Rheomicroscopy of hydrogels across the yielding transitions

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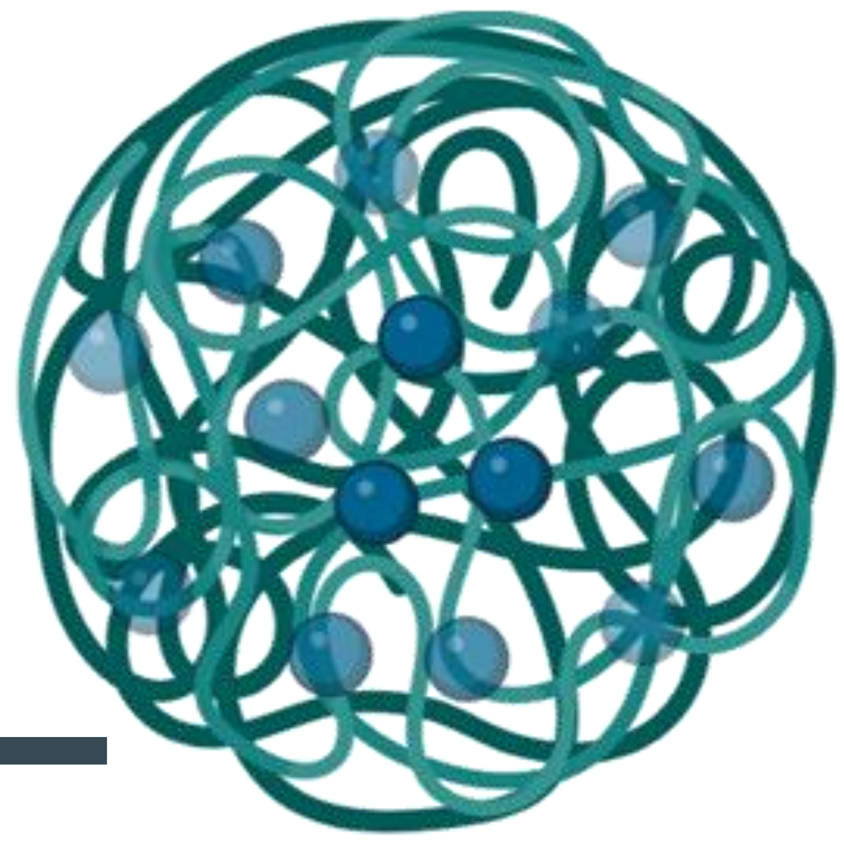


Introduction

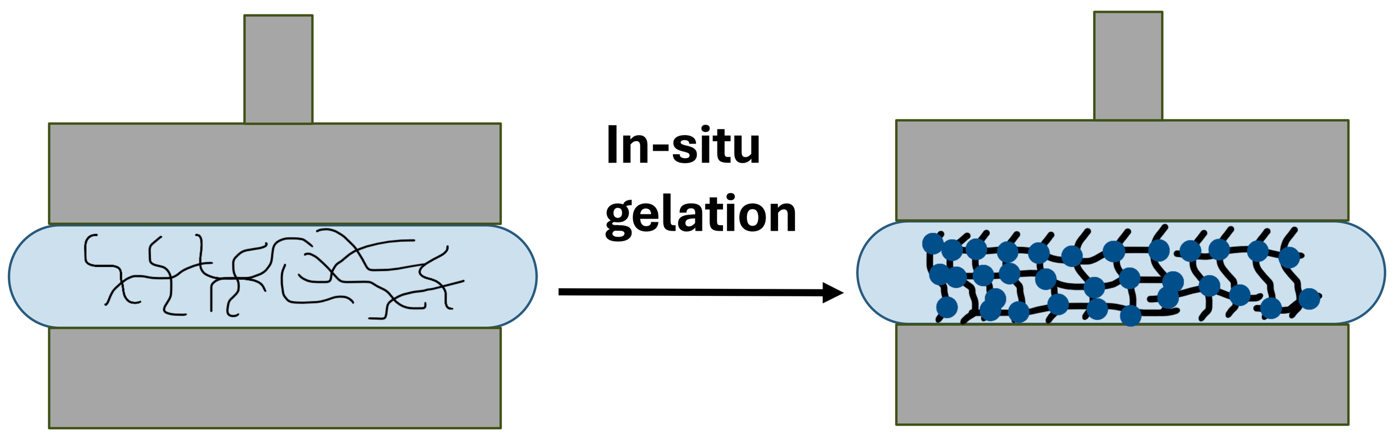
Hydrogels are 3D networks of hydrophilic polymers that can absorb and retain large amount of water while maintain their structure. They are biocompatible, biodegradable, responsive to stimuli and can mimic the properties of natural extracellular matrices. Hence, they can be tailored to various applications.

