V. KOBYLIN
Faculty of Physical Engineering, Petrozavodsk State Univercity
(33, Lenina Ave., Petrozavodsk 185000, Russia; e-mail: kobv@onego.ru)

PACS 52.27.Lw

MULTISTRUCTURED DUST CLOUD FORMATION IN A DUSTY PLASMA GLOW DISCHARGE IN NEON WITH AIR

The results of experiments on the controlled formation of multilayer dust structures in a dusty plasma glow discharge in neon with the addition of air are presented. Polydisperse particles of Al_2O_3 are used. Different particle sizes are assumed in the upper and lower parts of the structure as a result of the selection of particle sizes, when the discharge conditions change. The results of experiments with monodisperse particles of two different sizes are presented.

Keywords: dusty plasma, extended dusty plasma structures, complex plasma.

1. Introduction

A number of articles devoted to the study of complex plasmas (see, e.g., [1]) provide the illustrations of peculiar formations of dust clouds, which consist of the layers of a dusty structure, arranged one above the other (Fig. 1). The causes for these formations are of particular interest. This paper describes an experiment, in which the similar structures of dust clouds are obtained in a controlled mode.

2. Experimental Setup

A vertically placed glass discharge tube with a diameter of 30 mm is used. The distance between the anode and cathode assemblies was 40 cm. Narrowing from glass in the form of the truncated cone with an internal diameter of 4 mm is established by top up above the cathode assembly at a distance of 11.5 cm for the stabilization of a provision of the dust cloud. The initial Ne pressure was 70 Pa, and the discharge current was 1 mA. Micron-size polydisperse particles of aluminum oxide were used. The experimental setup is shown in Fig. 2.

3. Experiment

The first face-off of particles into a pure neon shaped structure having vertically elongated "spindle" shape with a diameter of about 1 mm and a height of 10 mm is shown in Fig. 3, *a*. After the formation of dust structures in pure neon, air at 5 Pa was added into the discharge tube without turning off the discharge. The dust cloud was shifted up and rounded up from the bottom (Fig. 3, *b*). In the next step, the additional injection of particles was made that leaded to the second layer of the dust cloud formed below the first layer (Fig. 3, *c*). When repeating the procedure of addition of air and the injection of particles, the structures similar to those shown in Fig. 3, *d* were formed as a result. It should be emphasized that, in our experiments, it was impossible to get a layered structure in pure neon, as well as directly in a mixture of neon and air, without carrying out the procedure described above.

4. Results and Interpretation

Work [2] shows the results of calculations of the form of a Coulomb ball (CB) formed by two kinds of particles with different sizes in the field of gravitational, thermophoretic, and electrostatic forces (Fig. 4). In this case, the smaller particles form CB on the vertical axis higher than CB of larger particles. It is possible to make assumption that, in our experiment in pure neon, the conditions for levitation are created only for one of the fractions of dust particles. In work [3], the separation of dust particles in size during the formation of a plasma crystal was assumed. With the addition of air, the conditions for levitation of larger particles appear. At the addition of dust particles into plasma, the larger fraction forms a structure under the primary dust cloud.

In order to study the phenomenon further, the series of experiments were performed with monodisperse particles of melamine-formaldehyde ($\rho = 1.5$ g/cm^3), in size 3.38 ± 0.09 micrometers and

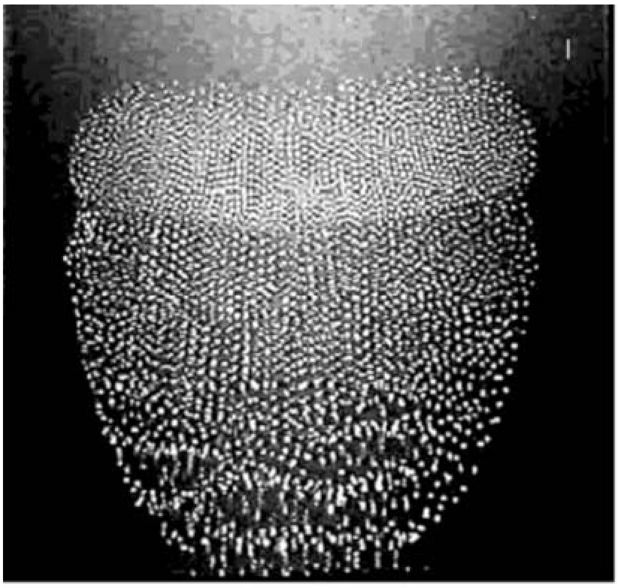

Fig. 1. Image of a plasma crystal from [1]

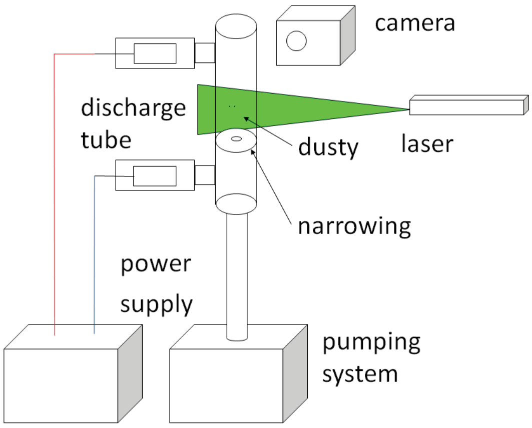

Fig. 2. Experimental setup

4.83 ± 0.12 micrometers in size in pure neon and with the addition of air. A discharge tube of 30 mm in diameter was used at the distance of 20 cm between the cathode and anode assemblies. One of the tube's distinguishing features is that there are two containers for particles. Narrowing was made of Teflon, hole's diameter was 3 mm, and a form of narrowing was flat with ridges at the edges. The distance from the narrowing place to the cathode assembly was 5 cm. The initial pressure of neon in experiments was 80–100 Pa with a current of 0.8 mA. The first and second fractions of particles were injected one after another. It is

