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Experimental studying of dynamical processes of phase transition's boundary in dusty plasma structures

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Abstract. In present work it is for the first time experimental researches of phase transition dynamics in dusty plasma layer were carried out. Diameter of dust structure was greater then its width more then 10 times. The motion of the boundary between dusty plasma liquid and crystal was experimentally studied. Time dependence of the velocity of this boundary was found. Space distributions of particles, kinetic temperature and density in dusty plasma liquid, crystal and interphase region were obtained by analysis of experimental data. Values of interparticle distance, diffusion coefficient and the nonideality parameter Γ were also calculated.

Experiments with a variation of parameters RF-discharge (RF-power (3-12 W) and gas pressure (0.07- 0.7 torr) were carried out. The RF-discharge electrodes were made as two parallel plates of 19 cm diameter. A lower electrode is ground and powered upper electrode with centrally located hole of 5 cm diameter, is connected with high-frequency generator f = 13.56 MHz. The trap-ring of 5 cm diameter is centrally located on the lower electrode. This ring prevents a movement of particles to the edge of electrode. The discharge gap is 5 cm wide. This system is placed in vacuum chamber of 35 cm diameter and 50 cm height with four horizontal and one top observation windows. As a background gas we used argon.

In experiment we use polydisperse Al_2O_3 particles of 3-6 μm diameter. The structures formed by dust particles in RF-discharge are suspended above lower electrode, where the electric field force balances the weight of the particle. A horizontally expanded laser beam from the HeNe-laser illuminates the levitating structures. The dust particles are viewed with a video camera. Dust cloud first being in solid phase as experiment goes on started to melt gradually from one side as result of slight change of one of parameters of discharge.

On the results of analysis was obtained the picture of changes of dusty cloud. The velocity field for different states of dusty plasma structure is shown in Fig.1, they clearly demonstrate phase transfers in concerned object. Region within which there is the larger kinetic temperature is depicted by darker color.

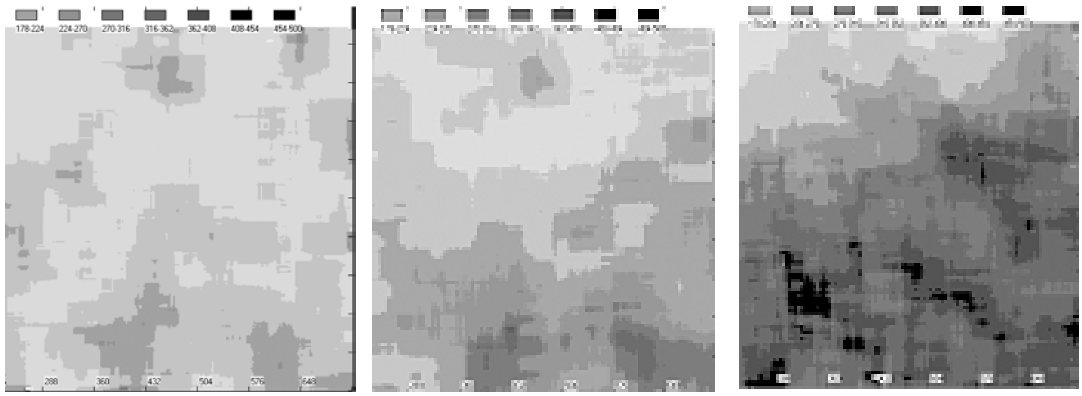
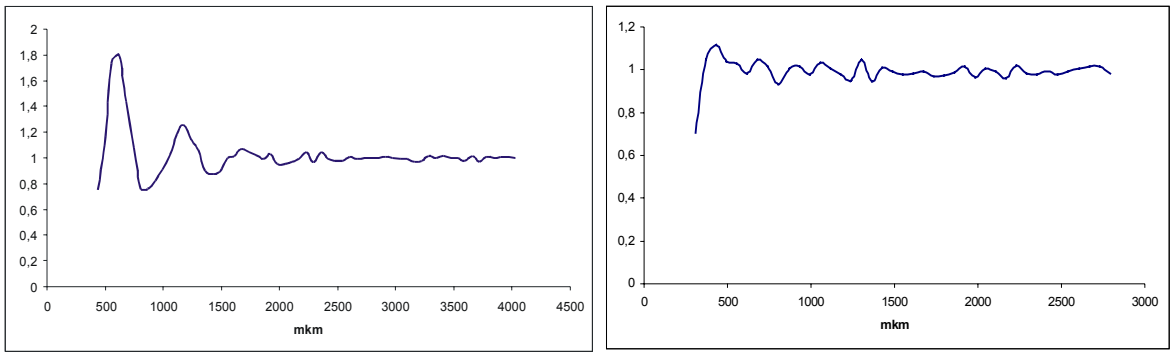


