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Separation Process of Polydisperse Particles in the Plasma of Radio-frequency Discharge

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Method of separation of polydisperse particles in the plasma of radio-frequency (RF) discharge is considered. Investigation of plasma equipotential field gave conditions for separation. The purpose of this work was an obtaining of monodisperse particles in the plasma of RF discharge. Samples of monodisperse microparticles of silica and alumina were obtained. The size and chemical composition of samples were studied on a scanning electron microscope Quanta 3D 200i (SEM, USA FEI company). Average size of separated silica nanoparticles is 600 nm, silica and alumina microparticles is 5 mkm.

Keywords: Monodisperse particles, Separation, Radio-frequency discharge, Plasma.

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1. INTRODUCTION

As is known, the particles can be divided for polydisperse and monodisperse particles depending to the geometric parameters. A distinctive feature between the two is their dispersion, which is obeyed the normal law of the Gaussian distribution. At small values of dispersion some properties of particles are improved. At present there are many methods of obtaining monodisperse nano-, submicro- and micropowders [1-3]. One of them is the method of separation of polydisperse particles. Depending on the medium of separation, distinguish a wet and dry separation, separation with electric and magnetic fields [4] and etc. The main disadvantages of the existing methods of separation are large dispersion of separated particles and limited choice of material. Present work is devoted the method of separation of polydisperse dust particles in the plasma of radio-frequency discharge, where as an instrument of separation uses electric field. Using proposed method is possible to reduce the dispersion of the dust particles and avoid of limited choice of materials.

2. EXPERIMENTAL PART

The experimental setup for separation of polydisperse particles (SiO_2 and Al_2O_3 particles, with initial size of several hundred nanometers to 100 μm) is consisted of working chamber (1), high-frequency (4) and sonic generators, "electrical trap" (8), dispersion element (5), a pair of disk electrodes (2), ring (6) for dust trapping and container (7) for collecting the separated particles (figure 1). Also there are side windows (3) for visualization of plasma processes. For separation process were used the following values of plasma parameters: gas pressure (Argon) 10^{-2}-1 Torr, discharge power 0.5-30 W. The condition of formation of dusty plasma is well described [5, 6]. The polydisperse particles were injected into the plasma volume by dispersion element, which regulates the amount of injected particles.

The separation of polydisperse dust particles in the plasma of radio-frequency discharge is based on capture and control of the dusty plasma structures by electric field of lower electrode.

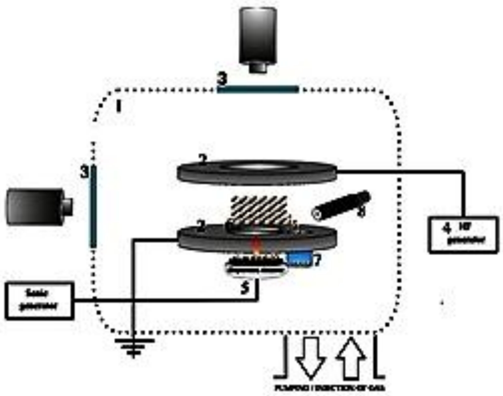

Fig. 1 – Experimental setup

3. RESULTS

Obtained particles after separation were examined by electron microscope Quanta 3D 200i (SEM, USA FEI company). The SEM images of obtained samples and their corresponding histograms are shown on figures 2-5. An average size of silica and alumina microparticles after separation was 5 μm, whereas before separation the sizes were equal to 1-100 μm. Those samples were obtained at the following plasma parameters: RF power is 1.5 W and gas pressure for silica and alumina is 0.3 and 0.15 Torr, respectively.

The proposed method includes a stepwise separation of polydisperse particles by masses, so deviation of separated silica microparticles from the average size of 5 μm is small than the deviation of separated alumina microparticles and it can be explained as follows – silica microparticles have a spherical shapes, whereas shapes of alumina microparticles are violated, hence for silica microparticles with the same geometrical size corresponds the same mass, while for alumina microparticles with the same mass corresponds different sizes of particles.

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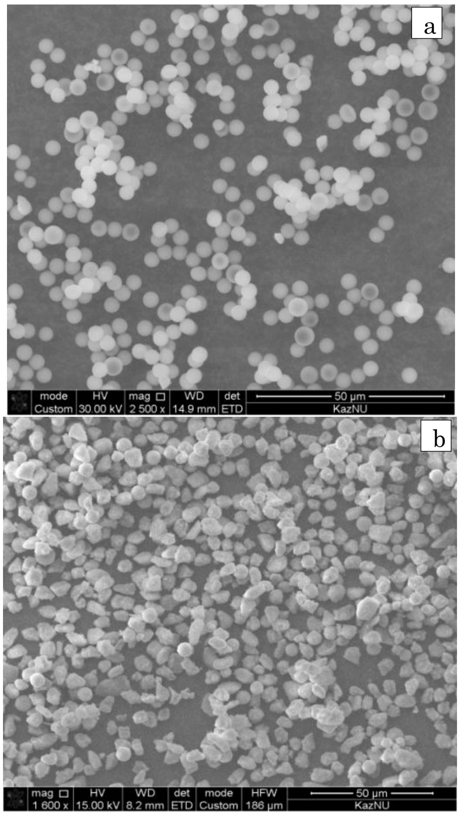