Sample Preparation

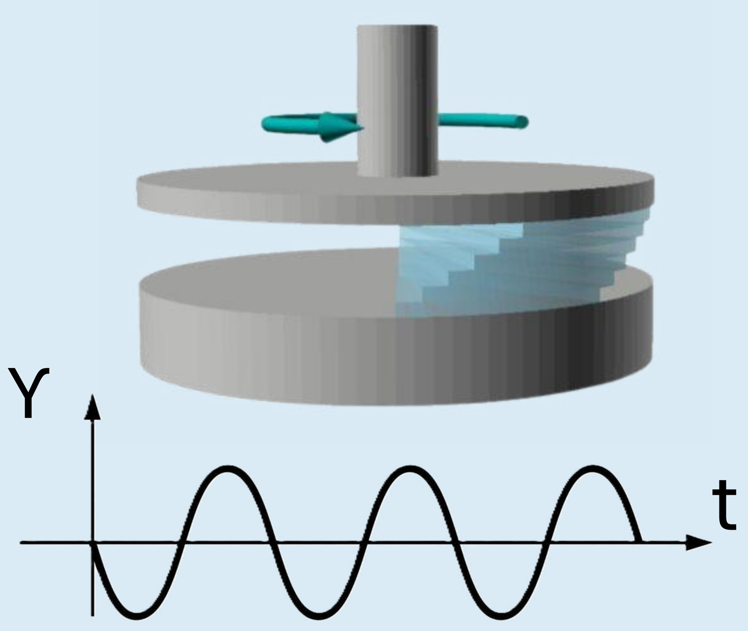
Example

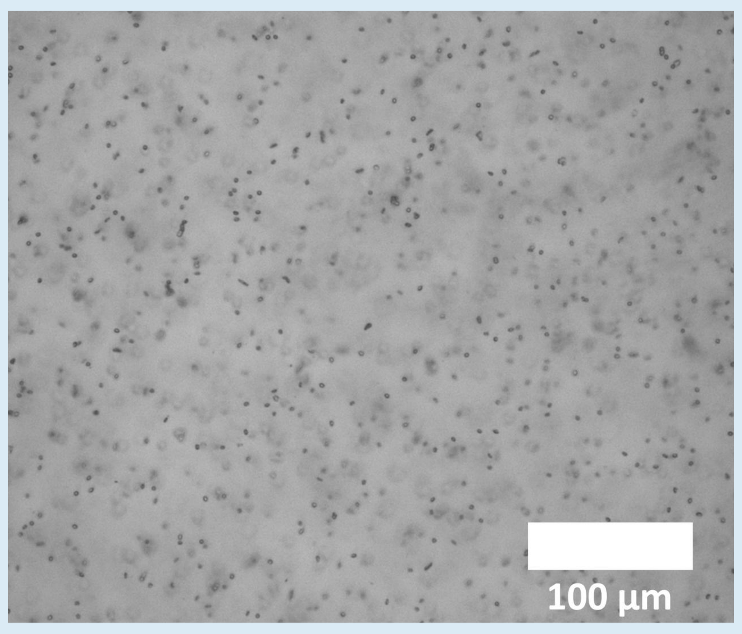
Sodium alginate hydrogels
Polymer - Sodium alginate
Crosslinker - Calcium Carbonate ($CaCO_3$)
Acidifier- Glucono-delta-lactone (GDL)

