PROPERTIES OF DIFFERENT SIZE PARTICLE STRUCTURES FORMED IN A MAGNETIC FIELD

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We present the results of experimental researches of the behavior of dust structures formed by particles with different properties (material densities, sizes, forms) under the external influences (applied magnetic field). Only monolayers in structures of a complex geometrical form are used in the experiments. The parameters that can affect the structure and the properties of a glow discharge are selected. The strength of a magnetic field, at which the rotation direction changes the sign, depends linearly on the gas pressure and is independent of the discharge current.

1. Introduction

3D dust structures are objects of interest for the research of a wide number of physical characteristics: the dynamics of dust particles, action on the phase state of structures, interaction of the dust component with the background plasma, *etc.* External actions on a structure are used to research the stationary or nonstationary processes. These influences can affect the dust component directly or indirectly through the interaction with plasma particles.

The magnetic field in the interval from zero to hundreds of gausses affects dust particles through the plasma fluxes. In works [1–4], the complicated dynamics of dust structures in a magnetic field was researched. Particularly, the influence of a dust structure on plasma fluxes was discovered. The investigation of this subject is essentially important. One of the possible ways to study it is a variation of the structure parameters such as the volume charge, size, and geometrical configuration.

The dynamics of dust structures in a magnetic field have been discussed during last four years [1–4] for the interpretation of mechanisms of structure's rotation. The detailed measurements made with a variation of the dust structure parameters can be useful to solve the problem. These parameters can be changed by a change of the discharge conditions and the properties of dust particles.

In this work, we present the results of experimental researches of the behavior of dust structures formed by particles with different properties (material densities, sizes, forms) under external influences, e.g., the applied magnetic field or thermophoretic action.

2. Experiment

The experimental setup was described in [3] in detail. We used the following powders: silicon with $\rho = 2.5$ g/cm^3 and sizes 2–6 μm; $LiNbO_3$ with $\rho = 4.6$ g/sm^3 and sizes 1–4 μm; and melamine-formaldehyde particles with $\rho = 1.5$ g/sm^3 and sizes 1.1μm and 7.8 μm.

The experiment is performed in a stratified glow discharge, and the plasma parameters are typical of such experiments and measurements: the plasma density is 10^{14}–10^{15} m^{-3}; the electron temperature (average electron energy) is about 3–4 eV; the longitudinal electric field is 10–20 V/cm (for Ne, the pressure is 0.2–1.0 Torr, and the discharge current is in the interval 1–5 mA).

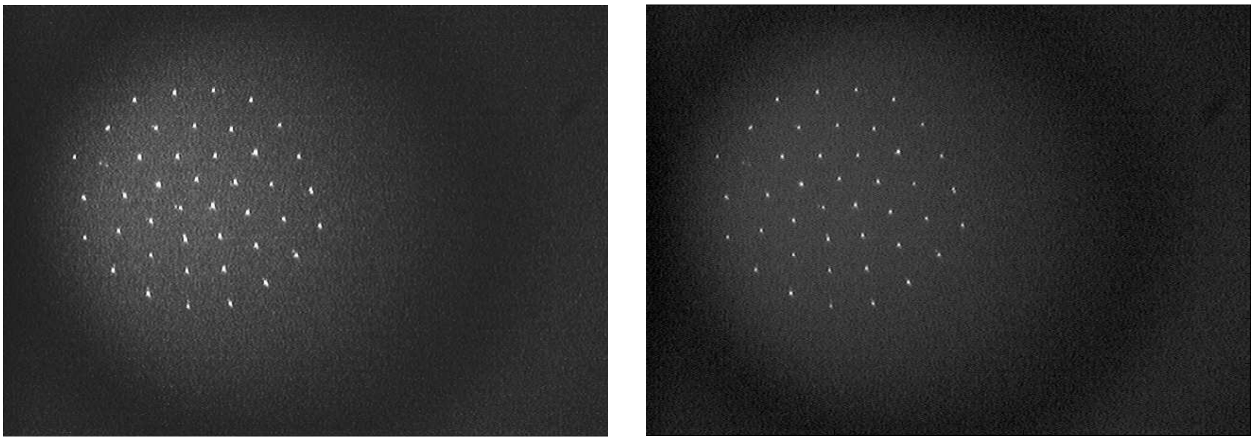
The horizontal section of the volume structures had been observed. We investigated the rotation motion of the layers. The magnetic field was oriented straight up. The examples of horizontal layers of dusty structures formed by melamine-formaldehyde spherical particles are showed in Fig. 1.

