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Experimental Investigation of Processes in Dusty Plasma Structures under Electron Beam Action.

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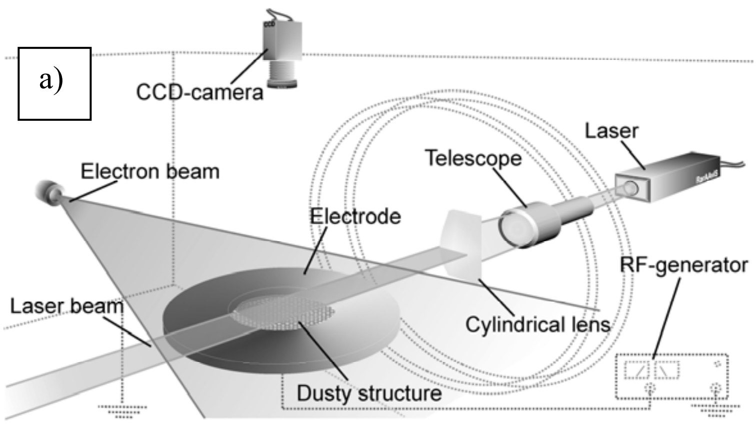
The electron beam is the convenient instrument that allows one influencing on dusty plasma structures trapped in a confined electric field of the RF-discharge chamber. This influence results in changing of the parameters of plasma within which under gravitational and electrical force dust macroparticles are levitating. It, in turn, leads to the variations in parameters of dust structures (dust temperatures, concentrations, coupling parameters).The relaxation processes that took place in the system after electron beam switching of were also studied. It was marked that the characteristic relaxation time (during which the system calms down to its initial state) is much less than the time of system perturbation caused by the electron beam. The relaxation time is estimated about several tens of seconds. The dependencies of macroparticles concentration on time and the coupling parameter on time were obtained on the basis of the experimental data. Also the kinetic temperature-time dependence for the dusty plasma system was presented.

Here we present the experimental study of heat transfer for macroparticles in RF- discharge plasma under action of electron beam. The scheme of experiment is given in Fig.1a.



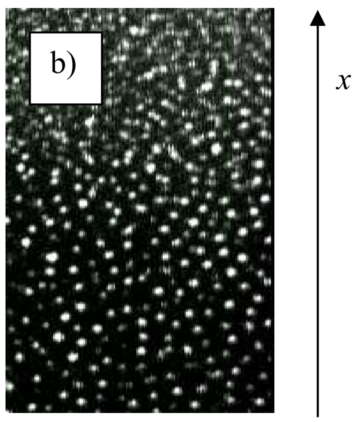


Fig. 1. The scheme of the experiment (a) and video- image of dust structure (b) in plasma with the electron beam.

For diagnostics, the particles of a dust cloud were illuminated by a *He-Ne* laser and video filmed (frame frequency $f = 50$ s^{-1}). The experiments were performed in air ($P \approx 13$ Pa) with Al_2O_3 particles (particle radius $a_d \approx 2$ μm, particle density $\rho_d \approx 2.4$ g cm^{-3}) and latex particles (particle radius $a_d \approx 0.5$ μm, particle density $\rho_d \approx 1.5$ g cm^{-3}). Under the experiments, the observed dust clouds were the liquid structures (consisting of ~15 dust layers ~ 5 cm in diameter). One of the cloud edges was illuminated by the flat electron beam. A density of electron current j_e in the beam (a power of electron beam) was changed from ~ 0.05 mA/mm^2 to ~ 0.2 mA/mm^2. Video image of dust structure under the action of electron beam is shown in Fig. 1b. The dust parameters (temperature, concentration, heat flux, correlation function) changed in the horizontal direction ***x*** (perpendicular to the flat of electron beam) only. We have registered no changes for dust parameters in other directions. The analysis of measured dust velocity distribution functions has also not revealed any convective (or anther regular) motion in analyzed structures. Dependencies of measured parameters (particle concentration n_d, dust temperature T, coupling parameter Γ^*, heat flux density q) on distance x from the end of video-image towered the electron beam are shown in Fig. 2 for experiments with latex particles ($j_e \approx 0.1$ mA/mm^2).

