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Experiments on the formation and melting of dusty plasma crystals in a DC glow discharge plasma

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Dusty plasma crystals have traditionally been observed and studied in radio frequency discharge plasmas, and their formation in a DC glow discharge plasma remains always experimentally challenging. We report various experimental investigations in a stable dusty plasma Coulomb crystal produced in the cathode sheath of a DC glow discharge plasma [1]. These observations are made in the dusty plasma experimental (DPEx) device where crystals made of mono-disperse melamine formaldehyde grains are produced in the background of an Argon plasma. The crystalline nature of the structure is confirmed through a host of characteristic parameter estimations, which includes the radial pair correlation function, Voronoi diagram, Delaunay Triangulation, the structural order parameter, the dust temperature, and the Coulomb coupling parameter. The crystal formation is frequently found to be accompanied by the presence of one or more slightly heavier particles suspended a little below the monolayer. The interplay of one such test particle with the crystal is investigated for two distinct cases—(i) when the particle remains confined (trapped) in the space below the crystal and (ii) when it interacts for a short while with the crystal and then moves out of the vicinity. The trapped particle orbit induces permanent structural changes in the crystal in the form of microcracks, which can be enhanced by energizing the test particle with an incident laser [2]. This crystalline structure can be melted to a liquid state by changing the discharge parameters. The nature of the melting or formation process in our experiment is established as a first-order phase transition from the variations in the Coulomb coupling parameter, the dust temperature, the structural order parameter, and from the existence of a hysteresis behavior [3]. Our experimental results are distinctly different from existing theoretical predictions for two-dimensional crystals based on the Kosterlitz-Thouless-Halperin-Nelson-Young mechanism or the grain boundary induced melting and indicates a mechanism that is akin to a fluctuation induced first-order phase transition in complex plasmas. In some set of the experiments, the liquid and crystalline states are found to coexist at a specific discharge condition.

References:

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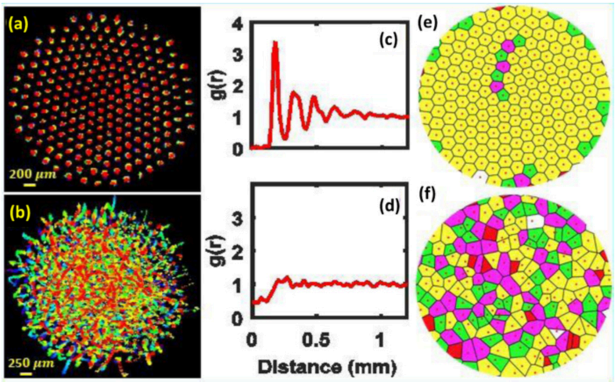

FIG. (a) and (b) Overlapped position coordinates of dust particles for consecutive 50 frames. (c) and (d) Correlation functions and (e) and (f) Voronoi diagrams correspond to (a) and (b), respectively. (a), (c), and (e) correspond to P = 6.9 Pa whereas (b), (d), and (f) correspond to P = 6.7 Pa.