Dusty Plasma Rotation and Acceleration in Inductively Coupled Discharges at High Magnetic Fields

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We report on results from magnetized dusty plasma experiments carried out in collaboration with the Magnetized Dusty Plasma Experiment (MDPX) research group at Auburn University. Using RF antennae external to a non-conducting cylindrical vacuum chamber we produced inductively coupled plasmas (ICP) free of filamentary structures that have been previously observed in capacitively coupled plasmas (CCP) at high magnetic fields and low pressures (E. Thomas Jr., et al., Phys. Plasmas 23, 055701, and references therein). In our experiments, silica hollow microspheres with a diameter of 50 µm and wall diameter on the order of 100 nm were levitated in ICP at neutral pressures varying from 5 to 300 mTorr, and magnetic fields ranging from 0 to 3.25 T. Filaments were not observed in the entire parameter space. However, dust rotation was observed similar to previous experiments at lower magnetic fields (N. Sato, *et al.*, Phys. Plasmas 8, 1786 – 1790).

Our experimental setup included a metal tray in which the dust normally rests (no dust shaker was used for these experiments), and an upper electrode immersed in an argon plasma that is normally at floating potential. The upper electrode is only connected to a DC power supply (enabled concurrently to the RF discharge) to purposely create filaments and arcing to the bottom tray, leading to dust particles being 'kicked up' and then being levitated by the resistive plasma sheath as they fall back down. Once enough particles are captured at the plasma sheath, the DC voltage is turned off and levitation is only sustained by the ICP. The RF frequency is chosen to be 22 – 30 kHz, which is low compared to other experiments that use CCP and RF of 13.56 MHz. Given this low frequency, RF is cutoff close to the chamber's cylindrical wall, leading to a plasma density gradient that peaks at the wall and is minimum at the chamber's axis. We conjecture that such density gradients cause pressure gradients that are in turn responsible for dust rotation through ion momentum transfer in the $\nabla P \times B$ direction, initially proposed as an explanation for the Sato experiments (P.K. Kaw, *et al*., Phys. Plasmas 9, 387 – 390). However, our rotation is faster than that reported by Sato *et al.*, albeit at much higher fields and larger dust diameter. At the combination of low neutral pressure and high magnetic field, we did not observe levitation or rotation. Instead, we observed dust being impulsively 'kicked up' and ejected at high speeds, which we conjecture is caused by the Debye length increasing for dust resting on the tray given the low plasma density and low collisionality with neutrals, resulting in high electron temperatures. Once the Debye length becomes larger than the interparticle distance for some of the dust particles resting on the tray, these are subject to electrostatic repulsion that can easily overcome gravity, leading to fast ejection from the tray.