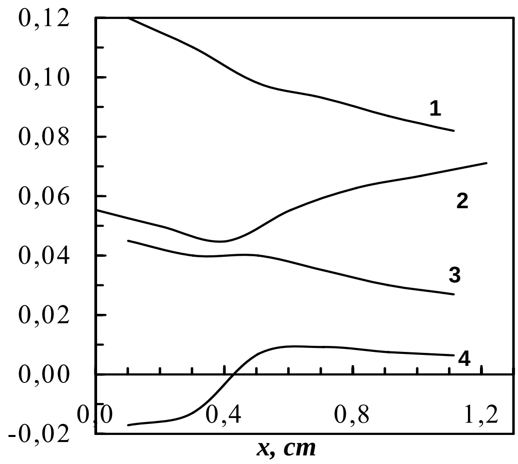


Fig. 2. Dependencies of measured parameters (r_d, T, Γ^*, q) on distance x from the end of video-image (see Fig. 1b) towered the electron beam: **1** – r_d , cm; **2** - T , eV; **3** - Γ^*/1000; **4** – q/ρ ,cm^3/s^3.

The values of heat flux density q were determined. Then the values of conductivity χ (from Fourier law) and the values of thermal diffusivity $\theta = 2\chi/(5n_d\, k_B)$ were obtained. The errors in measured values of θ were less than 30%.

The retrieved values of θ for different experiments are presented in Table 1 along with the measured mean interparticle distance l_p, dust temperature T, and Γ^*. Normalized thermal diffusion constants $\theta^* = \theta / [(\omega^* r_d^2)(1 + \xi)^{5/8}]$ vs. Γ^* are shown in Fig. 3 for numerical calculations and for different experiments ($r_d = n_d^{-1/3}$, $\xi \equiv \nu_{fr} / \omega^*$, where $\omega^* = eZ\,\{(1+\kappa+\kappa^2/2)\exp(-\kappa)/(r_d^3\pi M)\}^{1/2}$ is the characteristic frequency ω^* of charged particles, ν_{fr} is the effective frequency of their collisions with neutrals of surrounding gas, M denote the mass of a dust particle and $\kappa = r_d/\lambda$, λ is the screening length).

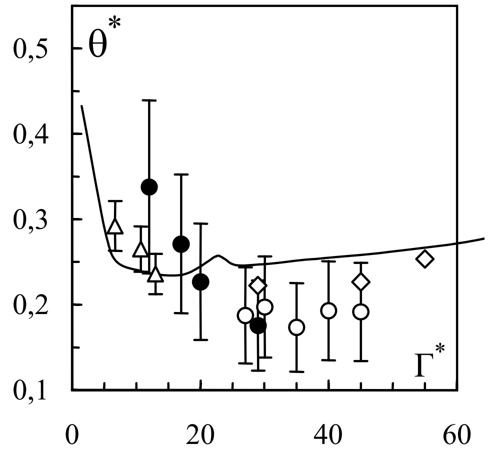


Fig. 3. Normalized thermal diffusion constants θ^* vs. Γ^* for numerical calculations (line) and for different experiments in plasma with electron beam: ● - latex, $j_e \approx 0.05$ mA/mm^2; ○ - latex, $j_e \approx 0.1$ mA/mm^2; ◇- Al_2O_3 – particles, $j_e \approx 0.1$ mA/mm^2; and for Al_2O_3 – particles in gas discharge plasma (△) for stationary case.

T, eV	Γ^*	r_d, mm	θ, cm^2/s
Al_2O_3 ($j_e \approx 0.1$ mA/mm^2)			
2.0	55	0.71	0.027
2.8	45	0.70	0.024
3.7	29	0.69	0.022
Latex ($j_e \approx 0.1$ mA/mm^2)			
0.055	45	1.20	0.132
0.050	40	1.10	0.111
0.055	35	0.93	0.080
0.063	30	0.87	0.077
0.067	27	0.82	0.067
Latex ($j_e \approx 0.05$ mA/mm^2)			
0.027	29	1.10	0.082
0.037	23	0.93	0.080
0.048	19	0.85	0.087
0.050	14	0.81	0.093

Table 1. Thermal diffusion constants θ for different experiments in plasma with electron beam.

We can see that the numerical and experimental results agree closely with each other. The value of ω^* were determined from experimental data (see Table 1): $\omega^* = (T\Gamma^*/(\pi M r_d^2)\}^{1/2}$. The friction coefficients (in a free-molecular approach) were $\nu_{fr} \approx 17.5$ s^{-1} for Al_2O_3 particles, and $\nu_{fr} \approx 112$ s^{-1} for latex particles.

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