Russian Academy of Sciences
Institute of Problems of Chemical Physics RAS
Joint Institute for High Temperatures RAS

XIII International Conference on

Physics of Non-Ideal Plasmas

September 13 — 18, 2009, Chernogolovka, Russia

Poster session S8

Chernogolovka 2009

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8 Dusty plasmas

8.2 Dynamic properties of dusty plasmas with an external ionization source

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Recently, it was established [1] that the screening of the charge of a dust particle absorbing plasma ions and electrons is described, in the presence of an external ionization source, by a superposition of two exponents with different screening lengths. These results are applied to generalize the theory of dust sound, in particular, on the basis of the non-perturbative moment approach [2, 3]. The static correlation functions are calculated corresponding to the above interaction and taking into account the plasma sinking to the dust particles.

The results can be used to study the dielectric and collective properties of dusty plasmas with external ionization sources like, e.g., electric probes, in particular, the stopping power of such systems with respect to heavy ions and fast electrons.

This work is partly supported by the Russian Foundation of Basic Research, project no. 08-02-01212-a and by the Polytechnic University of Valencia, programme PAID-05-08.

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8.3 Effective interaction potential of dust particles on the basis of the Poisson equation and experimental data

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Experimental observation of Coulomb dust crystals, first, in high frequency discharge [1] and, later, in glow discharge [2] introduced a new area in the physics of strongly coupled systems. Despite intensive experimental, theoretical and numerical research devoted to investigation of charged dust grains in plasma environment in the past, several fundamental questions regarding such system remain to be opened. One of the most striking phenomena still requiring further explorations is the nature and the form of attractive forces acting between like-charged dust particles [3–5]. The existence of attractive component in force between dust particles was experimentally studied and verified by several methods in different setups. In the present work, effective interaction potential of dust particles was calculated on the basis of pair correlation functions derived from experiments performed in dc discharge of argon using the Poisson equation. Calculations were performed for two types of boundary conditions: the Coulomb and the Yukawa type potentials. For both cases the interactive potential has an oscillating character in the certain range of system parameters. Existence of attractive component in interaction among dust particles as implied by results of the current paper requires further thorough investigation, both experimental and theoretical, to provide the differentiation between the existing theoretical concepts. For example, one should understand the influence of confinement (trap) potential that may contribute significantly under conditions of experiment. Several generalizing modifications of the presented numerical model are also discussed like the rejection of assumption of weak interparticle interaction in buffer plasma. Within the validity range of the current model, we can confirm existence of the attractive component in the interaction of dust particles. Further investigation is required to get insights into the origin of attraction and non-linearity of Coulomb interaction screening.

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8.4 Ordered structures in nuclear-track dusty plasma for potential and nonpotential forces of interparticle interaction.

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In recent year the stable dust structures and the dynamic instabilities in various types of laboratory dusty plasma are of growing interest, for example in electrode sheath of an high-frequency (hf) discharge, in thermal plasma, in standing strata of a glow discharge and in nuclear-track plasma. The experimental and theoretical studies of dust particles charging, interparticle interaction, interaction with external fields and collective effects are actively carried on. To understand the physical processes leading to the observed phenomena an analysis of the interaction forces between dust particles and an estimations of their charges are needed. The negative charge of a dust particle is estimated as product of its capacity and the floating plasma potential governed by the difference of plasma electron and ion fluxes incident upon a dust particle and essentially depends on high-energy asymptotic behavior of a electron distribution function. It is well known, that the asymptotic behavior of an electron distribution function essentially depends on spatial inhomogeneity of electric fields accelerating electrons and on the local losses due to the ionization of atoms. This is the physical reason of explicit dependence of the particle charge on its location, i.e., on its coordinates: $Q = Q(r)$. According to estimations the dust particle charges $Q(r)$ (in the electron charge units) range from 102 to 106. Below we take $Q = 103$ as a typical value for nuclear-track plasma. Consequently, one of the main components of the interaction of dust particles in a plasma is, in one way or another, the screened Coulomb repulsion. Besides the electrostatic forces associated with the negative charge of dust particles, a number of other physical processes affecting their space arrangement are under investigation in literature. The most notable are the anisotropic forces associated with ion fluxes drifting toward the electrodes of traps and the dust