3. Results

We present some results in the interval of magnetic fields up to 200 G as graphs. All the structures are rotating in magnetic field. The direction of rotation is changing, while the direction of the magnetic induction is constant.

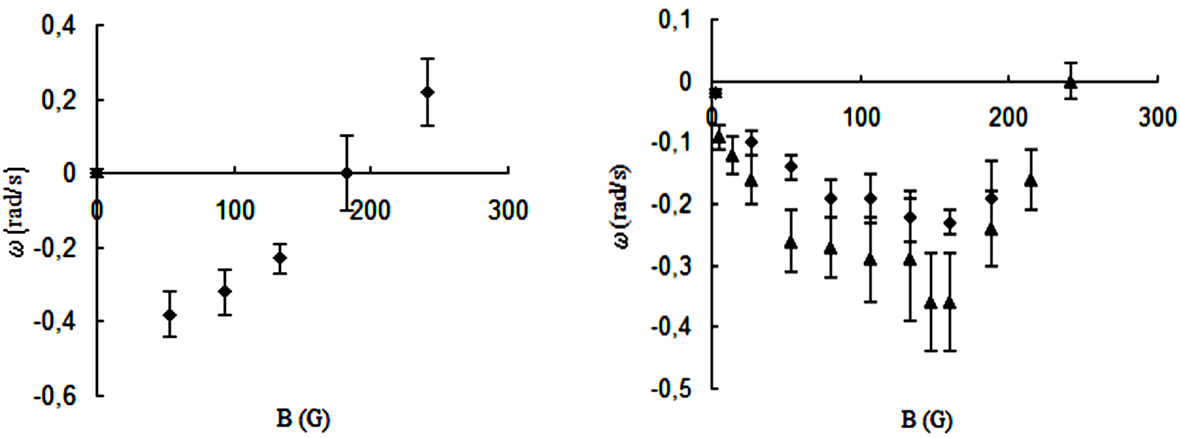
The magnitude of magnetic induction B_0 (B_0 is the field, in which the direction of rotation changes the sign) was registered for the all kinds of powders.

The dependence obtained for monodisperse particles (the examples are shown in Fig. 2,a is similar to the



a *b*

Fig. 1. Horizontal section of dusty structures formed by monodisperse particles of melamine-formaldehyde: (*a*) 1.1 μm, (*b*) 7.8 μm. Conditions: Ne, $P = 0.3$ Torr, $i = 1.5$ mA, $B = 0$



a *b*

Fig. 2. (*a*) Dependence of the angular velocity on the magnetic induction. Melamine-formaldehyde particles: 1.1 μm, $i = 1.4$ mA, $P = 0.55$ Torr, Ne. (*b*) Dependence of the angular velocity on the magnetic induction for two values of discharge current. Melamine-formaldehyde particles: 1.1 μm, $P = 0.8$ Torr; rhombs – 0.8 mA, triangles – 1.1 mA

