

Study of a field-tunable colloid-polymer solution

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Abstract

In a colloid-polymer mixture, non-adsorbing polymer controls the magnitude as well as the range of an effective attraction between micron-sized colloidal particles. In such a system, various phases, including network-forming gels, can be observed. With tunable interactions, such systems could also be used for studies of phase transition kinetics. An externally controllable tuning can be achieved by the application of an external ac electric field. The external ac electric field induces dipolar interactions in the colloidal suspension, which is an important driving force for nanoparticle self-organization. We report on preliminary work to prepare the system to study the effect of an external ac field on Brownian colloidal particles suspended in a polymer solution. Study of such tunable systems can lead to the development of switchable and responsive materials.

Introduction

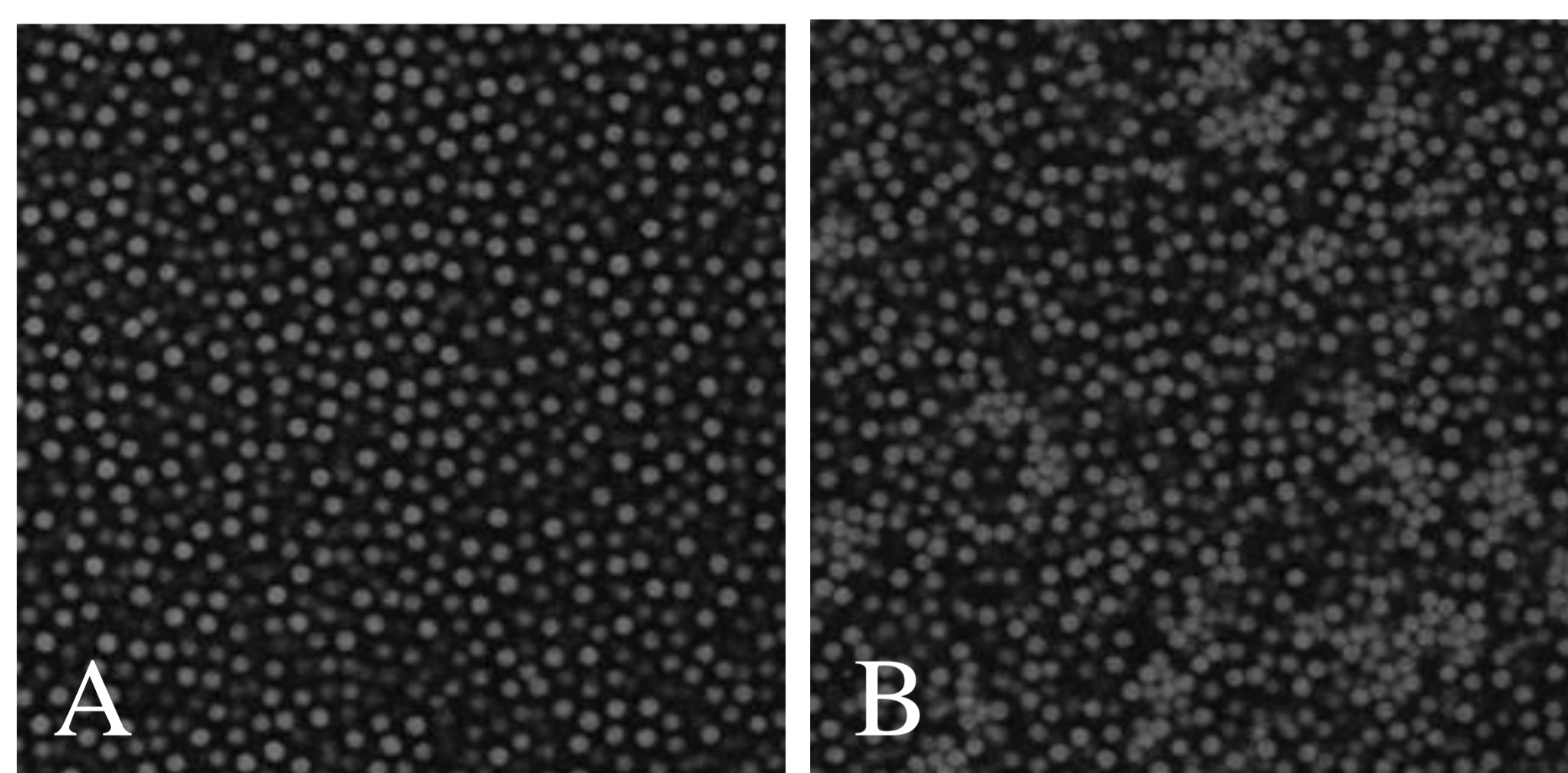


Fig. 1: 2D confocal micrographs of system structure as a function of increasing depletion pair potential strength. (A) $c/c^*=0.15$, (B) $c/c^*=0.21$ [Dibble *et al. Physical Review E*,74(4) (2006)]

