Abstract

Understanding the different physical phenomena like collective behavior and self-organising pattern in active matter systems has been an active area of emergent research in soft matter physics. These systems are composed of self-driven units where energy consumption occurs on the level of individual constituent and consumed energy is converted into persistent motion. This energy consumption on individual particle level, makes the system out of equilibrium. Examples of such systems include birds swarm, cytoskeleton of living cells, bacterial suspensions, cell layers, aerial flocks, colloidal systems etc. The first part of this thesis addresses the properties of passive particles when they are put in the binary mixture of active and passive particles and how the active particles will be affected if some kind of physical disorder is present in the system. This we have done using the approach of microscopic simulation. In the second part, we have observed the role of temperature on the ordering kinetics of the active particles and also the relevance of hydrodynamic field on the orientation of polar particles using coarse grained description. We organise this thesis into following chapters: Chapter 1 starts with the detailed introduction of active matter system along with its historical background, existing literature and relevance to study such systems. Further we discuss about the different methodologies and observables present in the system. In Chapter 2, we study the mixture of passive and active Brownian particles. In this chapter, we aim to understand the steady state and kinetics of small passive particles in the mixture. In our system, the passive particles are small in size and large in number, whereas ABPs are large in size and small in number. The system is studied on a two-dimensional substrate using overdamp Langevin dynamic simulation. The steady state and kinetics of passive particles are studied for various size and activity of active particles. Passive particles are purely athermal in nature and have dynamics only due to bigger ABPs. We observe that for small size ratio and activity the passive particles remain homogeneous

in the system, whereas on increasing size ratio and activity they form periodic hexagonal close pack (HCP) spanning clusters in the system. We have also studied the kinetics of growing passive particle clusters and find that the mass of the largest cluster shows a much slower growth kinetics in contrast to conserved growth kinetics in ABP system. Our study provides an understanding of steady state and kinetics of passive particles in the presence of bigger active particles. Chapter 3 is about the steady state properties of active Brownian particles (ABPs) in the presence of a random quenched obstacle. In this study, we fix an obstacle in space and time and use the overdamp Langevin dynamics to analyse the steady state properties of the ABPs by varying the size of the obstacle and peclet number of the ABPs for different packing fraction of the system. We find that the obstacle enhances the phase separation in ABPs and system shows the coexistence of low density and high density regions. Further we make the phase diagram in the plane of packing fraction and peclet number for various sizes of the obstacle and compare it with the case when there is no such obstacle present in the system. we observe that the phase boundary shifts towards lower value of peclet number and packing fraction side as we increase the size of the obstacle and system developes an binodal envelop which provides the range of parameters for which the phase separated densities collapse onto a single coexistence curve. Chapter 4 addresses the role of noise on the ordering kinetics of the collection of active Brownian particles which is modeled using coarse-grained conserved active model B (AMB). The ordering kinetics of the system is studied for the critical mixture when quenched from high to low temperature. We find that the structure of the growing domains changes from isolated droplet type for AMB without noise to bi-continuous type for active model B with noise (AMBN). We find that the noise is important for the growth kinetics of AMB. We use extensive numerical study as well as dynamic scaling hypothesis and find that asymptotic growth law for AMBN is diffusive Lifshitz-Slyozov (LS) type whereas for system without noise it is 0.25. The kinetics of the growing domains shows a strong time dependent growth law for AMBN. For different noise strengths and activities the growth exponent shows a crossover from early time 0.33 value to intermediate time 0.25 value and it again traverses from 0.25 to 0.33 asymptotically. Correspondingly the two different scaling functions are found for intermediate time with growth exponent 0.25 and late time with growth exponent 0.33. In Chapter 5, we study the ordering kinetics of AMBN for off-critical composition. First we study the system when the system is slightly away from the critical mixture and further we analyse the results for deep off critical mixture. We see that for slighlty off critical mixture, the system develops a competition between the activty and asymmetry due to the off-criicality present in the system and growh exponent is always 0.33 for any strength of noise. When there is no such competition, the exponent approaches to value 0.25 for intermediate strength of noise for some intermediate time and asymptotically it goes to 0.33. For deep off-critical mixture we find no such competition and exponent always remains 0.33. In Chapter 6, We have addresses the relevance of hydrodynamic field on the orientational field. We study the ordering kinetics in active polar fluid. We model the active polar fluid as a collection of orientable objects supplied with active stresses and momentum damping coming from the viscosity of bulk fluid medium. The growth kinetics of local orientation field is studied. The effect of active fluid is contractile or extensile depending upon the sign of the active stress. We explore the growth kinetics for different activities and find that for both extensile and contractile cases the growth is altered by a prefactor when compared to the equilibrium Model A. We find that the extensile fluid enhances the domain growth whereas the contractile fluid suppresses it. The asymptotic growth becomes pure algebraic for large magnitudes of activity. We also find that the domain morphology remains unchanged due to activity and the system shows the good dynamic scaling for all activities. Chapter 7 provides the conclusion with the brief summary of entire work along with the future prospects of the work with the possible extension and practical applications.