particle conglomerations. The negative charge of the dust particles interacts with ion fluxes and, as a result, the regions with lower and higher ion density are formed in the vicinity of a dust particles. So the background plasma is polarized. The polarization of a dusty plasma is of great interest, as the resulting interparticle forces can not only be repulsive but can be also attractive and can capture the other dust particles. Laboratory experiments have confirmed the existence of Anisotropic interaction forces between dust particles. Numerical calculations based on the quasiparticle method have demonstrated the possibility of the plasma polarization and of there being many ordered equilibrium configurations, with energies depending on both the charge-to-mass ratio of the dust particles and on the number and location of levitating particles. Limitations of this model have, to a significant degree, been overcome by a more realistic three dimensional model considered ion fluxes, plasma particle collisions and charge exchange of ions with atoms of the Neutral gas. The performed calculations showed that the plasma ions not only can be captured by the potential wells of dust particles, but uncaptured ions can be focused and this is leading to the emergence of regions of enhanced spatial positive charge density in the direction of the ion flux. So the forces acting on the dust particles are defined not only by the mechanical forces resulted from changes in the momenta and trajectories of ions but also by the electrical forces associated with the existence of stationary regions with enhanced ion density. To simulate the evolution of the dust particle system we invoke the Brownian dynamic method, which is based on solution of ordinary differential equation with stochastic Langevin force, taking into account random collisions with plasma neutrals. We take into account the gravity, the electric fields of trap and assume that the effective interparticle forces can be potential and non potential. This allow us to analyze the influence of different physical factors on stability of ordered structures of dusty particles in electrostatic traps and formulate some practical prescriptions for stable confinement of dusty particle in electrostatic traps.

8.5 2D Molecular Dynamic Simulations of the Dusty Plasma in the Glowing Discharge.

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The dusty plasma is a modern and important physical object. It is interesting to study it not only because of its fundamental properties as for example ten-

dency to arrangement, also complex plasma emerges in the variety of physical systems, so it has practical applications: TOKAMAK's, atmospheric entry of space vehicles, interplanetary and interstellar clouds.

Actually the dusty plasma is an object that emerges in the different types of plasma discharges, for example glowing discharges. To investigate it properly we have to take into account discharge itself to obtain electric fields, ion and electron concentrations and temperature — the parameters that are important for the dust particle dynamics.

The two dimensional cylindrical computational model of a direct current discharge with a dusty plasma is presented in this work. This model is based on the drift-diffusion model of the glow discharge at pressure 1, 2 tor and EMF 600, 2000 V. Regions of the charged volumes are taken into account. It is assumed that the glow discharge exists in the normal mode. To describe dynamics of the dusty particles inside column of the normal glow discharge a molecular dynamic model is used. In this model each particle is affected by the following forces: gravitational force; electric force, produced by discharge; electric field, produced by all other particles, according to Yukawa potential; drag ion force (collection and orbital parts) and drag neutral force (Epstein expression). Charging model is simplified.

It is shown that initially homogeneous dusty plasma distribution follows to the two dimensional structure of a glow discharge in normal mode. A final configuration of the dusty particles assemble is located inside the column of a glow discharge between cathode and anode charged volumes. It is possible to change dimension of the dusty particle volumes by variation of the total current through the glow discharge in the normal mode.

8.7 Thermodynamic characteristics of dusty plasma

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There is an essential distinction between physical and chemical properties of electron-ionic plasma and dusty plasma (plasma with macroparticles). This fact causes rapid development of scientific researches in this area of physics of plasma within last decades.

Formation of dust particles in plasma, as a rule, leads to considerable change plasma charging structure. Dust particles are the centres of recombination of plasma electrons and ions. Besides dust particles can be a source of electrons owing to various emission processes (thermionic emission, photoemission, secondary electronic emission) [1].

Debye approach describing ionization equilibrium in dusty plasma is considered. Plasma is considered as a mixture of almost ideal gases (electron-ionic gas and dusty gas). Interaction of these gases is weak. Macroparticles are considered as multiply charged ions. Ionization equilibrium is described by a set of the Sakha equations [2].