- Mixing a non-adsorbing polymer with a colloidal suspension can induce an effective attraction between the particles – the so-called depletion interaction – leading to separation between colloid-rich (liquid-like) and colloid-poor (gas-like) phases.
- Range and magnitude of the attractive interaction can be precisely controlled by varying polymer size and concentration.
- When colloids are charged, the competition between repulsion and the depletion interaction promotes finite clustering, which tends to suppress phase separation and enriches phase behaviour.
- While the gas-liquid transition has been extensively studied, and transitions to various gel and glass states have been observed [3], a field would enable controlled crossings of phase boundaries that would be useful in studying phase transition kinetics

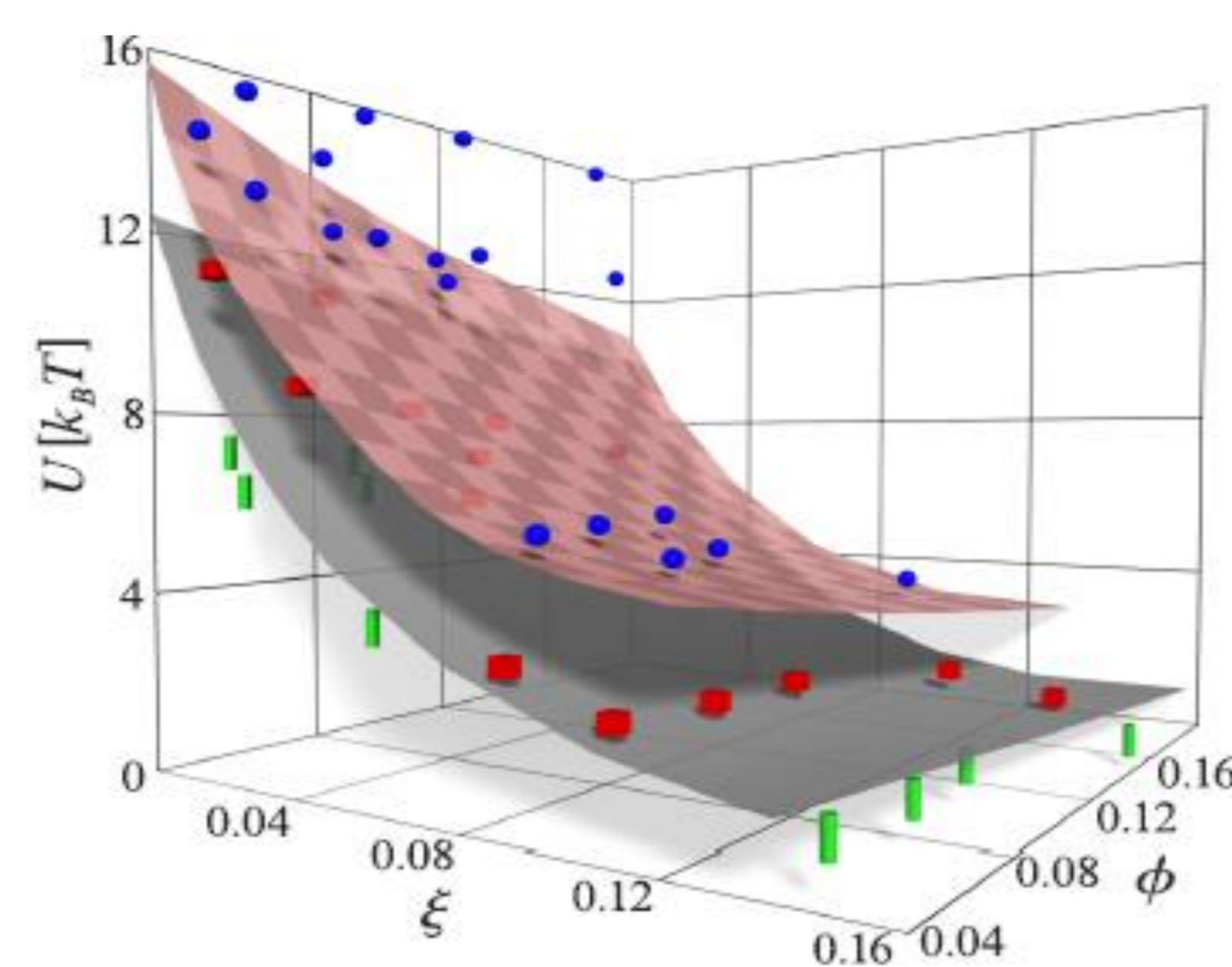


Fig. 2: U - Φ - ξ phase diagram for colloid-polymer mixtures for charged PMMA spheres with non-adsorbing polymers, where U , Φ , and ξ are interaction energy, volume fraction and polymer to colloid size ratio, respectively. Gel (spheres), fluid of clusters (cubes), and monomeric fluid (cylinders) [Lu *et al., Physical Review Letters*, 96(2), 2006]

