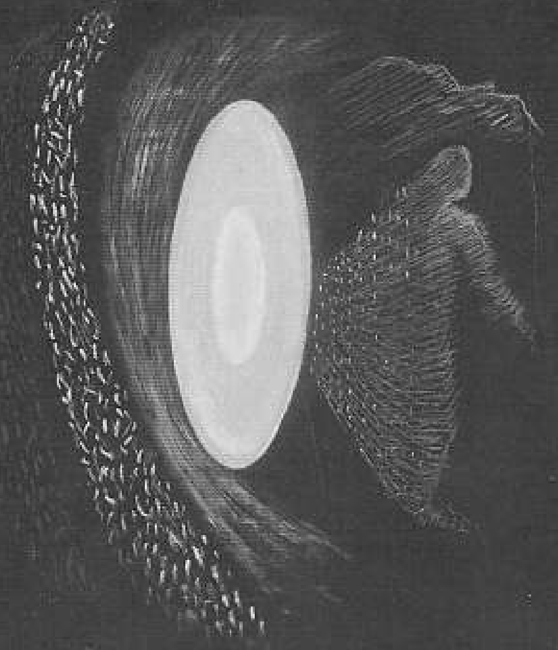
DUSTY PLASMAS
in applications

3rd International conference on The Physics of Dusty and Burning Plasmas



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Obtaining of composition nanoparticles in dust-plasma medium

M.K. Dosbolayev, T.S. Ramazanov, T.T. Daniyarov,
S.A. Orazbayev, S.B. Momynov, A. Kissan

*IETP, al-Farabi Kazakh National University, 96a Tole bi Str.,
Almaty 050012, Kazakhstan* merlan@physics.kz

There is currently a great interest to obtain microparticles with nanocoatings for manufacturing of abrasive, wear resistant, corrosion resistant, high strength materials for future use in various technological applications, including generation of dispersed catalyst for savings of expensive materials [1]-[4].

In this regard, we carried out preliminary experiments to obtain particulate-composite materials (DCM) using thermal spraying of dust component levitating in bulk plasma. This method does not require expensive specialized equipment and allows one to generate small particles of various materials (the average size in the range of 40-120 microns) with coatings of thickness of 10-20 nm.

Experimental facility

Experiments on generation of composite materials were performed in the upgraded camera VUP-5 in inert gas plasma of pressures of 0,1-1 Torr with immersed polydisperse spherical particles with diameter 40-120 microns. Schematic diagram of the facility is shown in Fig.1.

Experimental facility consists of the following components:

RF -chamber. Chamber volume is about 10 liters. Inside the chamber, there are two flat electrodes (2, 3) in the form of a disk with a diameter of 10 cm, made from stainless steel. Also, there are mechanisms for the ejection of dust particles (4) in plasma volume (1) and as well as for their collection (6) after the experiment.

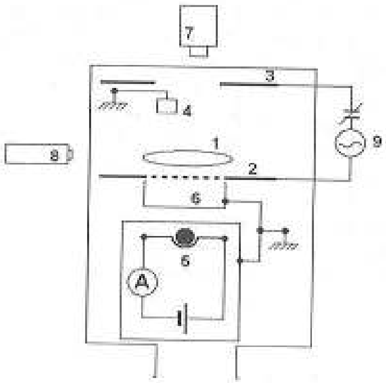

FIG. 1: Schematic diagram of experimental RF facility.

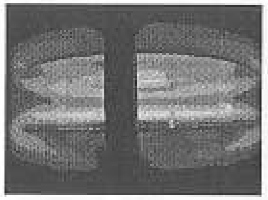

FIG. 2: Experimental facility in working regime.

Vacuum system VUP-5.

RF - generator (9) (f = 13.56 MHz) power of $W = 0 \div 50$ W.

The pressure measurement system of the working gas in the RF - cell. For this purpose special 0 "SAPPHIRE-22MT" designed to measure the low-pressure range is utilized.

The system of illumination. Illumination system includes: 1) diode-pumped solid-state laser (8) of green spectrum with total power 200 mW and 2) optical system consisting of a telescope used to expand the laser beam and a "laser knife" consisting of cylindrical lenses.