The report contains description of method of calculation of thermodynamic characteristics of dusty plasma. This method includes model of ionization chemical equilibrium. Electronic concentration calculations according to Debye approach. The report includes results of numerical experiment for the plasma of polyformaldehyde containing fine-dispersed aluminum particles.

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8.8 Crystallization dynamics of spherically confined dusty plasmas

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In the last few years it has become possible to routinely create 3D dust crystals in experiments [1], where the particles arrange on concentric spherical shells. These so-called Yukawa balls are very similar to confined ions but the interaction between the dust particles is screened [2] due to the ambient plasma. Here we investigate the short-time dynamics of these systems by means of accurate Langevin dynamics simulations which fully include the Coulomb correlations, the confinement and friction with the neutral gas. We start from a weakly correlated initial state using two scenarios: (i) rapid switch of the confinement potential [3], and (ii) a laser-heated initial state followed by a rapid turn-off of the laser power. We analyze the different time-scales in the emergence of the crystal state and the dependence of the dynamics on screening and friction. Our results suggest how to detect the formation of binary correlations in dusty plasma experiments.

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8.10 Experimental study of orientation and dynamical properties of rod-like particles in RF discharge plasma

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In the majority of the experimental and theoretical works deal with researching of properties of strong non-ideal dust plasma, spherical particles were used. Only during the latest time works in which dust particles have the strongly

asymmetric form appeared. Using of such particles should lead to occurrence of new states of dusty plasma structures (liquid crystal and crystal phases with various degree orientation and position ordering), those demonstrate a great number of unstuded properties and new phenomena. These phenomena may be studed at the kinetic level. Thus, experimental studying of the dusty plasma structures formed by particles of the asymmetrical form represents significant interest.

The present work deals with the experimental investigation of structural and dynamic properties of dusty plasma with rod-like macroparticles in the high-frequency gas discharge. These plastic particles were 300 μm in length and 15 μm in diameter. A series of experiments were carried out at various pressure in a range of 0.11-0.28 Torr. Movements of particles was recorded by two videocameras. On the basis of experimental data three-dimensional coordinates were obtained. Also dependence of speed of the centre of mass of the particles on time and dependence of speed of their rotation on time were calculated. It should be noted that at low pressure (0.11-0.15 Torr) all particles were orientated in a horizontal plane and changed their orientation with pressure increasing (0.15-0.28 Torr).

8.11 Experimental study of the transition of the dusty structure from monolayer to multilayer state in RF discharge plasma.

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In this paper we report about experimental research of dynamical and structural features of gas rf discharge dusty plasma with spherical melamine-formaldehyde particles 12.74 μm in diameter. We studied a formation of dust plasma structures in near–electrode layer of rf discharge, including an investigation of influence of discharge parameters and sort of gas on quantity of levitated particles in structure. The diagnostics of dusty plasma structures with measuring of basic parameters of dusty component (quantity of particles in a layer, mean interparticle length, particle temperature subject to discharge parameters such as pressure of buffer gas and power consumption) was carried out. Varying a quantity of particles, a conditions of formation a new layer, mechanisms of such a formation, dynamics and structural features of such

processes were studied. Using synchronized sistem of video surveillance on horizontal and vertical plane, we measured kinetic temperatures of dust particles on horizontal and vertical sections of dusty plasma structures and made comparative analysis of measurement.

