ATTEMPT OF MEASUREMENT OF SPACE DEBRIS MICROPARTICLE FLUX IN GEOSYNCHRONOUS ORBIT

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ABSTRACT

The report presents the results of measurements of fluxes of solid particles with the sizes of order of 1—100 μm and velocities over 0.1 km/s in geosynchronous orbit (GEO). The measurements were done on Russian geosynchronous satellites GORIZONT-41 since December 1993 to October 1994, and GORIZONT-43 in May 1996. The detector consists of two thin metal-dielectric-metal (MDM) structures which were installed one above another. Time-of-flight method was used for measurement of particle velocities in the interval v = 2—70 km/s.

GORIZONT-41 data are following: the average flux of the particles with velocities higher than 12 km/s was $5.9\cdot10^{-5}$ $m^{-2}s^{-1}$, total flux of all the registered particles was $1.2\cdot10^{-4}$ $m^{-2}s^{-1}$. Flux values obtained in terms of the GORIZONT-43 data are higher than the GORIZONT-41 ones by an order of magnitude: flux of the particles with velocities higher than 12 km/s was $3.6\cdot10^{-4}$ $m^{-2}s^{-1}$, total flux of all the registered particles was $1.1\cdot10^{-3}$ $m^{-2}s^{-1}$. Particle velocity distributions are similar in both cases. Maximum is achieved for v=20—25 km/s.

1. INTRODUCTION

Main aim of our experiments was GEO measurements of flux of the low-velocity (v=0.1—2 km/s) particles which can be interpreted as space debris particles.

The interest to such measurements is explained by that in low-earth orbit (LEO) significant fluxes of space debris microparticles are experimentally registered, but for GEO such data are not available.

At the same time it is necessary to point out the significant difficulties of measurement of space debris microparticle fluxes in GEO, caused by low velocity of particles relatively to the measuring device.

Our measurements were done on Russian geosynchronous satellites GORIZONT-41 since December 1993 to October 1994, and GORIZONT-43 in May 1996.

The device containing two MDM-structures was oriented along the satellite velocity vector. Also, it contained collectors for electron emitted by the particle impacts over MDM-structures. But due to technical restrictions, the emission channels were not used in both experiments that has produced difficulties for interpretation of our measurement results.

Before passing to the detailed description of the device design and the results of our measurements, our previous researches on the basis of which the device was created are described below briefly.

2. INP MSU ELECTROSTATIC ACCELERATORS AND SIMUALATION EXPERIMENTS

In INP MSU, three electrostatic accelerators of solid microparticle present:

- cascade generator, U=0.2 MV;
- cascade generator, U=0.5 MV;
- Van de Graaff generator, U=4.0 MV.

Following particles are accelerated: Al, Cr, Fe, Ni, Cu, Mo, W and other metal particles or dielectric ones with thin conducting cover. The sizes of particles are 0.5—10 μm, velocity range is 0.1—30 km/s.

Special particle source was developed, where particles receive a positive charge at contact to a needle and then are injected in accelerator tube.

All accelerators are supplied with the system of measurements of the particle velocities and separation of particles with given velocity which is placed after the accelerator tube.

Our experiments on accelerators have two main directions.

1. Study of solid microparticle impact on materials and equipment of space vehicles:
   a. Formation of craters and surface erosion;
   b. Degradation of lenses and mirrors;
   c. Break-down of thin films;
   d. Effect on the high-voltage equipment;
   e. Handicaps to the scientific equipment operation.

2. Development of devices for registration of particles in space:
   a. Piezoelectric effects;
   b. Thin-film MDM structures;
   c. Electron and ion emission;
   d. Ion mass-spectrometry;
   e. Light flashes.

In our experiments, we have paid significant attention to study of electron and ion emission, especially for low impact velocity (v=0.1—10 km/s). This velocity interval is important for research of the space debris particles.

It is shown, in particular, that for low impact velocities there are the additional emission mechanisms, besides the thermal ionization of the evaporated substance in the impact zone.

On the basis of our laboratory researches some result of which are presented in more details in [1—3], the device for measurements in space was designed.

3. DEVICE DESIGN AND PERFORMANCES

The device design is presented on fig. 1. We have two 20 μm MDM-structures located one under another on distance 8 cm. The area of the detector window was 230 cm^2. For particles penetrating through the upper MDM-structure (MDM1), the particle velocity is measured on flight time between MDM1 and MDM2.

If the particle does not penetrate MDM1, it produces the signal due to the shock compression of dielectric.

Besides, there are two channels for registration of electron emission on MDM1 and on MDM2. However, as it was pointed out in the Introduction, due to technical restrictions, the emission channels were not used in both experiments.

The time-of-flight part of the device was only used, that has created ambiguity in the experimental data interpretation.

On fig.2 in coordinates 'particle-velocity v — particle diameter d', following particle registration regions are shown:

1. Shock compression of the dielectric in MDM1 by particles with velocities $v \leq 1.6$ km/s (minimal energy of particles $E_{min}=10^{-6}$ J);

2. Penetrating of particles with velocities 2 km/s $\leq v \leq$ 12 km/s through MDM1;

3. Penetrating of particles with velocities v>12 km/s through MDM1;

4. Shock compression of the dielectric by particles with sizes d<3—4 μm and velocities v> 12 km/s.

We see that slow particles (region 1) which should be interpreted as the space debris particles can be registered due to the MDM1 shock compression only in the case d≥10 μm.

Sizes of micrometeoroids which are registered with velocity measurement (region 3) and without velocity measurement (region 4) depend on the velocity of these particles.

Note that it is impossible to separate signals produced by particles in the region 1 (space debris particles) and by ones in the region 4 (micrometeoroids) in the employed configuration of our device.

4. RESULTS OF GEO MEASUREMENTS

81 particles were registered in GORIZONT-41 measurements during 11 months, including: 34 without velocity measurements, i.e. by the MDM1 signal only, and 47 were registered with the velocity measurements. 39 of the latter 47 had velocity v>12 km/s. These results are shown on fig. 3 (bottom line).

In the GORIZONT-43 experiment during 1 month, 39 particles were registered without velocity measurements, and 29 ones were registered with