The system of registration. For this purpose the high-speed CDD camera (7) (250 frames / sec) that records video images of dust structures is used.

System of video capturing and processing (digitization). For this purpose, computer with a special built-in video capture card (Pinnacle Studio 9) is used.

Various controlling and measuring equipment (oscilloscope, voltmeter, ampermeter).

Discharge occurs between two parallel electrodes at a distance between the electrodes up to 2 cm (Fig. 2).

The lower electrode has the form of disc, whereas the upper electrode - the form of a ring or mesh. The discharge is created in an inert gas at pressures from 10-1 to few Torr. RF power inserted into discharge is estimated to be of around 1-15 W.

Analysis of initial microparticles

To determine structure, chemical properties and geometric parameters of microparticles used in the experiments, electron-scanning microscope is used. The results are presented in the corresponding figures. Figure 3 shows a group of spherical particles with sizes ranging from 40 microns to 120 microns. Figure 4 shows a particle in the section which is produced by the ion beam, the thickness of the section is around 7 microns. As can be seen, spherical particles are hollow; the thickness of walls is 1.5 microns. As the result of the study (Figures 5,6) the chemical composition of microparticles (inside the selected rectangle) is determined as follows: carbon (C) 78.4% , an oxide (O) 21.6% .

Experiment

Dust particles are injected into the volume of argon plasma and form consequently dust structures. Levitating particles are covered by atomic beam of thermal spray system. Copper and aluminum are used as coating material. Metal atoms, resulting in a sputtering process,

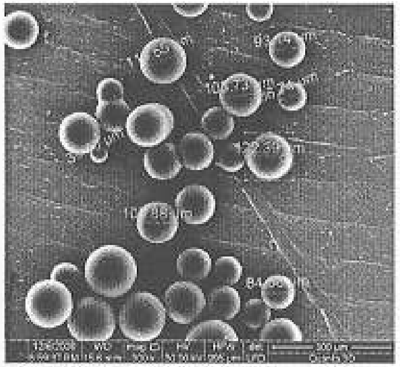

FIG. 3: Initial spherical hollow particles.

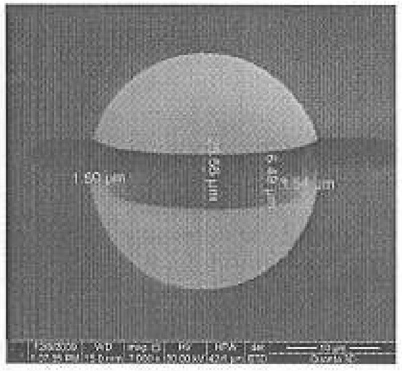

FIG. 4: Microparticle cut by ion beam.

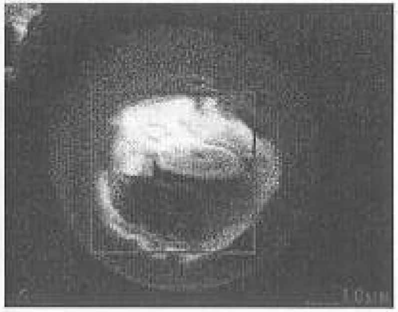

FIG. 5: Scanned microparticle *CO*.

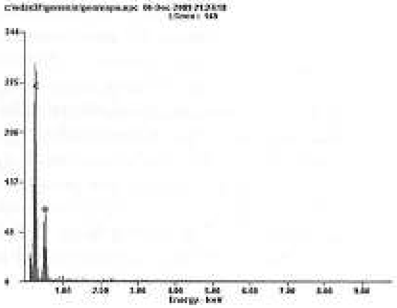

FIG. 6: Corresponding spectrum.

form nanocoatings at the surface of microparticles. The properties of the coatings depend on the nature of the interaction between sticking atoms and their interaction with the surface of dust particles.