8.12 Abnormal kinetic temperature of charged particles in crystalline dusty plasmas

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A mechanism of an increase of the average kinetic energy of charged dust particles in crystalline plasmas is investigated. The mechanism is based on the phenomenon of a parametric resonance. Possible particle charge variation is the main reason for the parametric resonance appearance. A number of physical factors which could produce particle charge oscillations are analyzed. Mechanisms of energy transfer from an external source to dust particle motion in plasmas are analyzed. The equations of motion of dust particles are derived by the consideration of plasma-dust system using the theory of vibrations with the account of a dust particle charge-variability. The latter is related to fluctuations of plasmas flow falling on the particle and oscillations of dust particle in near-electrode plasmas with sharply changing parameters. Overlapping of frequency intervals of various types of processes in dusty plasmas is analyzed. A range of eigenfrequencies of oscillations in a cluster of dust particles overlaps with a range of eigenfrequencies of particle vertical oscillations in near-electrode plasmas. Due to this overlapping it is possible to propose a parametric resonance model which could explain an anomalously high kinetic temperature of dust particles. Conditions of occurrence of parametric resonance of dust particle oscillations are estimated. It turns out that the conditions of occurrence of the resonance are close to the conditions of abnormal increase heating of dust particle average kinetic energy in plasmas in laboratory experiments.

8.13 Ion heating in two-component dusty plasma of noble gases

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Indication of heavy ion heating in two component weakly ionized plasma of noble gases was reported recently and still requires understanding of underlying mechanisms [1]. Several processes like Penning ionization [2], charge exchange, pre-sheath acceleration [3], etc., are known to play important role under typical conditions of experiment, and, thus, should to be considered in parts or together. In dusty plasma the physical picture can be even more complicated [4, 5]. Therefore, the purpose of our contribution is to consider possible mechanism of heavy ion acceleration and heating to explain existing data. As a result, physical model of ion heating in low pressure dc discharge of helium and argon is formulated and compared to the presented experimental data. In our experiments dc discharge setup for dusty plasma investigation described elsewhere is used [6]. Optical emission spectroscopy (OES) and probe diagnostics are employed as sources of information on the influence of metastable heluim atoms on argon ions. In addition to traditional methods of diagnostics, dust particles of Al_2O_3 with average diameter of 5 μm are used to gain indirect insights into physics of discharge. Obtained data are summarized to provide comparison with theoretical prediction. Importance of metastable helium atoms and pre-sheath acceleration of argon ions in explanation of observed phenomena is revealed.

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8.14 Macroparticle motion in ordered dusty plasma structures

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In this work experimental investigation kinetics of ordered dusty structures is discussed. We studied movement of macroparticles in dusty formation with the help of machine vision system. The research was carried out in DC glow discharge plasma at the pressure P = 80 Pa and current I = 1 mA in Ne, Ar, Xe gases. Polydisperse powder of Al_2O_3 macroparticles was used in the experiment. We calculated, analyzed and compared kinetic characteristics of macroparticles (velocity distribution histogram, mean macroparticle velocity, trajectories of macroparticle movement, diffusion coefficients) in dusty formation in Ne, Ar, Xe plasma at the same discharge current and gas pressure.

8.15 Coulomb clusters of diamagnetic particles levitating in nonuniform magnetic fields

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Strongly coupled Coulomb systems (SCCS) are of considerable fundamental and applied interest. In recent years, dusty plasma structures are frequently considered as a macroscopic physical model of SCCS which can visually be observed. However, charged dust particles in plasma are screened, and the potential of interparticle interaction becomes a Yukawa (Debye) one. Besides, in dusty plasmas, the charge of the dust particles is responsible both for interaction with other particles (and consequently for the formation of a cluster or structure) and for its levitation in electrical fields (of rf or dc discharges). So, changing the interparticle potential, one changes the levitation conditions.

In this communication, we present an alternative way for formation of macroscopic Coulomb systems. We have considered the possibility of the stable levitation of a Coulomb cluster of charged diamagnetic particles in nonuniform magnetic fields. In this case the levitation conditions are independent on the particle charge and depend on the magnetic susceptibility of the particle matter. We present an experimental setup for keeping in a stable state the Coulomb clusters of charged graphite grains in magnetic fields $B \sim 1$ T with $|\nabla B| \sim 10$ T/cm. An analysis of the cluster structure and dynamics is performed. We have developed a simple theoretical model for calculations of the position of equilibrium levitation of the diamagnetic grains and the frequencies of their oscillation. The calculation results are in agreement with the experimental data. We conclude that, using more intensive magnetic fields $B > 10$ T under terrestrial conditions, one can form stable 3D dust crystals and liquids containing several thousands of grains. Less intensive magnetic fields ($B \sim 0.1$ T, $|\nabla B| \sim 0.1$ T/cm) will be required for studying of analogous structures under microgravity conditions onboard a space station.

