

Reversible-irreversible transitions in particle trajectories near the jamming transition

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The reversible-irreversible (RI) transition of particle trajectories in colloidal suspensions under cyclic shear deformation is an archetypal nonequilibrium phase transition and attracts much attentions recently. In the low density limit, the RI transition is predicted to belong to a universality class of the absorption transitions [1], whereas at the high densities well above the jamming transition point, φ_J , it has more to do with the yielding transition of the amorphous solids [2]. The link to bridge the gap between the low and high densities is missing and the relation of the RI transitions with mechanical and flowing behaviors of colloidal suspensions are largely unexplored.

In this presentation, we show the RI transitions over a wide range of densities above and below φ_J by using oscillatory sheared molecular dynamics simulations. It is revealed that the nature of the RI transitions dramatically change across φ_J . When the density is above φ_J , the discontinuous RI transition and concomitant

yield transition are observed. Below φ_J , however, the nature of the RI transition becomes surprisingly rich. We find the three distinct phases; (i) continuous RI transition at small amplitudes and low densities followed by (ii) reentrance to the reversible phase at larger strain amplitudes, and (iii) semi-discontinuous RI transitions in the vicinity of φ_J . Here, we have confirmed that these results are quantitatively agreed with those obtained from the simulations in the athermal quasi-static (AQS) limit. We show that these transition behaviors are strongly correlated to the number of the contacts, characterized in AQS limit. This implies that these distinct transitions strongly correlated with hidden geometrical properties of particle configurations.

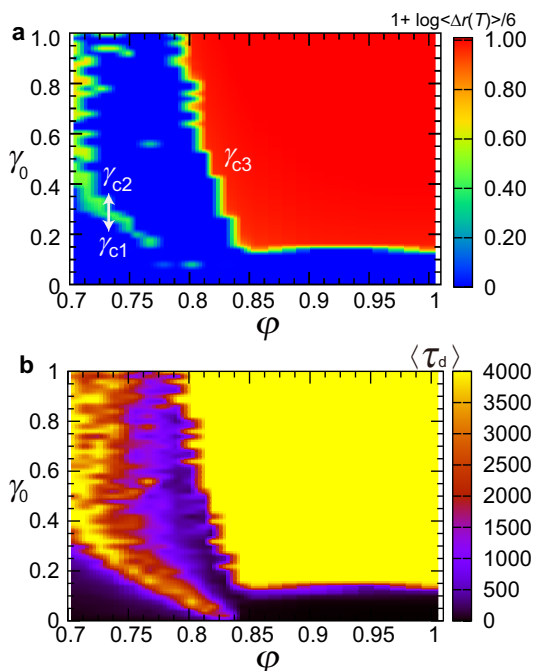


FIG. 1. State diagrams for RI transitions obtained from finite frequency simulations. (a) Averaged one-cycle displacement $\langle \Delta r(T) \rangle$ in the steady state for various strain amplitudes γ_0 and packing fractions φ . The color field presents the value of $1 + \log \langle \Delta r(T) \rangle / 6$ (see the color bar). The RI transition boundaries γ_{c1} (continuous), γ_{c2} (re-entrant), and γ_{c3} (semi-discontinuous or discontinuous) are illustrated as eye guides. (b) Averaged lifetime of irreversible trajectories $\langle \tau_d \rangle$ for various strain amplitudes γ_0 and packing fractions φ . The color field demonstrates the value of $\langle \tau_d \rangle$ (see the color bar).

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