Experiments

Polymer-induced Interaction in a solvent mixture of
CHB/Decalin(65.6:34.4)

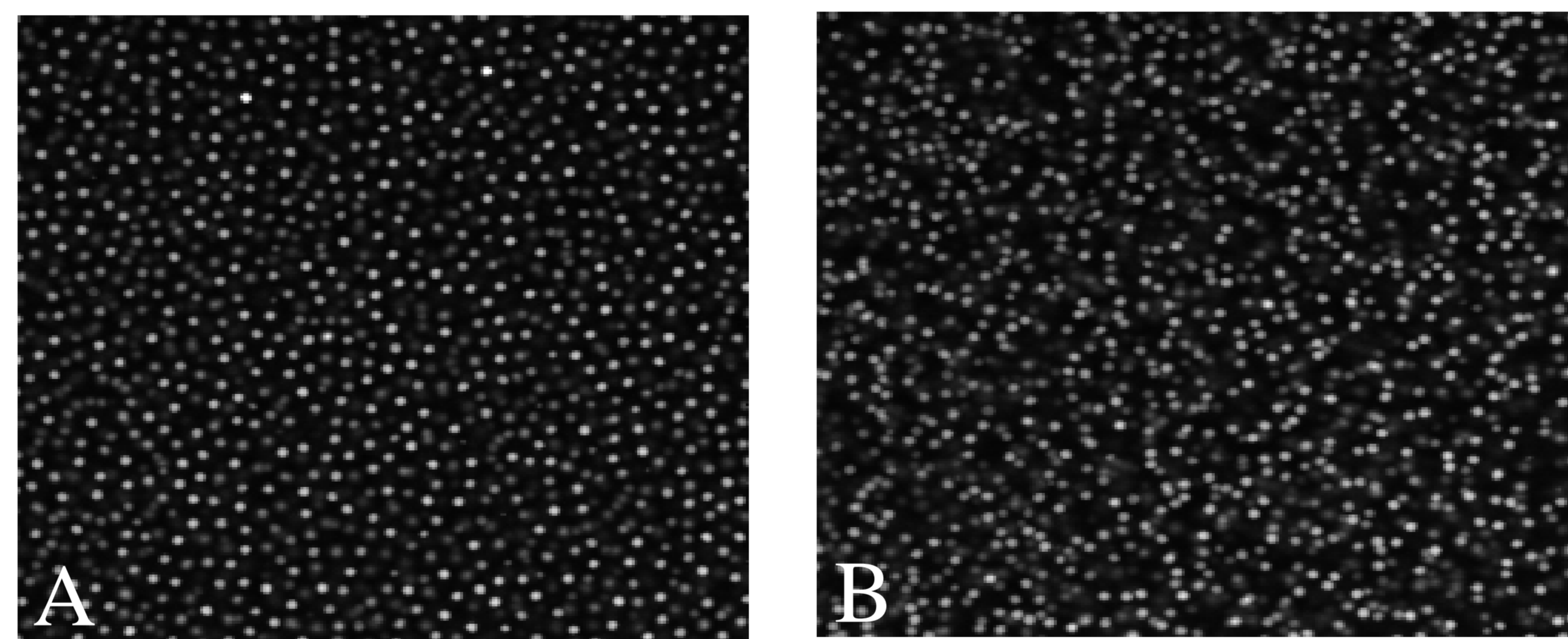


Fig. 3: A) PMMA suspension without polymer (Polystyrene), volume fraction $\Phi \approx 0.20$, size ratio $\xi = 0.05$ B) PMMA suspension with polymer concentration, $c/c^* \approx 0.21$, $\Phi \approx 0.20$, $\xi = 0.05$. The polymer behaves as a depletant leading to depletion interaction between colloidal particles.

