Abstract

The study of active systems is an active area of current research in soft matter physics. Active systems show fascinating collective behavior and statistical properties which include both living and non-living matter. These systems are composed of self-driven units, self-propelled particles, and each has the ability to transduce stored energy into systematic movement, for example: a swarm of myxobacteria, cytoskeleton of living cells, bacterial suspensions, cell layers, terrestrial and aquatic animals, aerial flocks, and colloidal systems. A distinct feature of active matter systems compared to other nonequilibrium systems is that the energy input at the level of each particle drives the system out of equilibrium.

In this thesis, we discuss various properties of a collection of polar particles and also the dynamics of a single polar particle. Further, we study the effects of intrinsic inhomogeneities in polar systems and also the growth kinetics of the polar systems. Moreover, we also use the mean-field theory and linearization approximation to solve hydrodynamic equations of motion written from the symmetry arguments and the associated conservation laws. This thesis is organized into seven chapters.

Chapter 1 is the introduction which describes active systems and the historical background of the problem. This chapter includes definition and basic properties of active systems. We also discuss the different approaches to study the active systems like: agent-based simulation and hydrodynamic equations of motion. The rest of the chapters are organised as follows:

In chapter2, we model a binary mixture of self-propelled particles moving with variable speed. The variable speed model is introduced, where the propulsion speed of each particle varies with their neighbour's orientation ($\chi(t)$) through a power exponent γ such that $v(t) = v_o|\chi(t)|^{\gamma}$. Where $v(t)$ is the self-propulsion speed of the particles at time t and v_o is the maximum self-propulsion speed. Two types of particles can be characterised by

different power exponents γ_1 and γ_2 . In the ordered state, we find phase separation when the difference in the two's exponent is large. In the disordered state, when the difference in the two's exponents is large, one type of particle with a large exponent forms static clusters, which act as a nucleation site for another type of particle with smaller exponents.

In chapter3, we introduce a minimal model for a collection of polar self-propelled particles with the bond disorder in the deep-ordered state. We find that the presence of the disorder does not destroy the usual long-range ordering in the system. Further, density clustering is enhanced, hence there is more cohesion in the presence of the disorder. Furthermore, ordering kinetics and giant number fluctuation does not change with bond disorder.

Chapter4 describes the study of the polar flock with bond disorder near the order-disorder transition. We find that the nature of the phase transition changes from discontinuous to continuous by tuning the strength of the disorder. The bond disorder also enhances the ordering near the transition due to the formation of a homogeneous -flock state for the large disorder. It leads to faster information transfer in the system and enhances the systems' information entropy.

In chapter5, we study the properties of polar self-propelled particles along a thin junction. Inside the junction, particles experience a high noise-disorder state, and outside they are in the ordered state. The width of the junction is adjusted by the junction width parameter 'd'. The model is motivated by the Josephson junction, an analogous equilibrium system. At the junction, we have found the current orientation reversal for a critical width of the junction, which is a common feature of the Josephson junction. Further, the particle current at the junction decreases with an increase in the junction width.

In chapter6, we studied the phases of passive disk-shaped particles of different sizes with external potential on a two dimensional substrate using overdamped Langevin dynamics. Where the potential is obtained from the binary mixture of active and passive particles for variable size ratio S and activity. We find potential is an attractive type for small distances for large size ratio and activity. Four different phases are found: (1) homogeneous disorder phasec(HDP), (2) homogeneous crystal phase (HCP), (3) disordered phase separated phase (DPS), and finally, (4) ordered phase-separated phase (OPS). Moreover, the system is studied in two ways viz: microscopic and coarse-grain simulation. The observed phases are consistent in both ways.

Finally, in Chapter7, we conclude the thesis with a brief summary of all the chapters discussed above with future prospects.