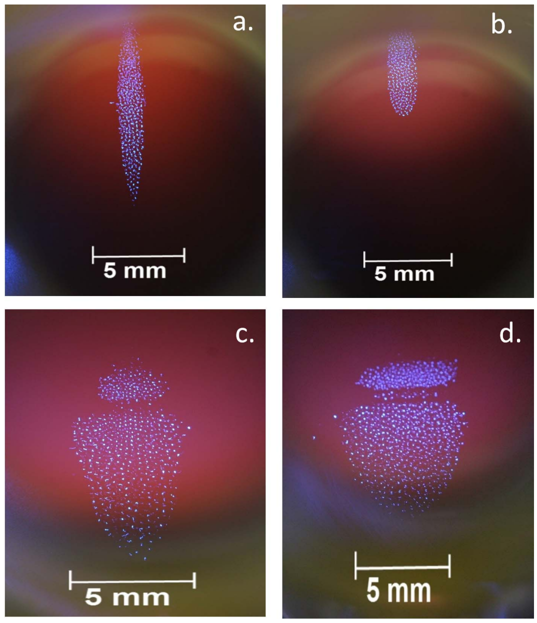

Fig. 3. Plasma crystal modification: *a* – pure Ne, *b* – Ne with 5-Pa air, *c* – after the addition of particles, *d* – after several cycles of addition of particles and air

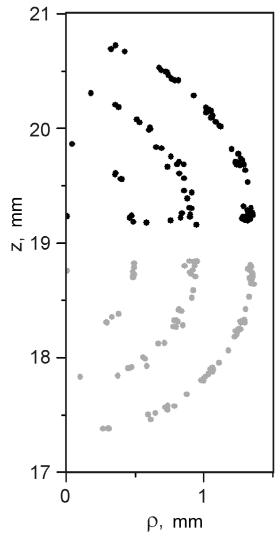

Fig. 4. Special distribution of particles in Coulomb balls. Projection of the spherical coordinates on the plane. Radius of black particles is 2.4 microns. Radius of grey particles is 2.41 microns

remarkable that if the injection of a big fraction only was made, the structure had no dust layers, and the addition of air formed only a very small additional layer (Fig. 5, *a*). At the same time, the addition of

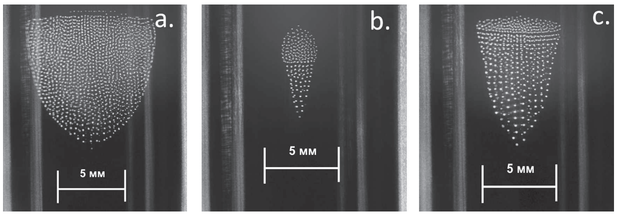

Fig. 5. *a* – Ne $P = 80$ Pa, air $P = 10$ Pa, particles are 4.83 micrometers in size. *b* – Ne $P = 80$ Pa, particles are 3.38 micrometers in size. *c* – Ne $P = 80$ Pa, air $P = 10$ Pa, particles are 3.38 and 4.83 microns in size

a small fraction of particles immediately formed a two-component structure (Fig. 5, *b*). The reason for the appearance of the second layer in this case is unknown. The injection of a large fraction of particles into the plasma leads to the growth of the lower part of the structure. With the addition of a small fraction, the upper part is growing. Figure 5, *c* shows a dust structure formed by the injection of both types of particles in a mixture of neon and air into plasma. As stated above, the primary dust structure was formed by the injection of the small fraction of particles. Then particles and air were added in small portions several times.

5. Conclusions

We find the conditions for the formation of multicomponent plasma-dust structures of polydisperse dust particles. The assumptions about the causes for their occurrence are made. The experiments to study of the formation of the structures from monodisperse particles of two sizes, which are introduced in the discharge at the same time, are initiated.

The idea and the design of a special discharge tube with two containers to work with different types of particles belong to Dr. Sergei Podryadchikov at the Petrozavodsk State University. The author is also grateful to colleagues Lidia Luizova and Alexandr Scherbina for the advice and useful discussions. The work was supported by the Ministry of Education and Science of Russia, grant No. 14.B37.21.0755 and subproject "Complex plasma: surface modification" of the Program of strategical development of PetrSU.

1. V.E. Fortov, A.G. Khrapak, S.A. Khrapak, V.I. Molotkov, and O.F. Petrov, Phys. Usp. **47**, 447 (2004).
2. S.G. Psakhie, K.P. Zol'nikov, L.F. Skorentsev, D.S. Kryzhevich, and A.V. Abdrashitov, Techn. Phys. Lett. **34**, 319 (2008).
3. E.S. Dzlieva, M.A. Ermolenko, and V.Yu. Karasev, Techn. Phys. **57**, 945 (2012).

Received 28.11.13

В.І. Кобилін

ФОРМУВАННЯ БАГАТОСТРУКТУРНОЇ ПИЛОВОЇ ХМАРИ В ПИЛОВІЙ ПЛАЗМІ ТЛІЮЧОГО РОЗРЯДУ В НЕОНІ З ПОВІТРЯМ

Р е з ю м е

У статті представлено результати експериментів з керованого формування багатошарових пилових структур у пиловій плазмі тліючого розряду в неоні при додаванні повітря. Використовувалися полідисперсні частинки Al_2O_3. Робиться припущення про різні розміри частинок у верхніх і нижніх частинах структури внаслідок селекції частинок за розмірами при зміні умов у розряді. Так само наводяться результати експериментів з монодисперсними частинками двох розмірів при їх почерговому введенні в розряд.