Abstract

The thesis can be categorically divided into two main segments. In the initial section, we present our findings on the phase transition occurring in a two-dimensional system, elucidating the two-stage transition process observed in both passive and active systems. In the second part, our investigation centers around the dynamic behavior of asymmetric particles, specifically those with non-uniform shapes such as ellipsoidal particles and rod-like particles.

In the first chapter, we investigate non-equilibrium phase transition in a system of a model colloidal suspension in two dimensions. We consider a model system of a two dimensional colloidal dispersion of soft-core particles that is driven by a one dimensional stochastic flashing ratchet. The driving induces a time averaged directed particle current through the system. The work explores the dependence of the particle current on the asymmetry of the potential, the density of the dispersion and frequency of the external drive. The competition between the natural relaxation frequency and that of the external drive leads to a resonance like behaviour in the particle current. An analytical expression is compared with data from the simulation that captures the behaviour of the particle current throughout the frequency domain. In addition to this, the system is known to undergo a non-equilibrium melting transition as the directed current reaches a maximum. We use extensive molecular dynamics simulations to present a detailed phase diagram in the frequency density asymmetry parameter plane. With the help of numerically calculated structure factor, solid and hexatic order parameters, and pair correlation functions, we show that the non- equilibrium melting is a continuous transition from a quasi-long ranged ordered solid to a hexatic phase. The transition is mediated by the unbinding of dislocations, and formation of compact and string-like defect clusters.

In the second chapter, we have expanded upon this concept by applying it to a two-dimensional active system, thereby investigating the dynamics and behavior of self-propelled particles within this particular framework.In our work we consider an active two dimensional system, where self-propelled particles interact via inverse-power-law repulsions (but without alignment interactions). The system experiences an external potential subjected to a periodic flashing on-off driving mechanism. In this study, we have conducted an extensive investigation into the behavior of a two-dimensional active colloidal suspension, both in its free state and under the influence of a ratcheting mechanism. Through the utilization of numerically computed structure factors, solid and hexatic order parameters, as well as pair correlation functions, we provide evidence of a transition in the active system from a quasi-long ranged ordered solid phase to a hexatic phase.

In the next two chapter We aim to study the unique characteristics and properties exhibited by anisotropic particles in terms of their motion, rotation, and interaction with their surroundings.The analysis of the Brownian motion of asymmetrical particles is considerably more complicated compared to the spherical case due to the coupling of rotational and translational motion. The long-time translational diffusion coefficient is equal to the average of the translational diffusion coefficients along the three semi-axes of the ellipsoidal or cylindrical particle.

In the third chapter by introducing this active element, we aim to investigate how the self-propelled velocity influences the dynamics and motion of the ellipsoid particles. In our work we have determined the expression for mean square displacement analytically by solving Langevin equation for active ellipsoidal particle for both parallel and perpendicular axis. In this study, we provided analytical and simulation-based results pertaining to the long-term diffusion coefficient of an active ellipsoid particle. Notably, we observed that, unlike passive particles, the long-term diffusion coefficient of the active ellipsoid particle is influenced by both the magnitude of its self-propelled velocity and the rotational diffusion coefficient. We also explicitly study here

transport of an active ellipsoidal particle confined in a plane different force field. In this work we consider free particle, harmonically trapped particle and particle under constant force field. We show analytically that in the presence of external forces, the long-time diffusion coefficient is modified from a free particle. The magnitude of the difference depends on particles asymmetry, being zero only for a perfectly spherical Brownian particle.

In the fourth chapter, we conducted a comprehensive investigation into the directed transport phenomena of noninteracting rod-like particles in a flashing ratchet potential. The rod is constructed with the *'Shish-kebab'* model built by N connected beads in a linear disposition. In this study, we have introduced a simulation model of a system comprising elongated rods immersed in a flashing on-off driving mechanism, presenting a computational framework to investigate their collective behavior and dynamics. We computed the time-averaged directed current of particles moving in the direction of ratcheting, demonstrating the relationship between the particle current in the system and the density and frequency parameters. Additionally, we conducted an investigation into the dynamics of rods with varying aspect ratios, exploring the distinctive behavior and motion exhibited by these rods in the system under study.