8.16 Dust Plasma Structures in DC Glow Discharges under Magnetic Field

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Dynamics of dust structures in the striation of dc glow discharges in axial magnetic fields up to 2500 G has been experimentally investigated. Dust structures were formed by monodispersed melamine formaldehyde particles with diameters 5.51 μm. The dependence of rotation frequency of dusty plasma structures as a function of the magnetic field was investigated. As it was observed, with the increase of magnetic field up to 700 G dust particles went from the axial region of the discharge to the discharge periphery with the continuation of the movement around discharge axis. For various magnetic fields kinetic temperatures of the dust particles, diffusion coefficients, and effective coupling coefficient Γ^* have been determined. The bulk dust structures without rotation in the experiments with neon in fields up to 300 G were obtained. It was found that the coupling parameter of the dusty plasma structure was increased with increase of magnetic field. Obtained results are analyzed and compared with theoretical predictions. The investigation of features and de-

velopment of various type of instabilities of the dust plasma structures in DC glow discharges in magnetic field actions was carried out.

8.17 Binary bilayers in complex plasmas

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Binary bilayers represent a novel type of systems, which can be created by dispersing dielectric microparticles of two different sizes in a gas discharge; the different charge to mass ratios and the spatial variation of the sheath electric field of the discharge result in the formation of two parallel, horizontal layers of particles. Such systems have already been investigated by simulations [1] and have been realized experimentally, too [2]. Here we present preliminary results on a combined theoretical and molecular dynamics simulation study of the structure of and collective excitations in a binary bilayer system [3,4] with a Yukawa interaction. The range of parameters covers the liquid phase of the system as well as the frozen, crystalline phase. Depending on the ratio of the densities of the two species, the latter can form an ordered or a frustrated disordered state, whose collective excitations are of special interest.

Supported by the Hungarian Fund for Scientific Research (OTKA-K77653, OTKA-PD75113), by the Hungarian Academy of Sciences (NSF/102), by the National Science Foundation, and by DOE.

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8.18 Influence of Dust Particles Concentration on Plasma Parameters in DC Discharge

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A self-consistent kinetic model of a low pressure DC glow discharge with dust particles based on Boltzmann equation for electron energy distribution function is presented. The influence of dust particles concentration N_d on gas discharge and dust particles parameters was investigated.

It is shown that the increase of N_d leads to the increase of averaged electric field and ion density, and to the decrease of a dust particle charge in the dusty cloud. For dust particle concentrations in the region $N_d r_0$ =10^0-10^2 cm^{-2} (r_0 is dust particle radius), the charges of dust particles decrease but the Havnes parameter P_H=$Z_d \times N_d/n_e$ increases that means that dusty plasma can be regarded as electron depleted system, (n_e¡n_i). In this region of dust particle concentrations (for different dust particle radii r_0), the electric field is an increasing function of parameter $N_d r_0^2$, and in almost the whole N_d-region the dust particle charge is the function of parameter $N_d r_0$.

The absorption of electrons and ions on the dust particles surface does not lead to the electron energy distribution function depletion due to a self-consistent adjustment of dust particles and discharge parameters. This result is rather unexpected and contradicts the naive conclusion that EEDF should deplete for electron kinetic energy $\epsilon > -\varphi_s(r_0)$ due to high energy electrons loss in absorption on dust particles ($\varphi_s(r_0)$ is the potential of dust particle). This fact reflects the self-consistent process of the adjustment of EEDF to a higher electric field in a dusty cloud relative to dust-free conditions in a discharge.

Financial support for this work was partly provided by RFBR Grant N 07-02-00781-a.

