Acousto-responsive microgels: A non-invasive approach for microgel dehydration

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Poly(N-isopropylacrylamide) (PNIPAM) microgels are archetypal stimuli-responsive soft materials that undergo a reversible volume phase transition (VPT) upon heating. Below the VPTT (~32 °C), the polymer network remains highly hydrated through hydrogen bonding with water; heating disrupts these interactions, triggering cooperative dehydration and network collapse. This thermo-responsive behavior underpins a broad range of applications, from smart coatings to biosensing platforms. Here, we introduce **high-frequency** , **low-amplitude** ultrasound as a **non-invasive** and fully reversible stimulus capable of inducing PNIPAM microgel dehydration without bulk heating. **MHz-frequency** ultrasound was applied at low amplitudes such that the macroscopic temperature remained well below the VPT threshold. We attribute the observed dehydration to localized viscous dissipation: acoustic energy absorbed by the surrounding liquid disrupts PNIPAM–water hydrogen bonds locally, driving network collapse while leaving the bulk temperature unaffected.

To probe this effect, we developed an innovative integration of ultrasound into a conventional dynamic light scattering (DLS) setup. DLS measurements reveal a pronounced and fully reversible reduction in microgel size upon ultrasound exposure; microgels reswell to their original dimensions upon cessation of the acoustic field, confirming the **non-destructive** character of the stimulus. Complementary small-angle neutron scattering (SANS) experiments provide direct structural insight into the internal network reorganization induced by ultrasound.

Beyond size changes, DLS autocorrelation functions exhibit well-defined oscillations at microsecond timescales matching the applied acoustic frequency. These ultrasound-induced features represent an additional characterization modality, offering sensitivity to the vibrational response of soft microstructures as a function of network stiffness – varied here through cross-linker density – and opening prospects for microrheological investigations.

Collectively, these findings establish ultrasound as a powerful, contact-free tool for the controllable and reversible modulation of microgel hydration and dynamics, with implications for the design of acoustically addressable soft matter systems.

Keywords:
Poly(N-isopropylacrylamide) (PNIPAM) microgels, Ultrasound, Volume Phase Transition