Measurements of electric field and dust charge in a plasma sheath

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When plasma comes into contact with material surface, a layer of net space charge called *plasma sheath* establishes itself between the surface and the bulk plasma. Despite decades of investigation in dc and rf sheaths, there are still uncertainties about aspects of sheath structure which remains a topic of contemporary theoretical and experimental interest. Another point of interest in plasma sheath investigation is the study of plasma crystals, which are ordered dust structures that have been observed to form in the plasma sheath region. The properties of such dust structures are determined mainly by the spatial variation of plasma sheath parameters. One of the properties of such dust structures that is not well understood is the dust charge. Usually the dust particles achieve electrostatic equilibrium with respect to the plasma by acquiring a negative charge.

The charge on the dust particle can be determined from resonant frequency measurements, measurement of the equilibrium position of the particle, dust-acoustic wave experiments, analysis of horizontal collisions of particle pairs, analysis of the trajectories of oscillating particles, dust sound speed measurements, and Mach cone experiments. The first two mentioned are the most convenient method in determining the charge of a particle levitated in the sheath. However, both methods need some information about sheath electric field.

The resonant frequency is given by $\omega = \sqrt{ZE'/m}$. And provided that the electric field gradient E' is known, then the dust charge can be determined. For micrometer-sized particles the force balance is dominated by the electric and gravitational forces, that is $ZeE = mg$. Hence the dust charge can be determined by knowing the value of electric field E at the equilibrium height. On the other hand, if the charge on dust particles is known, then these techniques can be applied to determine the sheath electric field.

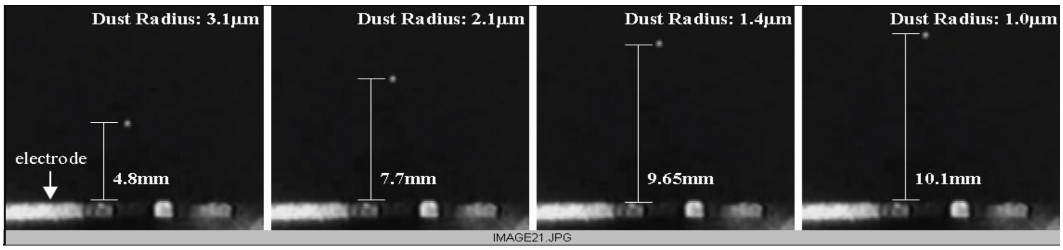

Fig. 1. *Images of levitation of particles of different size.*

We report here simultaneous measurements of sheath electric field and dust charge using various sizes of dust particle. As shown in Fig. 1, dust particles of different sizes are levitated at different positions within the sheath, corresponding to particular values of the non-uniform sheath electric field. By measuring the equilibrium position and resonant oscillation frequencies of particles of various sizes, the values of E and ZE' were obtained as a function of position within the sheath from which Z can also be determined as a function of position within the sheath. The E profiles obtained have been compared with sheath models. It was found that electric field is indeed linear in the middle of the sheath for a wide range of pressure (50-300 mTorr). A non-linear dependence for E in the region near presheath boundary was found for the pressures under 50 mTorr.