8.19 Viscoplastic flow of crystal-like dusty plasma structures

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During last years unusual dynamics of dusty plasma flow under the external influence have been demonstrated. It was shown that dusty plasma liquid is nonNewtonian one and its viscoplastic properties depend on shearing force. With aim to explain this behavior of dusty plasma structures at first part of present work we carried out the experimental investigation of dusty plasma liquid without shearing forces. Dusty plasma structures of various order degree were obtained experimentally. On the basis of experimental data was determined the boundary value of coupling parameter. If coupling parameter lower this value then the directions of particle trajectories were chaotic. In other cases trajectories and velocities of the particles were correlated in greater or lesser degree. The sizes of correlated moved particle groups (clusters) depended on coupling parameter. The possible explanation of nonNewtonian behavior of dusty plasma liquid was suggested from these clusters point of view. The second part of present work devoted to the experimental study of viscoplastic flow in the dusty plasma crystal. The coupling parameter values in the experiments were 170 and greater. Under the action of laser beam the dusty structures remain crystal–like and it was for the first time the viscoplastic flow of dusty plasma crystal was obtained. The width of the flow channel was about 0.6 cm. The threshold type of this flow was demonstrated. It was for the first time the mechanism of crystal viscoplastic flow was observed. This mechanism was generation and follow annihilation of boundary misfit dislocations.

8.21 Screening a microparticle's charge in a non-equilibrium plasma with two positive ion species

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The study of screening a microparticle's charge in a plasma taking into account electron and ion sinks to the microparticles and net processes of production and loss of charged plasma partcles is reported. The research objective is to investigate the effect of the conversion of the atomic ions Ar^+ to the molecular $Ar_2{}^+$ on character of screening in a plasma with an external ionization source. It is determined that the plasma due to the ion conversion consists of two positive ion species. This circumstance leads to three-exponential charge screening, moreover there exists a region of plasma parameters where all the screening constants have comparable values. Numerical simulation of microparticle's charging on the basis of the drift-diffusion approximation [1–3] and comparision of the obtained data with the analytical results are performed.

This paper is partly supported by the Russian Foundation of Basic Research, project no. 07-02-00504a.

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8.22 Influence of neutrals on nano-and microscale particle charging in dusty ionosphere

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Ion-neutral collisions in dust particle charging process in Earth's "dusty" ionosphere are taken into account. These collisions can result in a charge exchange between a fast ion and a slow neutral. The slow neutrals become slow positively charged ions which interact effectively with negatively and positively

charged dust grains. As a result a microscopic ion current on the dust grains changes in comparison with the case when ion-neutral collisions are not taken into account in the dust grain charging process. The microscopic ion current on the positively charged dust grains (due to the action of solar radiation) is derived. A condition on neutral density is obtained for which the influence of ion-neutral collisions on dust particle charging process is important both for negative and positive dust particle charges. It is shown that the effect of ion-neutral collisions should be taken into account when considering the charging of nano- and microsize dust grains in Noctilucent Clouds, Polar Mesosphere Summer Echoes, meteoritic dust, active geophysical rocket experiments such as Fluxus 1 and 2. We discuss also the effect of electrons with energies of the order of 1 eV which are produced as a result of photoelectric effect during the charging process, which can result in an increase of the electron temperature in plasmas. The most important effect resulting in cooling of such electrons is that of electron-ion collisions. We found a condition on the neutral density when the electron temperature in Earth's "dusty" ionosphere can become of the order of 1 eV. The importance of this effect for ionospheric plasmas is discussed.

This study was supported by the Division of Earth Sciences, Russian Academy of Sciences (the basic research program "Nanoscale particles in nature and technogenic products: conditions of existence, physical and chemical properties, and mechanisms of formation") and by the Division of Physical Sciences, Russian Academy of Sciences (the basic research program "Plasma physics in the Solar system"). One of the authors (S.I.P.) acknowledges the financial support of the Dynasty Foundation.

