DUST IMPACT MASS-SPECTROMETER FOR THE ELEMENTAL COMPOSITION OF MICROMETEOROIDS RESEACH

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ABSTRACT

Time-of-flight mass spectrometers are widely used for the solution of a set of problems at implementing space experiments for studying the chemical composition of cosmic dust, debris, the own atmosphere of spacecrafts, space objects ground, gas-dust tails of comets, etc.

So, for example, dust impact mass spectrometers are applied for the analysis of micrometeoroids flows. In such mass-spectrometers, because of the high energy scattering of ions, arising as a result of shock interaction of the impact- particle and the target, as a rule, sufficiently high resolution capability is obtained by means of application of the large accelerating voltages (about 1-1,5kV).

In accordance with the well-known data on the distribution of micrometeoroid flows both in terrestrial and outer space, notably in view of the low probability of shock interaction of dust particles with the target device, the working area of the sensitive surface of the dust impact of mass-spectrometer should be as big as possible when maintaining the device characteristics. The authors have proposed the construction implementation, which should satisfy the following requirements:

- minimization of dependence of the output characteristics from the point of collision;
- high resolution capability;
- high sensitivity;
- minimization of the overall and mass characteristics of the spectrometer.

To achieve this result the parabolic reflector is applied in the design of the device allowing significantly reduce the dependence of the mass-spectra from the point of collision of the particle and the target, diaphragm of the receiver that limits the number of possible trajectories of ions, reaching the receiver. However, it causes some decline of ions collection ratio, as well as non-linear electrostatic deflector allowing removal of the influence of the initial energy dispersion on the ions' flight time.

The design verification was carried out with the help of the electrodynamics amplifier and Van de Graaff generator. The device showed operating capacity in a wide range of particles velocities, as well as the conformity of the results of numerical simulation with the design parameters obtained experimentally.

1 EXPERIMENTAL RESULTS

TOF mass spectrometers are widely used not only in terrestrial but also in space. The latter include the study of outer space, the chemical composition of cosmic dust, its own atmosphere of space vehicles, etc.

The advantages of TOF mass spectrometers as compared to other devices operating principles are: small size, high sensitivity and the ability to determine the composition of cosmic dust particles with a random character interaction with the device. The latter property is especially important in space research. Space studies of physical and chemical properties of particles of natural and artificial origin is one of the scientific issues in the study of the cosmos. Comprehensive study of the characteristics of cosmic dust, its origin, chemical composition is of great scientific and practical interest, since the problems of astrophysics and cosmochemistry closely connected with the fundamental objectives of studying the structure, origin and evolution of the solar system. Mass spectrometry is a powerful analytical method. He has long been widely used, with each year getting increasingly common. Knowledge about the distribution of the particles by mass in the flow on the surface or volume provide important and often unique information necessary for the industrial and scientific applications. To study the elemental composition of cosmic dust, micrometeoroids and man-made particles are widely used TOF mass spectrometers [1]. An example of such a device is a mass-spectrometric transducer for the study of cosmic dust (Fig. 1).

The device operates as follows. Upon impact the particles of the target material particles and become part of the target in the weakly ionized gas and the receiver output (SEM-7) formed by ion spectrum. Creation of such a device with a large area of sensitive surface is a complex task. Ion pulses are amplified in amplifier and using the key after a certain amount of time required for ionization, the voltage is removed from the target, produced by the source of time-varying pulse voltage. The accelerated ions are emitted into the upper free

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space, reflected immersion lens so that the focus at the center of the reflecting grid, which forwards them to the receiver of the ions. Ions separated by mass over time, going through a nonlinear reflector. The signal from the receivers of ions enters the processing unit ion spectra. The voltage source generates a given potential in the nonlinear reflector, reflecting the net and immersion reflector.