Evaporation of the target creates temperature gradient due to the diffusion of heat, which leads to violation of homogeneity of the dust cloud that has its nature in thermo-phoretic phenomena in dusty plasmas. Dust structure is shifted in the opposite direction from the heating zone of the target, thus, escaping the central zone of discharge. Shutting down the heating of the target leads to the return of the dust structure to the initial position. Cooling of the electrode system were performed in order to obtain smaller reaction of dust structures to incoming heat flow.

The flux of atoms of sputtered material when moving to the dust cloud is thermalized due to collisions with atoms of the plasma gas and forms a cloud of nanoparticles of coating material. Thus, the dust plasma component consists then of two components, primary microparticles and nanoparticles formed during the condensation of the sprayed material.

After the deposition process and RF-discharge switch-off, coated microparticles fell to the special vessel located above the bottom electrode.

Results

Collected microparticles were examined by scanning electron microscope Quanto 3D 200i (SEM, USA FEI company). Micrographs of sprayed particles, corresponding spectra and chemical compositions are shown in figures 7,8.

Similarly charged microparticles and spray particles in the bulk plasma should generally repel each other, but large difference in particle size leads to the polarization effect that leads to creation of attractive interaction between particles of different sizes. The existence of attraction between microparticles and atoms of sprayed material is confirmed by data on chemical composition.

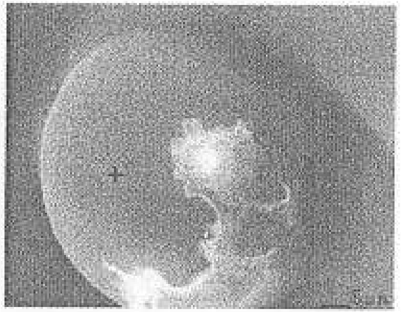

FIG. 7: Micrographs of sprayed particles.

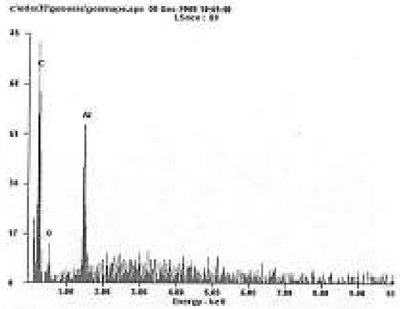

FIG. 8: Corresponding spectrum.

In addition to the sprayed particles, structures of sprayed material formed on the walls of the chamber (Figures 9, 10). As can be seen from the figures, the growth of the film on the walls of the chamber has a column-like structures with a height of 25 micron after 5 seconds of deposition. These results require further study and may be used for liquid filtration.

Injection of microparticles in plasma volume leads to the formation of structures where areas containing particles of the same size coexist. These areas have clear boundaries and sometimes are separated by empty space. The upper part of the dust structure contains an area consisting of smaller ejected particles. These grouped particles can fall into one place when discharge is switched off, so one observes structures shown in figures 11, 12.

Conclusion

Method of creation of composition nano-particles in RF discharge chamber is introduced. Aluminum and copper are coated on the surface of microparticles, which produced new

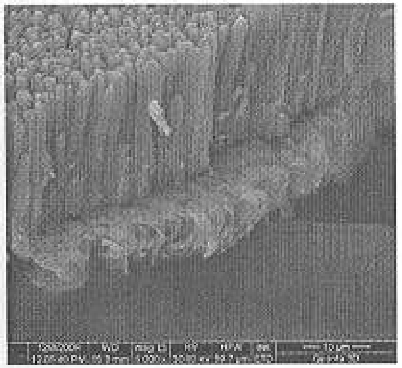

FIG. 9: Growth of coated material on walls of RF-chamber. Column-like structure.

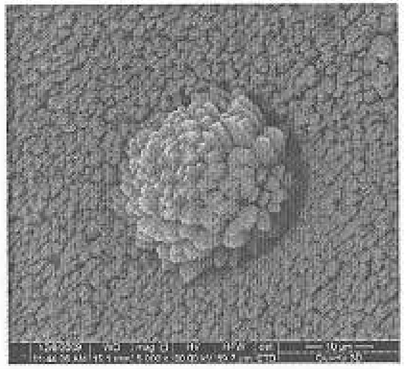

FIG. 10: Growth of coated material on walls of RF-chamber. Cauliflower-like structure.