Fig. 2 – Monodisperse particles of SiO_2 (a) and Al_2O_3 (b)

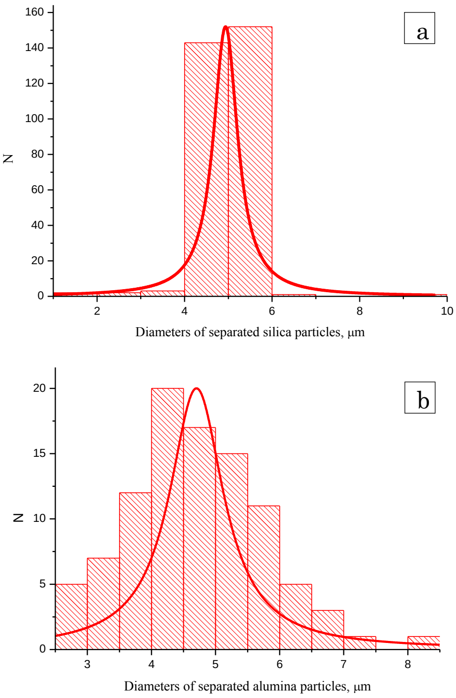

Fig. 3 – Histograms of separated silica (a) and alumina (b) microparticles

The "electrical trap" was involved for obtaining of separated silica nanoparticles, which is represented of two coaxial cylindrical electrodes with a dielectric between them.

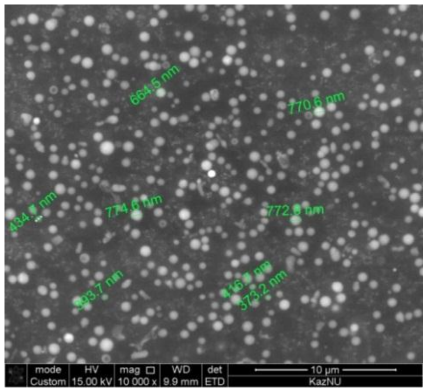

Fig. 4 – Separated nanoparticles of SiO_2

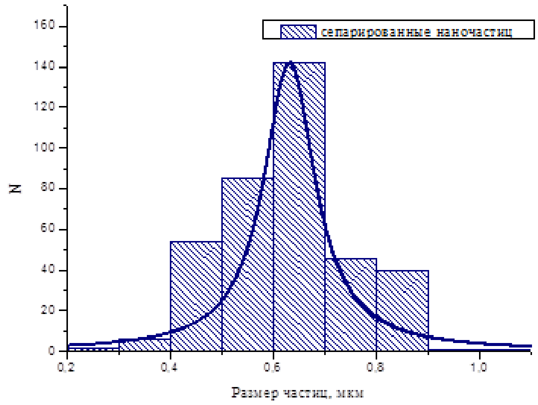

Fig. 5 – Histogram of separated SiO_2 nanoparticles

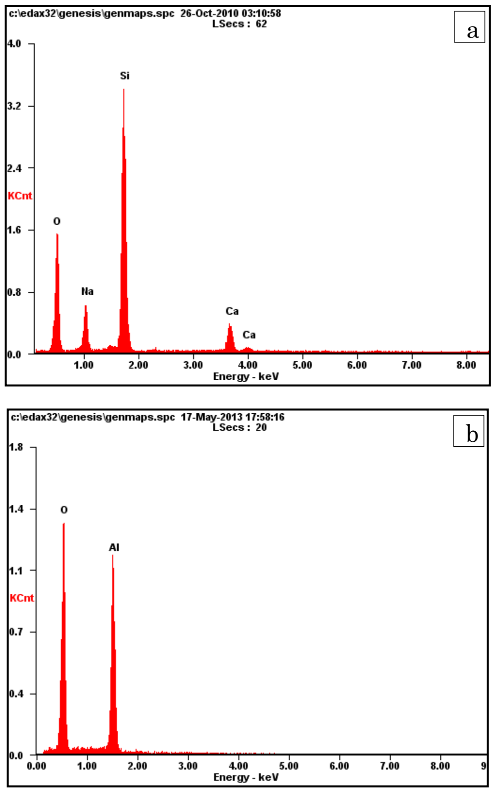

Fig. 6 – The spectra of the chemical composition of silica (a) and alumina (b) particles

The samples of silica nanoparticles were obtained at discharge power of 0.5 W, gas pressure of $6 \cdot 10^{-2}$ Torr and voltage at "electrical trap" of 350 V, figure 4 and corresponding histogram is shown on figure 5.

As figure 5 shows, the average size of obtained silica nanoparticles after separation is 600 nm and deviation is large, because of difficulties controlling and capturing of nanoparticles from plasma dust structure.

Analysis of the chemical composition of obtained samples of SiO_2 and Al_2O_3 particles on a scanning electron microscope Quanta 3D 200i (SEM, USA FEI company) are shown on figure 6.

Seen, that the obtained spectra correspond to the chemical composition of silica and alumina particles.

4. CONCLUSION

On the basis of the method of separation were obtained monodisperse microparticles of silica and alumina with average size of 5 μm and separated silica nanoparticles with average size of 600 nm. Deviation of obtained after separation silica microparticles from the average size was lower, than of separated alumina microparticles. Found that the separation does not depend on the type of materials. The range of separation is 600 nm-50 μm.

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