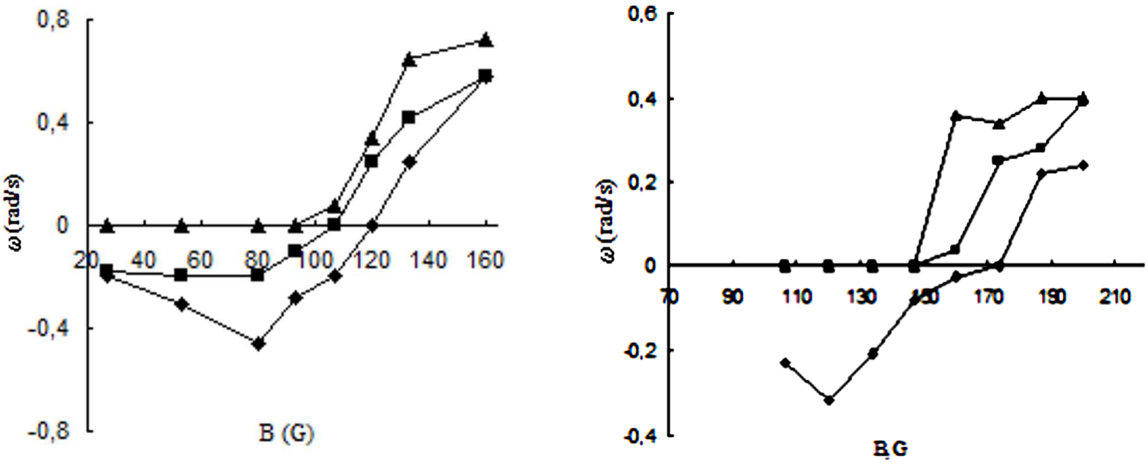
dependence obtained for polydisperse particles presented in Fig. 3.

We have found that the angular velocity of a structure increases with the current for the homogeneous structures. Under similar conditions, the angular velocity increases with the atomic mass of a discharge gas. The value of B_0 does not depend on the discharge current, Fig. 2,*b*.

The variation of B_0 with the gas pressure had been first discovered in [5], Fig. 3. In the present work, we investigated the dependence of $B_0(P)$ in detail. We used melamine-formaldehyde spherical particles 1 μm in size (Figs. 2, 4,*a*, 5,*a*), because they form a more ordered structure than silicon polydisperse particles. The dependence $B_0(P)$ has a linear character in the interval of pressures from 0.07 Torr to 0.8 Torr, Fig. 4,*b*.

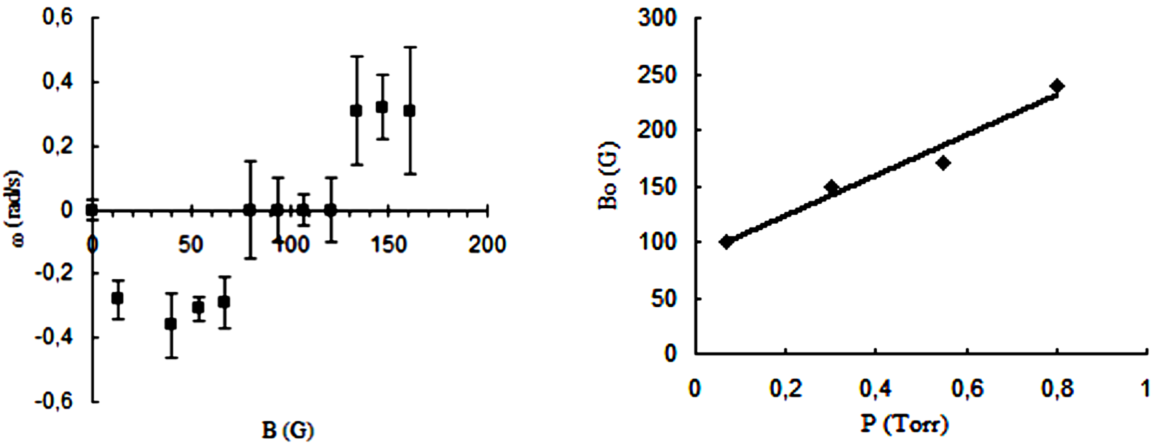
As we understand, the observed dependence of B_0 on the sections of a structure (vertical gradient of the angular velocity) (see Fig. 3 which was independently obtained in [3]) is connected with the presence of two different mechanisms of rotation in the upper and lower parts of the dusty trap [6–9].