Rheometer

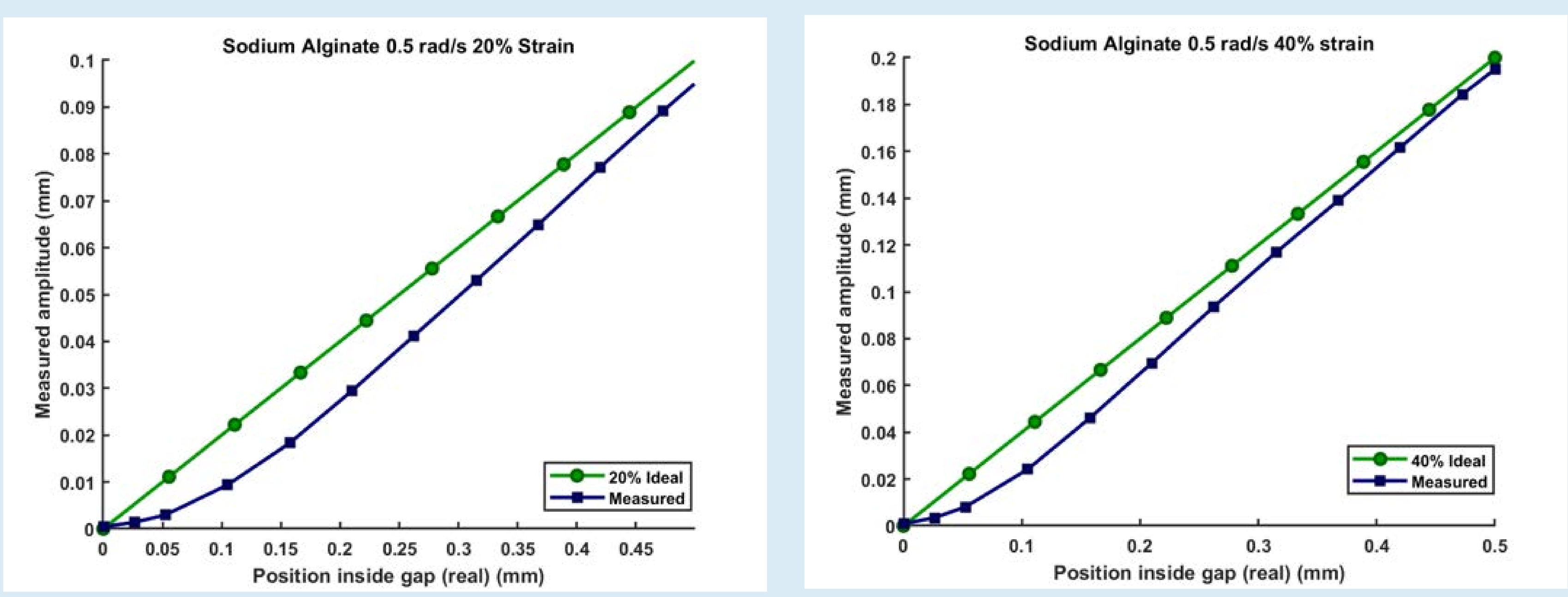


Rheomicroscopy





Sodium alginate hydrogel with Polystyrene tracer particles. (2 µm)



Profile measurements of sodium alginate hydrogel under 20% and 40% strain amplitudes, clearly illustrating the shear-induced banding (heterogeneity of deformation across the sample) behavior.

Next : Measure profiles at higher strain amplitudes and perform echo experiments to study microscopic dynamics and microstructure.

