flow direction starts, stretching starts then bridge breaking

IV Clusters become disconnected, decrease in z, c and shear band

Single oscillation (SPP)





A $\gamma = 0$

B Minimum G'_t

C Maximum γ

D Maximum G'_t

E Maximum $\dot{\delta}_t = \frac{\partial}{\partial t}\tan^{-1}\left(\frac{G''_t}{G'_t}\right)$ (Yield point)

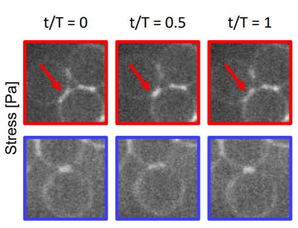
A Fully elastic cycle: removal of Hertzian repulsion, rotation

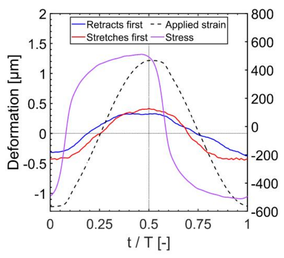
B First time shortly viscous dominated: flow direction movement starts

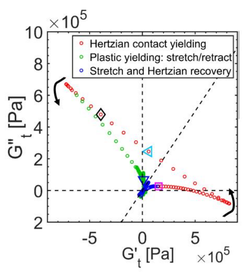
C Mostly viscous dominated: first bridge breaks

D G'_t goes negative: more reorganization than energy stored

Stretching vs Retraction







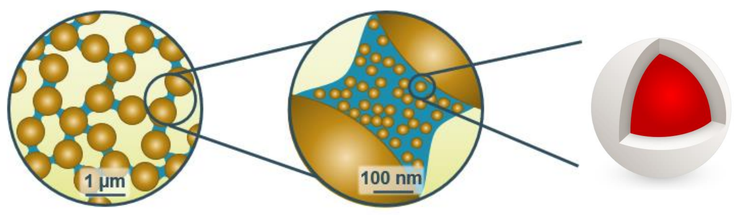
1 Removal of **Hertzian** repulsion, no stretching

2 Intracycle yielding, bridges **stretch** and **compress**

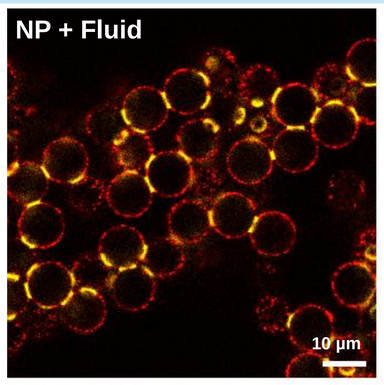
3 Restoration of **Hertzian** contact, bridge **stretching**

Stretching takes slightly **longer** than **retracting**!

Lubrication effect of nanoparticles



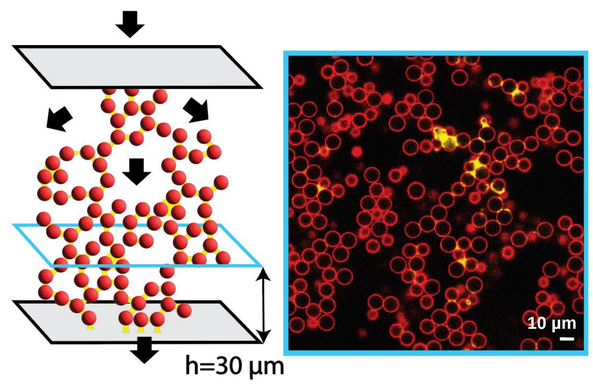
Φ_{MP}= 20 vol%, Φ_{sec}= 1 vol%, Φ_{NP}= 1 vol% * Φ_{sec}

