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Structure and melting of 3D anisotropic dust crystals in dc glow discharges.

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Introduction.

The nature of solid body melting is still debatable. Experimental data necessary for analysis are quite poor and contradictory by now. Furthermore the experimental data interpretation is aggravated by necessity taking into account the commensurability with substrate effects and substrate imperfections. Under certain circumstances a so-called plasma crystal in gaseous discharge is very valuable experimental model for melting phenomena investigation on kinetic level. One of the fundamental characteristic of any system under consideration is its response to controlled external influence and its behavior dynamics. For such phenomena investigation of the material response should be rapid enough and material itself should be easy to observe and control. Plasma crystal easily satisfies all this requirements.

Presently in most of papers crystalline dusty plasma structures formation is studied in radio frequency (RF) discharge plasma. However it is significant that under RF discharge conditions macroparticles as usual form quasi two dimensional crystals in the area where quasi-neutrality is disturbed. Three dimensional structures in the area of quasi-neutrality were firstly observed under DC glow discharge conditions.

Aim of paper presented is experimental studying of three dimensional crystalline dusty structures melting, which were formed under DC glow discharge conditions. The basic problem that was supposed to be solved for achievement of this aim was to obtain spatial positions of dusty particles and kinetic characteristics of dusty structure in three dimensions during melting process.

The simplest method from experimental point of view to obtain triaxial positions of macroparticles is using stereoscopic filming of dusty structure. In this case the third coordinate of a macroparticle is a function of its two dimensional coordinates from the first and the second cameras and of the angle between them. Similar technique and its applications were described in papers [1] and [2] where not uniform multibeam illumination method was used for preliminary estimation of the third coordinate of a particle.

In this paper, using analysis and comparison of two dimensional trajectories of each particle pattern from both cameras we had obtained coordinates of 270 macroparticles that is about 70 % of total number of macroparticles.

Experimental setup.

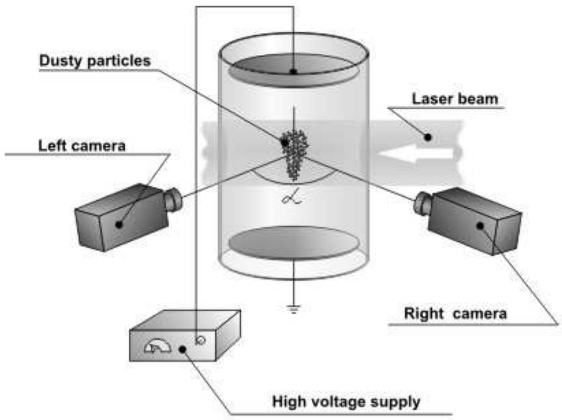

Fig. 1. Experimental setup scheme.

Experiments which realize binocular vision technique were carried out on the DC glow discharge setup. Discharge chamber was a glass tube of 900 mm length and has 55 mm in diameter. It was filled with neon at 0.51 Tor pressure. Discharge current and buffer gas pressure were adjusted to obtain striations. After particle injection, they are charged in the discharge glow and levitate at the bottom of striations forming three dimensional dusty plasma clouds. Dusty structures observation was fulfilled with two CCD video cameras with 25 frames per second frame rate and 720×540 pixels resolution. The cameras were timely and spatially synchronized. Dusty cloud was illuminated with expanded solid-state laser beam which power was up to 300 mW. By gradually changing the discharge current we were able to observe dusty structure evolution from crystal-like state with highly ordered chains of macroparticles to diffuse liquid-like cloud. The current changing range was 3 to 10 mA. Images of dusty structures corresponding to different moments of time are shown in Fig. 2a.

Video records obtained from this experiment were analyzed with special software. As a result three dimensional coordinates with subpixel accuracy (±1.5μm) were obtained.

Then correlation functions, mass transfer evolution functions, diffusion constants and concentrations regarding different stages of melting was calculated from obtained data.

In Fig. 3 one can see correlation functions in moments if time corresponding to Fig. 2b.

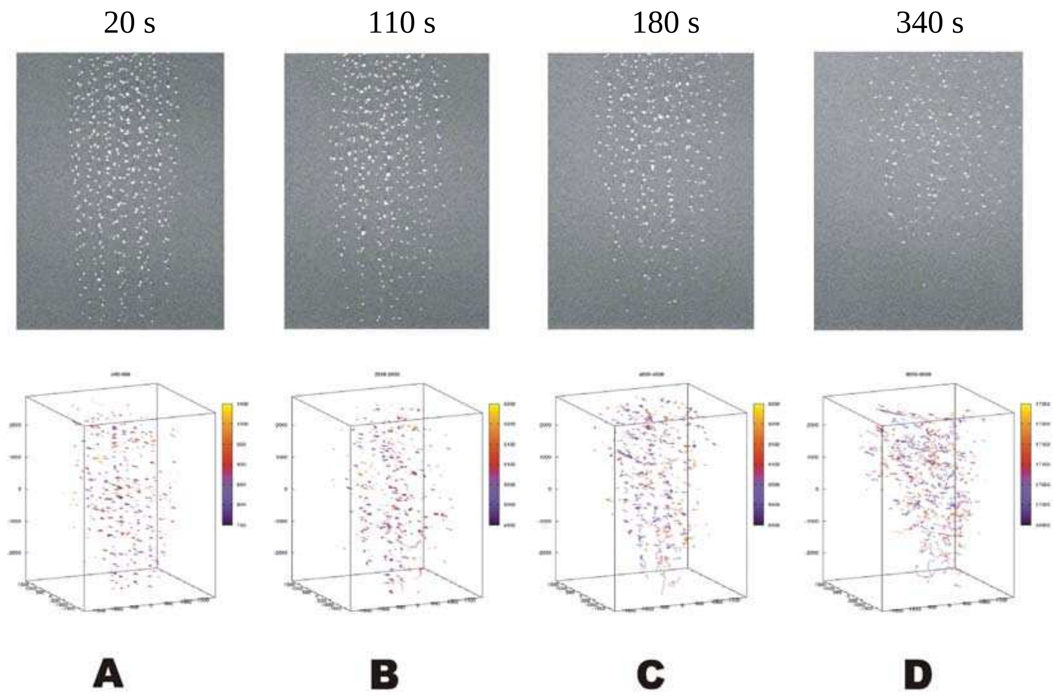

Fig. 2a. Images of dusty structures corresponding to different moments of time.