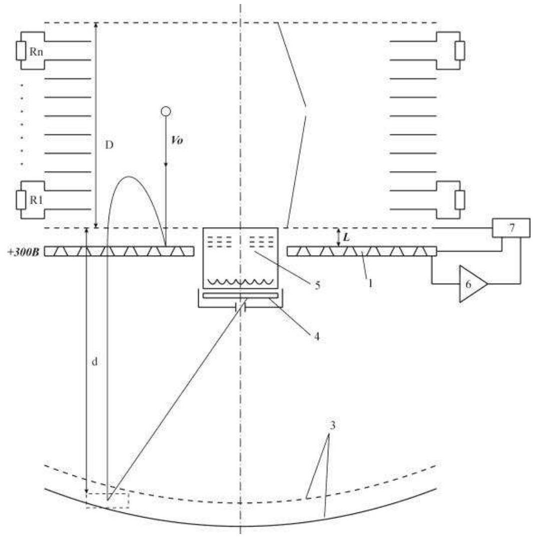

Figure 1 - Mass Spectrometer. (1 - target, 2 - electrostatic focusing mirror, 3 - parabolic reflector, 4 - Receiver ions, 5 - ion source, 6 - a charge amplifier, 7 - high-voltage impulse generator).

Features reflect the net is that it is concave towards the target with a radius R= 2 ... 3 m. This helps to further the spatial focusing of ion beams in≈ the receivers of the ions. Thus, the reduced loss of ions, which increases the sensitivity of the device. Focusing ion energy is produced using an immersion lens and additionally in a nonlinear reflector. Using a nonlinear reflector improves the resolving power of the device.

Basic relationship between the parameters of the mass spectrometer [1]:

$$\begin{cases} T = t_1 + \dfrac{2V_1}{a} + \dfrac{d}{V_1}, \\ T_P = \dfrac{2V_P}{a} + \dfrac{d}{V_P}, \\ V_P = \sqrt{\dfrac{2eU_0}{m_P M_P}}, \end{cases}$$

where m_P - proton mass; U_0 - initial voltage; d - the distance from the receiver to the focusing system; V_1 - particle velocity at time t_1; T_P - time of flight ion mass M_P.

This TOF device to determine the elemental composition of micrometeorites and dust particles of a low concentration of high resolution and is the only tool for solving such problems.

Obtained using mass spectrometer spectra are shown in Figure 2. They were obtained in the investigation of the collision products of the accelerated particles Al, Fe and SO_2 niobium target.

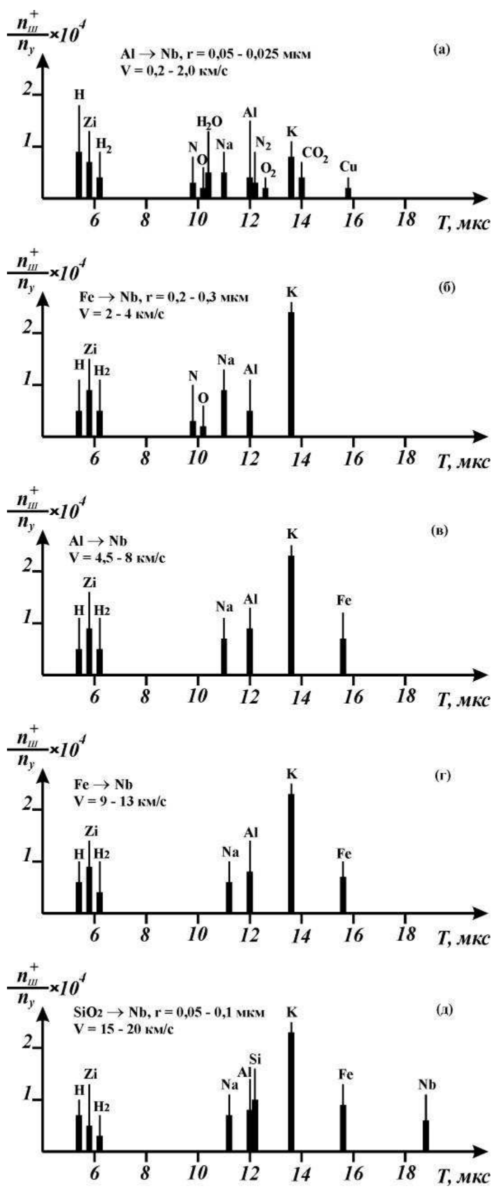

Figure 2 - Obtained using mass spectrometer spectra

2 REFERENCES

1. Semkin N.D., Voronov K.E., Myasnikov, S.V., Pomel'nikov R.A. / Instruments and Experimental Techniques, 2001, № 5.