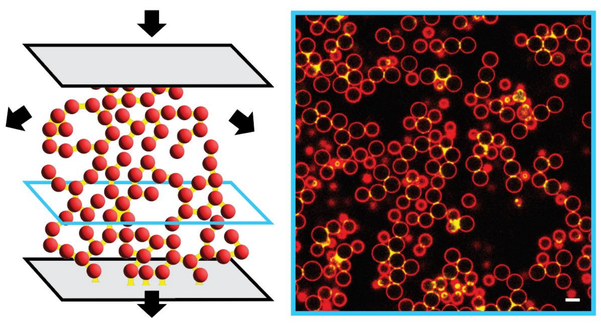


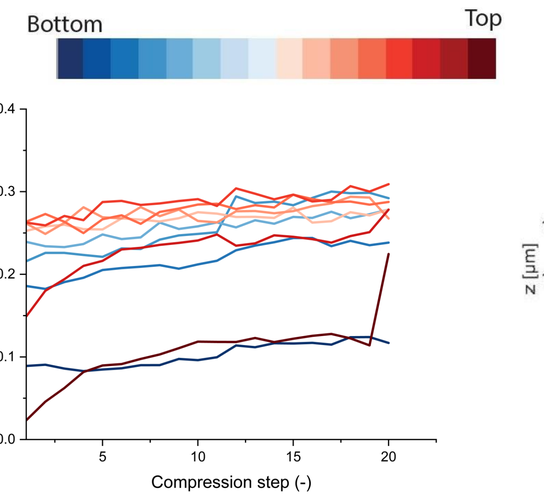
- NP inside capillary bridges **increase compressive strength** and **porosity** of sintered ceramics
- However, in wet precursor systems, NP **decrease** viscosity and yield stress
- Core-shelled silica NP **fluorescently** labeled
- Hydrophilic NP **deposit** on microparticle **surfaces**
- Distribution **homogenous**, inducing **liquid films**

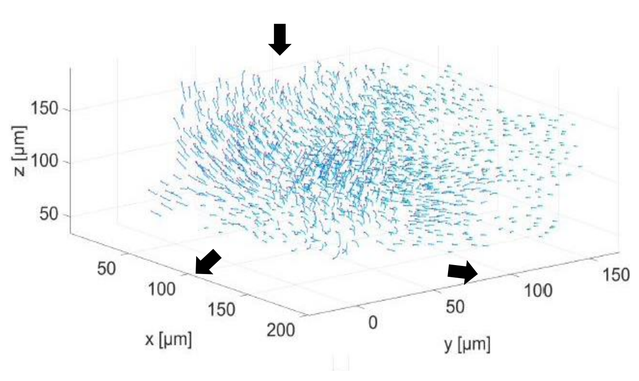
Compression test

1. No NP



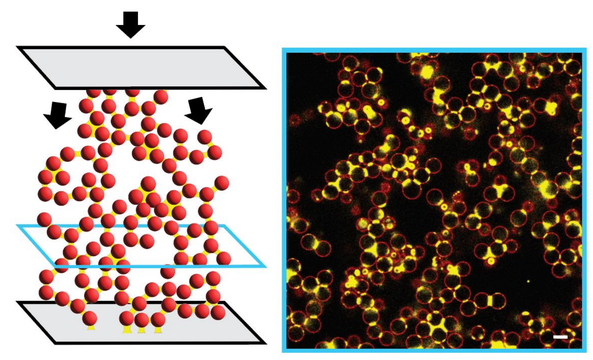


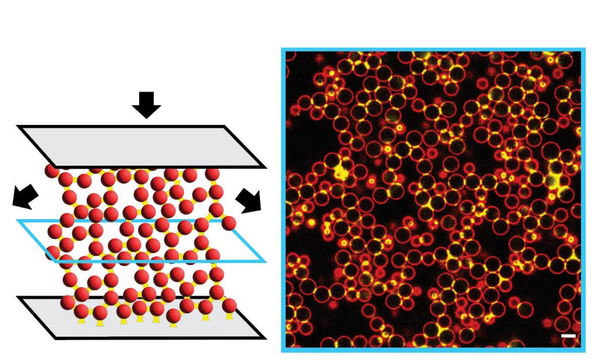


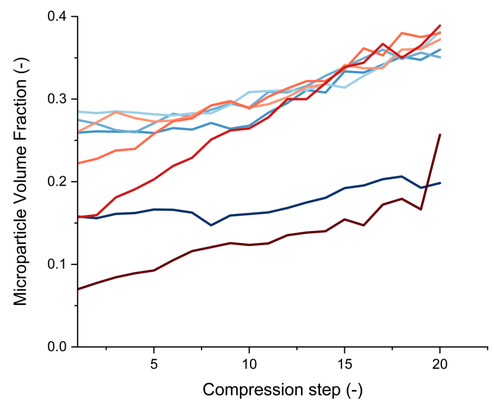


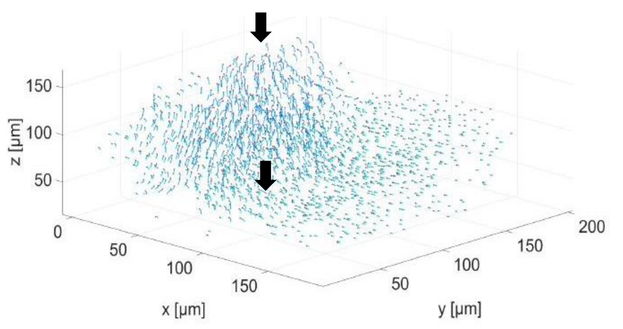
- **Rigid** network, Φ_{MP} increases **mildly,** F_{normal}→ bottom glass **deflects**
- Force **propagates** through MP chains, **X-Y** displacement

2. Hydrophilic NP









- **Flexible** network, Φ_{MP} **increases** homogeneously, each layer converges. Microparticle movements are **lubricated**
- Force is **dampened** through the sample, **Z** displacement

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