8.23 Increase of kinetic energy of dusty cluster particles due to parametric instability caused by nanosecond electric pulses

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Influence of high-voltage $2-11$ kV pulses of 20 ns duration on charged microparticles levitating in an rf-plasma is studied. A stainless-steel ring with the inner diameter of 8 cm was installed on the bottom electrode to provide radial confinement for the levitating microparticles. A thin copper ring of 4

cm inner diameter was used as a HV electrode. It was mounted coaxially with the stainless steel confinement ring 3 cm above it. The peak amplitude of the resonance increases with voltage of ns pulse from 0.15 mm at 1.5 kV to 0.65 mm at 8.1 kV. Parameters of the experiment are next, gas — argon, pressure 0.31 Pa, dust particles — melamineformaldehyde 7.17 μm diameter, rf peak-to-peak voltage 85 V, self bias on the rf electrode -36 V. Application of repetitive pulses leads to the vertical oscillations of the microparticles. Evolution of the total kinetic energy for the cluster during the instability is investigated. In the initial phase the kinetic energy oscillates around a certain value and its amplitude grows very slowly. At a certain moment it goes into the exponential growth phase and then saturates Flat clusters, consisting of small number of microparticles exhibit parametric instabilities of horizontal modes under the effect of repetitive pulses. It was shown that the parametric instability is caused by the vertical oscillations of the microparticles in the nonuniform electric field environment of the sheath. We suggested next mechanism of action.

1. Heating of plasma electrons by ns HV pulse.
2. Additional charging of dust particles by fast electrons.
3. Disequilibrium in trap due to additional force in vertical direction.
4. Charge relaxation by means of ions flow.
5. Particle disequilibrium in horizontal level as a result of vertical displacement.
6. Instability in horizontal level.

It is possible if the eigenfrequency is the function of height and the dust particle oscillates vertically.

8.24 Formation of dusty layers in linear electrical field: criteria and numerical simulation

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In this work, the conditions of formation of quasi-two-dimensional dusty structures are considered, which are held in the gravity field by the external electric fields. At present, it is common to use the Debye potential as the main approximation of the pair interaction potential of charged grains in plasma. But this approach fits the experimental and numerical simulation data only if the distance between the grains in plasma is small. With increasing of distance

between the particles the screening weakens, and the interaction potential can transform into power-law function. The model of the screened Coulomb potential can be inadequate also in the dense dusty cloud or near the walls of laboratory plasma chambers.

In present work, we investigated the power-law pair interaction potentials and also the screened Coulomb potential. For each of the potentials under study, the relations between the radial and the vertical gradients of electric field and the number of grains in the layer were found, that define the criterion of formation of new dusty layer.

The process of formation of quasi-two-dimensional system of dusty grains was studied also numerically. The simulations were carried out for two cases: 1) for the system, restricted radially by the non-zero electrical field, and 2) for the uniform dusty layer in periodical boundary conditions in the horizontal directions (no restricting electrical field). In both cases, the results of numerical simulation agreed well with the analytical criteria of formation of a new layer.

The presented results can be easily adapted to any pair potential, given analytically, and can be used for the passive diagnostics of the interparticle interaction parameters in quasi-two dimensional structures, forming in the near-electrode area of rf- discharge.

8.25 Structure of Dust Particles in Dusty Plasma Confined in Cylinders

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When a dusty plasma, an electrically neutral mixture of dust particles and ambient plasma of ions and electrons, is confined in a cylinder and dust particles are strongly coupled, dust particles form self-organized structures. These structures are obtained by numerical simulations over a wide range of parameters both in the case of one-component dust particles and in the case of binary mixtures. Theoretical analysis is made on the basis of the shell model. We assume that the ambient plasma is uniformly distributed in the cylinder providing the charge-neutralizing background for dust particles. In the potential due to this background, dust particles are organized into concentric shells (thin cylinders).

The structures are summarized as follows.

(1) When we increase the number of dust particles per unit length along the axis, the number of shells increases discontinuously at critical number densities.

(1a) In the case of weak screening, the new shell appears at the central axis.

(1b) In the case of strong screening, the new shell appears on the periphery.

(2) When we have two kinds of dust particles, each species does not mix and takes separated radial distribution.

(2a) In the case of weak screening, dust particles with larger charge form outer shells.

(2b) In the case of intermediate or strong screening, dust particles with larger charge form inner shells contrary to natural expectation.

We apply the shell model [1,2] developed by authors and try to reproduce the results of simulations. In the weak screening limit (the Coulombic case), these structures have been first obtained by a numerical simulation, reproduced by the shell model, and observed in real experiments in the Penning trap. The experiments under microgravity may provide us with ideal system to observe these structural transitions which will enable us to identify parameters in dusty plasmas.