Fig. 5. Velocity field for solid, mediate, and liquid state of dusty plasma structure.

We analyze two different states of dusty plasma structure (before and after the phase transfer) using data obtained. For more vivid description of changes occurring in dusty cloud pair correlation functions were drawn (Fig. 2).



a) **b)**

Fig. 3. Pair correlation functions g(r) corresponding to:
à) initiate state (Γ ~ 79)
b) final state (Γ ~ 23) of dusty structure.

One can manage to restore some characteristics of observed phase states. Namely, interparticle distance, diffusion coefficient, dusty particle velocities, the kinetic temperature, parameter Γ - the ratio of the Coulomb potential energy to the particle kinetic energy, T is a kinetic energy (or temperature) of dust particles (table 1). On the basis of these characteristics analysis we have found out the initiate state of the structure to be solid and final one to be liquid.

Time dependence of the velocity of melting wave front was found during experimental data processing.(Fig.3)

It's interesting for melting wave front to stop during experiment and therefore for two different phase states to exist simultaneously. But for all that the kinetic temperatures on two different sides of the wave front differ greatly.

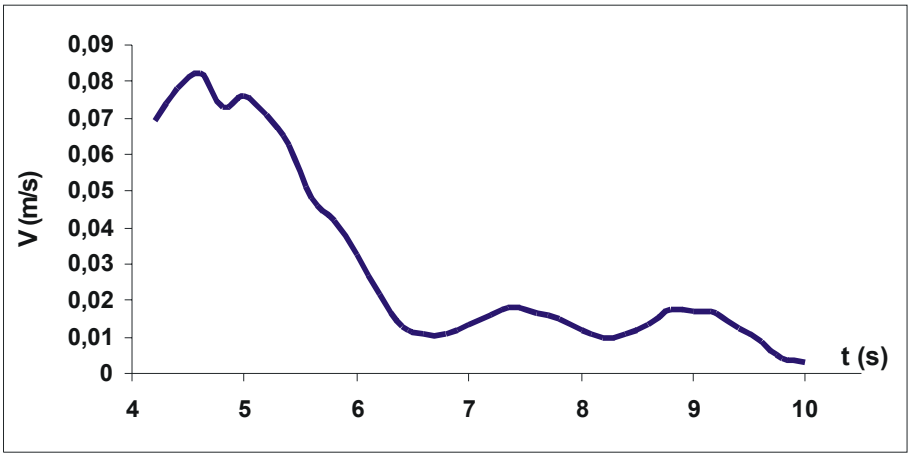


Fig. 6. Time dependence of melting wave front velocity.

	LIQUID	SOLID
Interparticle distance	558 μm	250 μm
Average velocity	0,0015 m/s	0.0022 m/s
Particle's mass	8e-14 kg	8e-14kg
Diffusion coefficient	5,77e-9 m^2/s	2,85e-8 m^2/s
Kinetic energy	0,59 eV	1.2 eV
Parameter Γ	78	23

Table 1. Values of dusty plasma parameters received on basis of experimental results.

Summary.

- Experiments for examing of dusty plasma structures' phase states have been carried out.
- Such basic parameters of dusty plasma states as: parameter, particles' velocities, its kinetic energy, interparticle distance, and diffusion coefficient have been obtained. Also correlation functions for different conditions have been ploted.
- The change of the velocity of melting wave front has been experimentally investigated.

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