Characterization of polymer

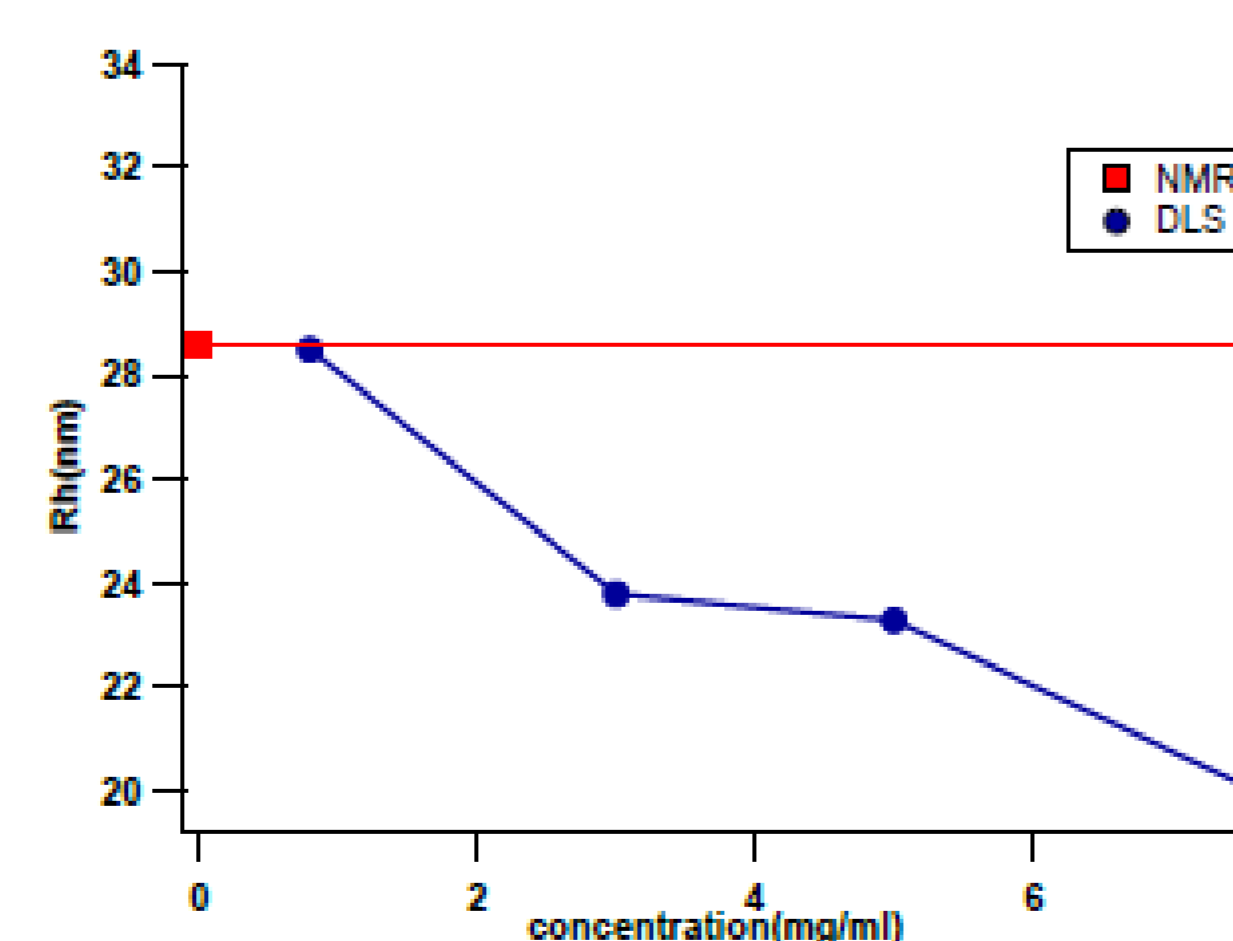


Fig. 5: Dynamic Light Scattering(DLS) and 1H Pulse Field Gradient Nuclear Magnetic Resonance (PFG-NMR) is used for characterizing the size of polymer. NMR experiments were performed for the dilute polymer concentration of 0.8mg/ml and DLS for a range of concentration varying from 0.8mg/ml to 8mg/ml.

References

1. Dibble, C. J., Kogan, M., & Solomon, M. J. (2006). Structure and dynamics of colloidal depletion gels: Coincidence of transitions and heterogeneity. *Physical Review E*,74(4), 041403.
2. Lu, P. J., Conrad, J. C., Wyss, H. M., Schofield, A. B., & Weitz, D. A. (2006). Fluids of clusters in attractive colloids. *Physical Review Letters*, 96(2), 028306.
3. Pham, K. N., Puertas, A. M., Bergenholtz, J., Egelhaaf, S. U., Moussaid, A., Pusey, P. N., ... & Poon, W. C. (2002). Multiple glassy states in a simple model system. *Science*,296(5565), 104-106.