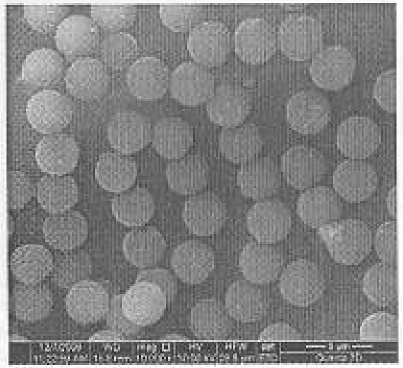

FIG. 11: Separation of microparticles of the same size in the process of spraying. ("percolation").

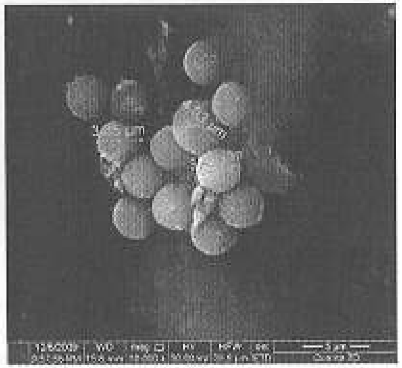

FIG. 12: microparticles of the same size stacked together in the process of separation ("grapes").

composite materials in a quantity suitable for further physical and technological experiments.

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Optical properties of dusty plasma in RF discharge

M.K. Dosbolayev, S.A. Orazbayev, T.S. Ramazanov, T.T. Daniyarov,
M.N. Dzhumagulov, K.B. Zhumanov, S.B. Momynov

IETP, al-Farabi Kazakh National University,
96a Tole bi Str.,Almaty 050012, Kazakhstan

Development of optical diagnostics of plasma is an interesting scientific task due to wide application of plasma technologies in modern microelectronics and material sciences. Within the latter special attention is paid to the case of dusty plasma, as it provides the researchers with the opportunity of collection of in-situ information on parameters of dusty plasma (temperature and concentration of plasma electrons), and, thus, develop deep insight into physical processes.

In contrast to traditional methods of diagnostics, optical diagnostics is contact-free and allows precise determination of various physical parameters. In the present paper, optical properties of dusty plasma generated in capacitive-coupled RF-discharge of argon are studied on the basis of spectroscopic analysis of plasma glow. The feature of this method is that it allows the collection of information without introduction of disturbance. Measured spectra are used to determine the influence of dust component on spectral characteristics of buffer plasma. Description of experimental facility for investigation of optical properties of dusty plasma was reported earlier [1]-[3]. Main parts of experimental facility are two plane parallel electrodes, of which the upper one is grounded. Electrodes are located in RF chamber separated by the distance of 2 cm. Both are 19 cm in diameter. To generate plasma, RF-voltage is applied to the lower electrode. Energetic input in the system under conditions of experiment is around 0,02 $Battcm^{-3}$. Argon with pressures 0,05–2 Torr is used as buffer gas. Poly-disperse particles of Al_2O_3 with average radius of 4 micron are used to create dust structures in plasma volume [4].

Vacuum chamber has optical windows used for measurements located sidewise. Optical system applied for plasma diagnostics consists of lens system and linear spectrometer Solar S100. Lens system is adjusted to provide clear image of inter-electrode space on the entrance slit of spectrometer.

The feature of Solar S100 spectrometer is its sensitivity and possibility of simultaneous linear measurements of optical spectra in wavelength range of 190 - 1100 nm.

After discharge ignition, dust particles were injected into plasma volume and form consequently levitating dust structures. During experiment, argon spectra were measured at different values of discharge power and buffer gas pressures with and without dust particles. On the basis of measured spectra temperature and concentration of electrons are calculated (Example of measured spectrum is shown on Fig. 2).

For calculation, the lines of argon spectrum are used that are shown in Table 1.

Atom	E, eV	λ, nm	g_n	A, $10^{-8}s^{-1}$
Ar I	13.33	696.5	3	6.8
Ar I	15.33	549.5	9	1.7
Ar II	19.22	480.6	6	100