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8.26 Electrostatic interaction of spherical microparticles in cases of constant charges and constant surface potentials

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The electrostatic interaction of two spherical microparticles in a plasma for the cases of constant charges and constant surface potentials of the microparticles is studied. The investigation of the interaction between a point-like charge and a conducting spherical body in a plasma shows that plasma screening results in decrease a potential barrier as the point charge approaches the likely charged microparticle, the decrease being more pronounced in case that the microparticle radius is comparable with the Debye screening length. The interaction of

two conducting spherical microparticles is considered in the bispherical coordinates. The interaction potentials are shown to highly differ in these cases, the electrostatic energy being the interaction potential only in the case of the constant charges independent on the interparticle distance. In the case of the constant surface potentials a work of external sources to sustain surface potentials should be taken into account. By integration of the interaction force calculated using the Maxwell stress tensor, the interaction potential is also defined for the latter case. Approximated analytical expressions for the interaction potential, which are more accurate than the available in the literature, are obtained for both the constant charges and the constant surface potentials.

This paper is partly supported by the Russian Foundation of Basic Research, project no. 08-02-01324a.

8.32 Effects of current modulating in complex low temperature plasma

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Work describes effects observed in ordered structures with external modulating of discharge current. Studied the dependencies of size and location of the dusty crystal from the amplitude and frequency of modulation.

Research was carried out in DC glow discharge plasma at different pressures and currents in N_2 and Ar. Polydisperse powder of Al_2O_3 and Zn with particle size range from 5 to 20 micrometers was used for creation of ordered structures. Sinusoidal signal with frequencies from 10 to 100000 Hz was inductively transmitted into discharge circuit at cathode branch with the control of amplitude before and after passing through the glow discharge.

Effects of stretching, compressing, shifting of the structures, stabilizing of unstable structures and resonance movements of the dusty particle were noticed at different frequencies. All the dependencies were graphically built and analyzed for different gas pressures, currents and dusty particles, boarder frequencies and amplitudes for all observed effects determined. All the experiments were performed for Ar and N_2.

This work was supported by CRDF, grant no. RUX0-000013-PZ-06/B2M413; the Ministry of Education and Science of the Russian Federation; the Government of Karelia.

8.35 Numerical Study of Heat Capacity in dissipative two-dimensional Yukawa Systems

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The problems associated with the physical properties of non-ideal dissipative systems are of significant interest in various fields of science and technology (plasma physics, medical industry, physics of polymers, etc.). The best-known model for description of pair interaction of repelling particles in physical kinetics is based on the screened potential of Yukawa type. In this paper we present the results of the numerical study of the heat capacity in non-ideal dissipative two-dimensional Yukawa systems. The calculations were performed in a wide range of parameters typical for the laboratory dusty plasma experiments. The parameters responsible for the heat capacity are determined and investigated. Comparison of obtained coefficients of heat capacity with the existing theoretical model was performed.

This work was partially supported by the Russian Foundation for Fundamental Research (07-08-00290), CRDF (RUP2-2891-MO-07), NWO (047.017.039) and by the Program of the Presidium of RAS.

8.36 Design of a system for cesium coated dust

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In this report, a design of a system for cesium (Cs) coated dust is described. The system comprises of a dust dropper, a Cs coating chamber and a Cs oven. The dust to be used is tungsten powder. The size of the dust grain ranges from 1-12 micron and is maintained with the help of a mesh of appropriate size. Cs vapour comes out from the Cs oven and enters into the Cs coating chamber to coat the dust grains. The Cs coating chamber is designed considering the time scale of monolayer formation of Cs on the surface of the dust grains and the transit time of dust grains in this unit. In the coating chamber, provisions to condensate and collect the unused Cs vapour and stop them from migrating into the plasma chamber are also made. Cs coated dust will

act as a surface area having low work-function and influence the effective production of negative ions. The experiment aims to optimize the production of negative ions by using dusts of different size and number density. This work is a part of a project to study a surface assisted volume negative ion source.

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