Image analysis technique

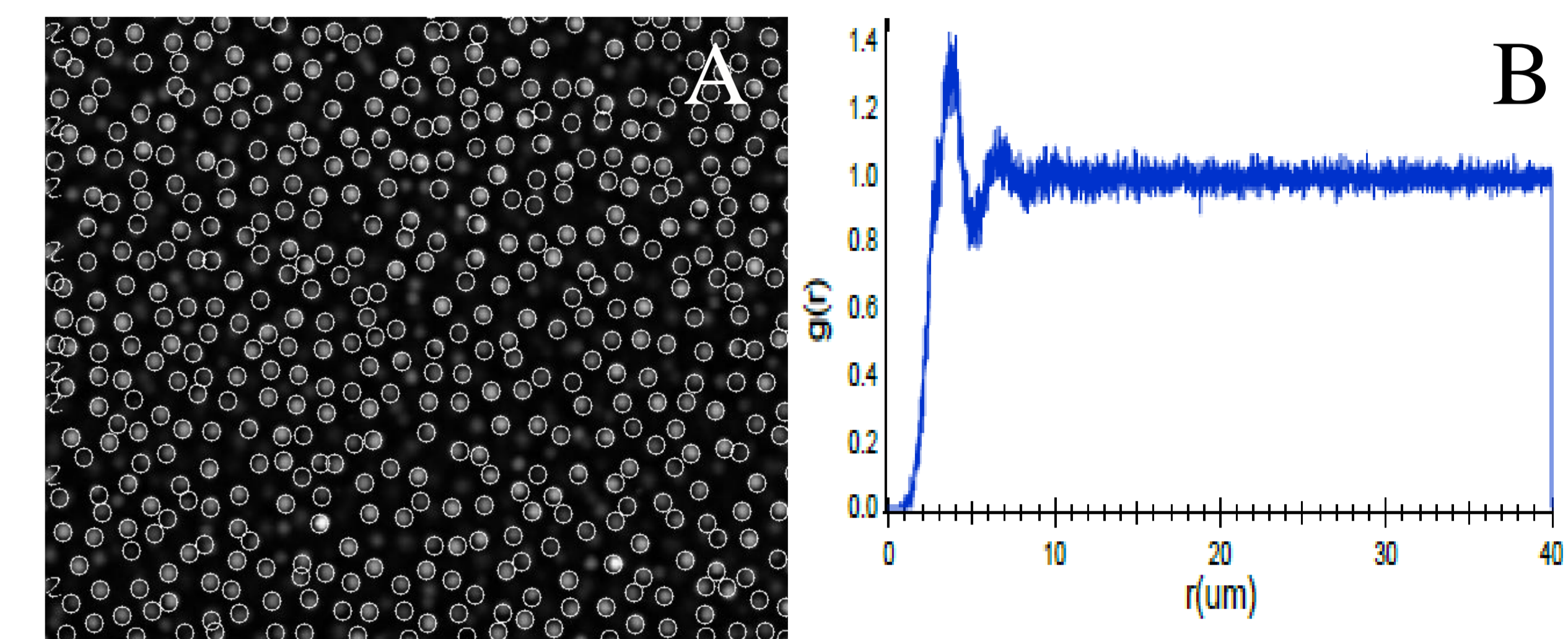


Fig. 4: A) quantitative analysis of video images using IDL® software (Interactive Data Language). The local brightness maxima within an image corresponds to particle location. B) The in-plane pair correlation function, $g(r)$, of the system with $\Phi=0.20$

Summary of Results

- The presence of polymer at lower concentration in a colloidal suspension induces depletion interaction that give rise to cluster formation.
- The self-diffusion coefficient measurement was performed using PFG-NMR for dilute polymer concentration at 0.8mg/ml, and mutual diffusion coefficients were determined as a function of concentration by DLS. Further, the corresponding hydrodynamic radius, shown in Fig. 5, is derived using Stokes-Einstein Relation.
- We were able to determine the polymer size by comparing sizes obtained from NMR and DLS[Fig. 5].

Future directions

- Revalidate the phase diagram of colloid polymer mixture obtained by Lu *et al.*[2]. Since we have charged colloids, the Debye length would be an experimental representation of ξ .
- Adding electric field induced dipolar interactions to the polymer colloid mixture would lead to the crossing of phase boundaries. This can be used to study the phase diagram. We will also plan to simulate field induced dipolar interaction.