Fig. 2b. The results of recognition in different moments of time.

Correlation functions obtained have two main peaks which correspond to typical distances between particles in a chain and between chains.

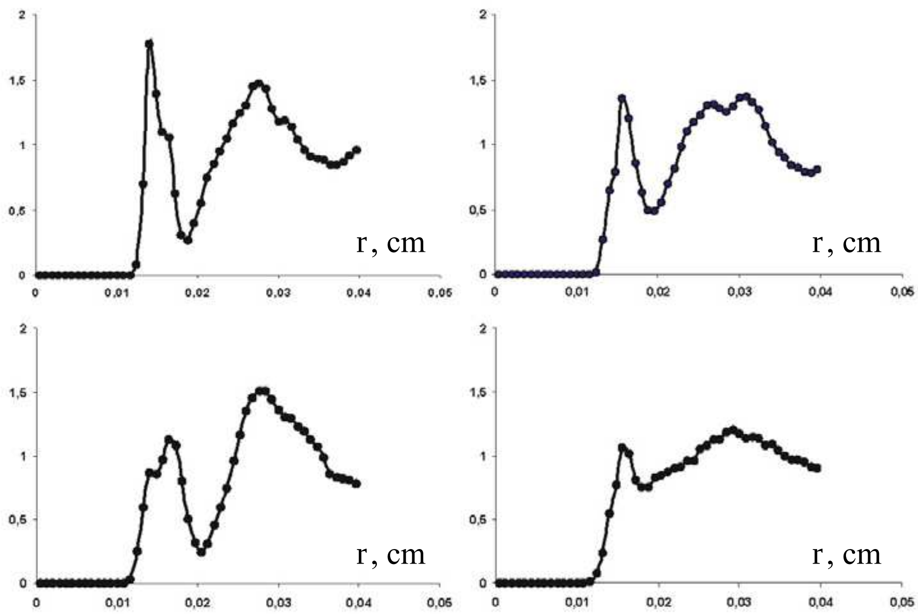

Fig. 3 correlation functions in different moments of time.

It authenticates high anisotropy of considered object. It is significant that double-peak structure remains even on the late stages of melting when peaks themselves nearly disappear.

Correlation peaks amplitudes decrease during melting process. It shows the decrease of coupling in the system. We can also tell about decreasing of nonideality through observing a disappearance of peak of mass transfer evolution functions (see Fig. 4).

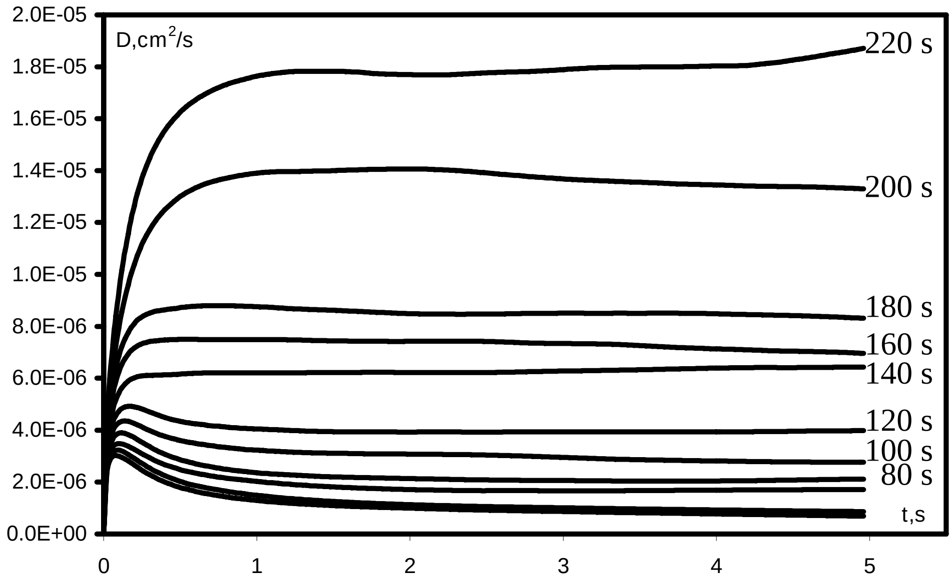

Fig. 4. Mass transfer evolution functions

Conclusion.

In present work are shown results of applying of special method of triaxial recognition of dusty structures. The process of warming and melting of dusty structure in DC discharge was studied and evolution of structure's characteristics was observed.

References:

[1] T.Antonova, B.M. Annaratone, D.D. Goldbeck, V.Yaroshenko et.all *ICPDP proceedings* P299 2005.

[2] B.M. Annaratone, T.Antonova, D.D. Goldbeck, H.M. Tomas, G.E. Morfill, *Plasma Physics and Controlled Fusion* 46, 2004, B495.