Abstract

In this thesis work experimental studis of dusty plasma in a hollow cathode discharge are presented. To measure the plasma parameter cylindrical Langmuir probe was used as a diagnostic tool, while CCD camera was used as a diagnostic tool to study the dust grain dynamics. Four different sets of experiments were carried out to study the dust grain dynamics in different regime of strongly coupled dusty plasmas. In these experiments three different sized alumina dust grains and two different anode geometories were used. Main feature of these experiments was, the levitation of bigger size (diameter $50-100\ \mu m$) dust grains in the sheath of hollow cathode discharge.

A DC Ar plasma was produced between the cylindrical hollow cathode and coaxial anode. The cathode was covered with a PVC tube to shield it's outer surface. During experiments two types of anode geometry were used. In first geometry the length of the anode was same as the length of cathode (60 mm) while in second case anode length was recessed by 20 mm. For convenience these geometries are named full anode (FA) and recessed anode (RA) respectively.

In FA geometry alumina dust grains of diameter $\sim 80\ \mu m$ were levitated. Under suitable discharge conditions these levitated dust grains formed a Coulomb solid structure, which was consistent with a large value of Coulomb coupling parameter ($\Gamma \approx 430$). Experimentally we have measured variation of intergrain spacing and plasma parameters (density n_i and temperature T_e) with discharge voltage. The scaling laws were compared with phenomenological model described by dipole-dipole interaction [32]. Experimental scaling laws were observed to match with theoretical prediction. Thus in addition to the screened monopole repulsive force, dipole-dipole attraction force played a crucial role in Coulomb solid formation.

Afterwards we followed melting transition of this Coulomb structure. When the discharge power was increased, the dust grains in the Coulomb solid started moving violently and resulted in melting. An anomalous increase in the part of the kinetic energy of dust grains was attributed to be the main reason for the observed melting of Coulomb solid. They were also found to melt with decrease in neutral gas pressure. These behavior have been reported earlier by Nefedov et.al. [40]. Thus our results are consistent with earlier reported experimental work.

In RA geometry, alumina dust grains of average diameter $\sim 50\ \mu m$ were levitated. Under suitable discharge condition these dust grains started rotating without imposition of any magnetic field. The dust particles rotate in vertical plane and show the influence of gravity. Dust mass rotation was observed only when it allowed to accumulate large number of dust grains. This behavior suggests that the self-consistent fields of the dust grains is crucial for achieving the state of rotation. During experiments the speed of rotation was found to increase with the increase

in discharge voltage. It was found to decrease with increase in neutral pressure. Valunia et.al. [6] have proposed that such rotatory motion of dust cloud could be due to dust charge gradient perpendicular to gravity. We have compared our experimental results with their proposed model and found to be consistent. When a small magnetic filed of 25 $Gauss$ was applied it has a pronounced effect on the vortex motion. It was observed that the particle orbit which was slightly elliptical without magnetic field, become more circular orbit in the presence of magnetic field. This was due to the $\mathbf{E} \times \mathbf{B}$ motion of ions which was dragging the dust particles. Further the rotation speed of the particles was found to increase with increase in strength of magnetic field. Increase in neutral pressure decreases the speed of rotation as observed in magnetic field free case.

We have introduced a small amount of manganese di-oxide (having high dielectric constant) dust grains along with the alumina dust grains. Enhanced dust number density and dust thermal motion were observed. We have observed dust acoustic waves (DAW), when the neutral gas pressure was progressively reduced. We have observed a transition from coherent to multimode turbulent oscillation when the neutral pressure was further reduced below a threshold value. Pramanik et.al. [5] have also observed such coherent to multimode turbulent transitons, when the pressure was reduced. In our experiments particularly the phase velocity obtained from measurements of the dispersion relation was in good agreement with the theoretical prediction. Experimental results suggest that the excitation mechanism of DAW modes was due to ion streaming instability taken along with the spatial charge gradient due to inhomogeneity in bulk plasma.

Further, specially prepared hollow dust grains with average diameter $\sim 100\ \mu m$ were used in the same RA configuration. We have observed high speed dust particles flowing to the central region of the cathode sheath and form nucleation site for dust cloud. By varying experimental parameters we were able to levitate one or two particles at the nucleation region. Several interesting phenomenons like scattering, collision, reflection, molecular formation were observed. It was observed that in addition to the screened repulsive force, the dust particles begin to experience attractive forces as the size of them increases. Thus experimental observation of large size dust-dust collision, gives an opportunity to test the existence of attractive force between a pair of dust particles.