References

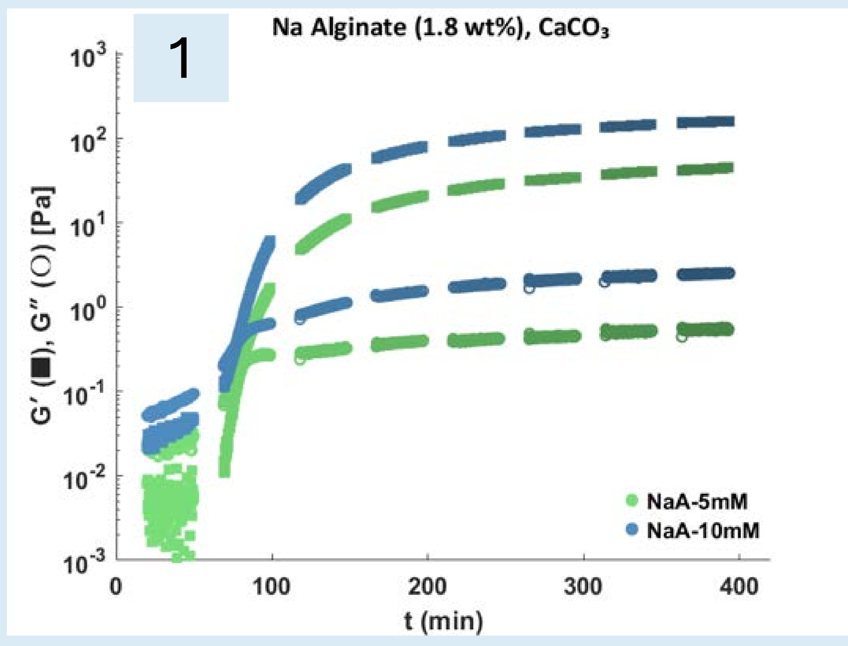
- Cerbino Roberto, Trappe Véronique, *Physica A* 631 128653 (2023),
- Ricky F. Lopez-Santiago and Rolando Castilloa, *Phys. Fluids* 37, 013110 (2025)

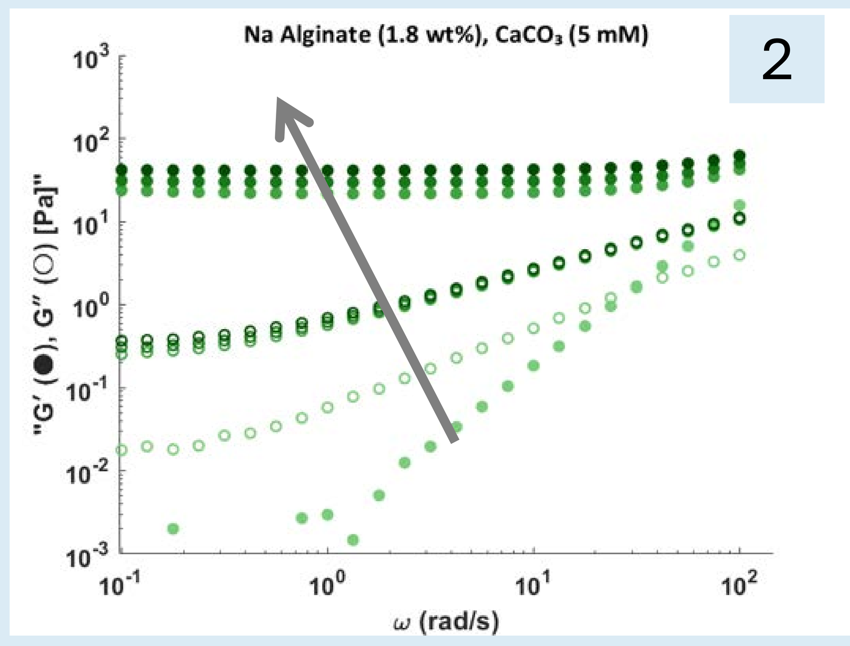
Objective

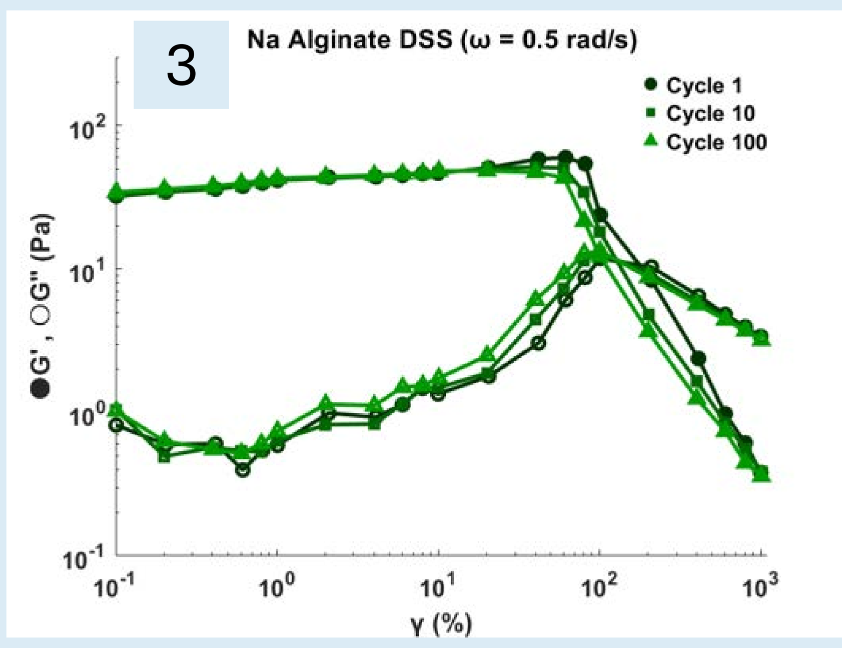
Combining the bulk rheology and particle tracking to understand the connection between microstructure and mechanical stability at aging and yielding points of hydrogels.

