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Investigation of electron beam charging of dust particles

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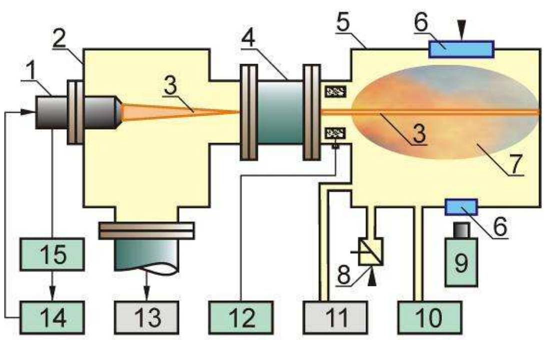
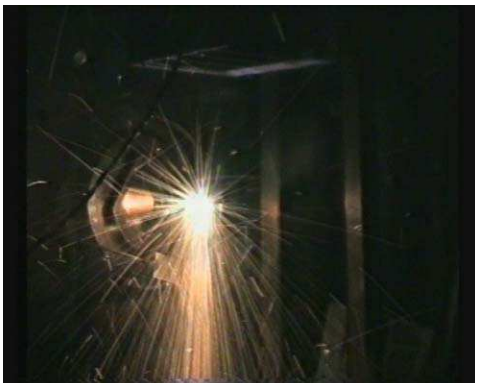
The experiments were performed on the experimental setup consisting of the electron-beam generator and the diagnostic complex, which includes the registration system of particles and different measuring equipment. In high vacuum chamber electron-beam injector generates an electron beam, which penetrates through the gas dynamic window in a working vacuum chamber (Fig. 1).



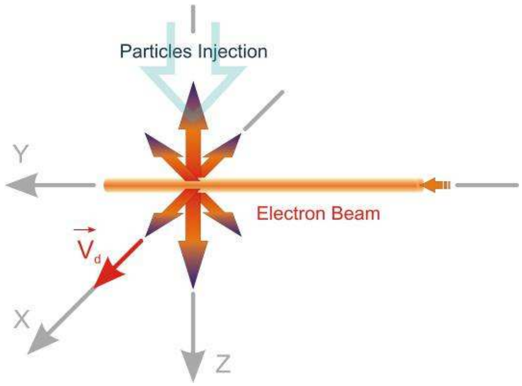
1 – Electron-beam injector;
2 – High vacuum chamber;
3 – Electron beam;
4 – Outlet device;
5 – Working vacuum chamber;
6 – Windows for input of illumination laser beam and shooting of structure;
7 – Electron-beam plasma;
8 – Vacuum valve;
9 – CCD-camera;
10 – Plasmaformative gas pressure measuring instrument;
11 – Roughing-down pump;
12 – Electron beam current measuring instrument;
13 – High-vacuum pump;
14 – Transformer-rectifier unit;
15 – Control unit.

FIGURE 1. Experimental setup.

Dust particles from a special dispenser, located at the top of the working chamber, were injected into the area of electron beam action. The experiments were carried out with particles of different materials (copper, lanthanum hexaboride, glass microspheres, aluminum oxide), forms and sizes (10-200 mkm) in various atmospheres (air, helium) at pressures ~10^{-4}, 0.2, 0.6 torr and above. The current of electron beam was varied from 1 to 10 mA; the energy of electrons was about 25 keV and the electron beam diameter was about 5 mm. Under the action of electron beam dust particles became charged. Due to Coulomb interaction these macro particles gained the velocity and spread in the different directions (Fig. 2 (a)).



(a)



(b)

FIGURE 2. (a) Particles spreading (video frame); (b) scheme of experiment.

Experiments, carried out with Al_2O_3 particles at ~10^{-4} torr pressure in air atmosphere, have shown a very strong effect of uniform spreading in all directions. The particles were charged negatively, because the rate of secondary electron emission from the surface of particles $\sigma \ll 1$ and the maximum depth of penetration of electrons with this energy does not exceed a few tens of micrometers. The particles with trajectories in horizontal plane were selected (Fig. 2 (b)) for the analysis. Coulomb interaction of charged particles significantly surpasses the influence of gravitational forces near the electron beam and gravitational forces do not influence on particles movement. On the basis of experimental data we found that the average velocities of dust particles were about 3 m/s at a distance of 15 cm from the axis of electron beam. For estimation of the average particle charge we developed the model, which takes into account the repulsion of the particles from each other and from the electron beam. For instance, the charge of Al_2O_3 particle was about 10^7 elementary charges. It is ~ 2-3 order more than the charge of macroparticle in the high-frequency discharge.

In a series of experiments, carried out at pressure 0.2 torr in air atmosphere, the largest cone spreading was observed for Cu particles and glass microspheres, while for LaB_6 this effect was very little. The effect is completely stopped for all particles at pressures more than 0.5 torr in air and ~2 torr in helium.

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