Figure 5 shows the dependences of the angular velocity on the magnetic induction for structures formed by monodisperse particles with different sizes under the same discharge conditions. The magnitudes of angular



a *b*

Fig. 3. Dependence of the angular velocity on the magnetic induction for dusty structures formed by silicon particles (*a*) $P = 0.6$ Torr, (*b*) $P = 1.3$ Torr. Conditions: Ne, $i = 2$ mA, rhombs, squares, and triangles correspond to the top, middle, and lower sections of the structure. The difference in the values of angular velocity and B_0 for structure sections are explained by different mechanisms of rotation in the top and lower parts of the structure [3]



a *b*

Fig. 4. (*a*) Dependence of the angular velocity on the magnetic induction for melamine-formaldehyde particles: 1.1 μm. Ne, $i = 1.4$ mA, $P = 0.07$ Torr. (*b*) Dependence of B_0 on the gas pressure for melamine-formaldehyde particles: 1.1 μm. Ne, $i = 1.4$ mA

velocities are comparable, but the values of B_0 are different. The small particles a have bigger value of B_0. Probably, the reason for the effect is a difference in the electric charges of dusty structures.

4. Conclusion

The detailed investigations with monodisperse particles of different sizes have shown that the dynamics of 3D monodisperse dusty structures in a magnetic field is similar to one observed for polydisperse structures. We point out the following main properties of the rotation of dusty structures:

1. The angular velocity of dusty structures changes its direction without magnetic field reversion.

2. B_0 has a linear dependence on the gas pressure and is independent of the discharge current.

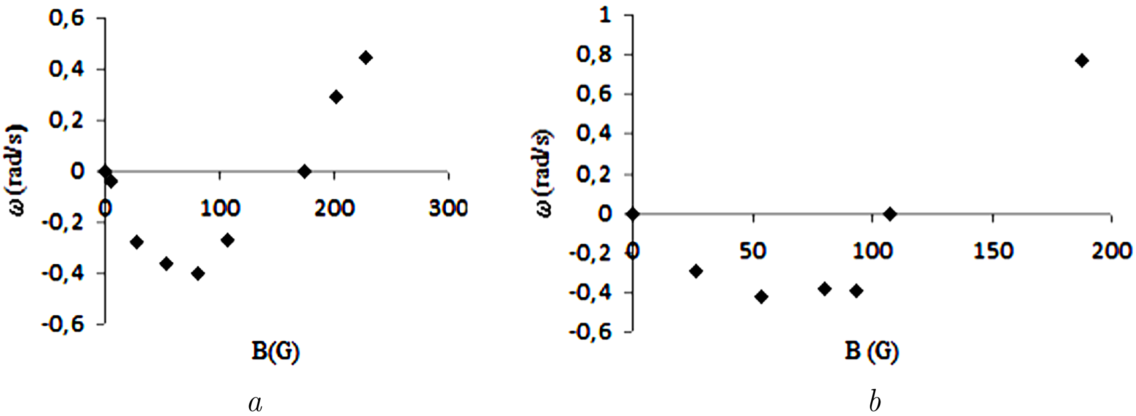


Fig. 5. Dependences of the angular velocity of structures formed by monodisperse particles on the magnetic induction (a) – for particles with a size of 1.1 mm, (b) – for particles with a size of 7.8 μm. Conditions: Ne, $p = 0.3$ Torr, $i = 1.5$ mA

The obtained results are actual with regard for the recent papers [6–9] and can be used in the investigations of the dynamics of dust particles in magnetic fields and for the control over and the manipulation by dust structures.

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ВЛАСТИВОСТІ СТРУКТУР,
СФОРМОВАНИХ ЧАСТИНКАМИ
РІЗНИХ РОЗМІРІВ У МАГНІТНОМУ ПОЛІ

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Р е з ю м е

У роботі наведено результати експериментального дослідження механічного стану плазмово-пилових структур, сформованих із частинок з різними властивостями (густина, розмір, форма) при впливі зовнішнього магнітного поля. Поведінку структур вивчали за спостереженням їх центральних горизонтальних перерізів. Результати дозволяють виділити параметри експерименту, які впливають на стан структури і властивості розряду. Показано, що величина магнітної індукції, для якої настає інверсія обертання, не залежить від розрядного струму і має лінійну залежність від тиску нейтрального газу.