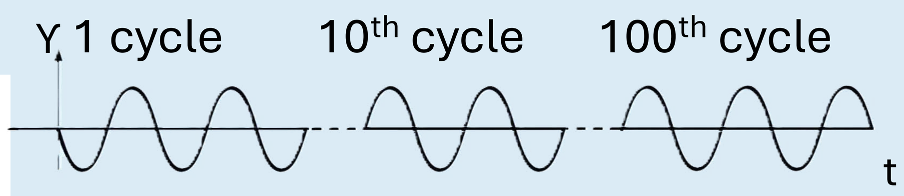
Aging and Yielding

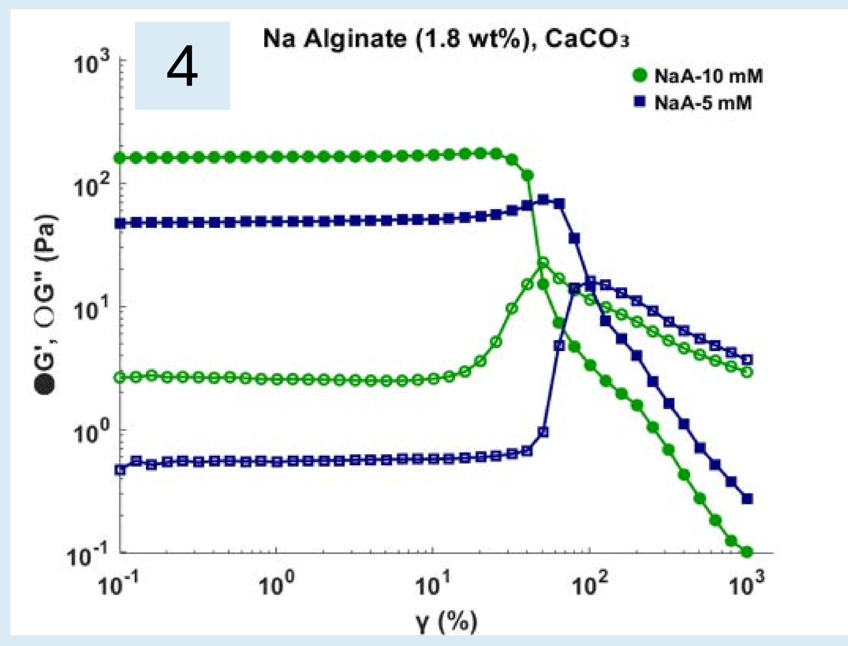
Measuring the viscoelastic properties of sodium alginate hydrogels.











1) and 2) Increased crosslinker concentration and aging time enhances the mechanical strength and viscoelastic stability of hydrogels.

3) With each cycle, the gel becomes more stable, indicating that the elastic component changes significantly as the system requires time to reach a steady state.

4) Dynamic strain sweep showing the shift in yielding point on increasing concentration of crosslinker.

Conclusion and Outlook

Conclusions

- Increasing crosslinker concentration increases hydrogel modulus but does not change aging kinetics.
- Gels require ~100 cycles to reach steady state.
- Gap size strongly influences results in parallel-plate geometry.
- At high strain near/above yielding, system shows non-affine motion *(under investigation)*.

Outlook

- Extend study to Agar gels, Matrigels, pNIPAM.
- Tune hydrogel properties using controlled mechanical oscillations.
- Determine optimal substrates for cellular spheroid growth.

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