A STUDY OF MICROCRATERS IN MATERIAL SAMPLES AFTER LONG DURATION EXPOSURE ON ISS KOMPLAST PANELS

S.K. Shaevich [1], N.G.Aleksandrov [1], A.E. Shumov [1]
L.S. Novikov [2], V.N. Chernik [2], M.S. Samokhina [2]
J. L. Golden [3], R. F. Graves [3], M. Kravchenko [3]
E. L. Christiansen [4], J. A. Henkener [4]
[1] *Khrunichev State Research and Production Space Center (KhSC)*
[2] *Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University*
[3] *The Boeing Company*
[4] *NASA Lyndon B. Johnson Space Center*

The Komplast materials experiment was designed by the Khrunichev State Research and Production Space Center, together with other Russian scientific institutes, and has been carried out by Mission Control Moscow since 1998. Komplast panels fitted with material samples and sensors were located on the International Space Station (ISS) Functional Cargo Block (FGB) module exterior surface. Within the framework of this experiment, the purpose was to study the effect of the low earth orbit (LEO) environment on exposed samples of various materials. The panels were sent into orbit with the FGB when it launched on November 20, 1998. Figure 1 is a photograph of the FGB shortly after it reached orbit, showing the installed Komplast experiment panels.

Fig. 1 FGB with Komplast Panels Installed - 1998

Panels #2 and #10 were retrieved during the Russian RS 28 extravehicular activity in February 2011 and sealed within cases to temporarily protect the samples from exposure to air until they could be studied on the ground. Panel #2 contained an experiment to detect micrometeoroid impacts, radiation and

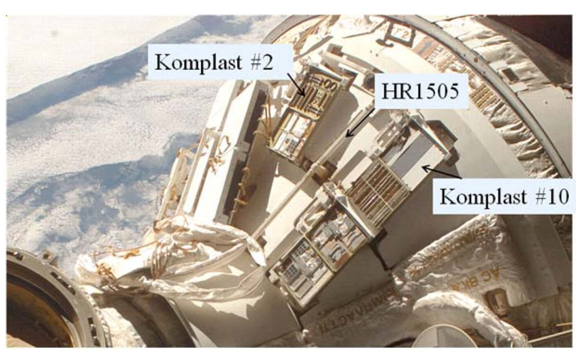


Fig. 2 Location of Panels #2 and #10 on the FGB

UV sensors, several pieces of electrical cable, and samples made from elastomeric and fluoroplastic materials. Panel #10 contained a temperature sensor and both carbon composite and adhesive-bonded samples. Figure 2 shows the location of panels #2 and #10 on the FGB module, and Figure 3 shows a closer view of panel #2, which contained the micrometeoroid experiment that is the subject of this study. The panels were subsequently returned to Earth by Space Shuttle Discovery on the STS-133/ULF-5 mission after 12 years of LEO exposure and opened in an argon chamber at the Institute of Nuclear Physics at Moscow State University in July 2011 (see figure 4.)

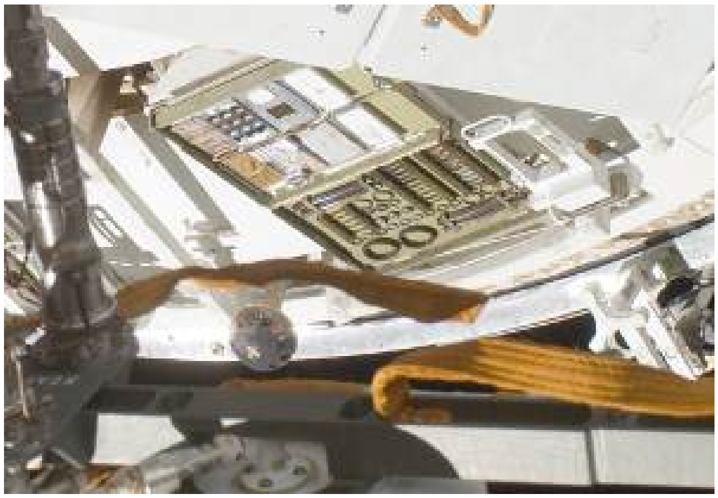


Fig. 3 Micrometeoroid Sensor Experiment on Panel #2

This report presents the results from studying the surface morphology of various materials from the Komplast panel that were exposed on-orbit to impacts from micrometeoroids and tiny debris particles. Examination revealed the presence of microcraters, measuring from 5 to 250 microns, in the surfaces of the silicon and the metallic materials that were part of the micrometeoroid experiment.

Fig. 4 Komplast Experiment Panel # 2 After Opening on July 12, 2011 at NIIYF, MSU

The microparticle sensor is shown in two different views in Figure 5, after removal from panel #2. The sensor contained 4 different test materials intended to characterize the interaction of microparticles with the different material substrates. The materials studied were silicon, aluminum alloy AMg6, a copper alloy, and titanium. Three square samples, each with an area of 1.96 cm^2, were prepared from each material with carefully polished surfaces. The total area of all 12 samples is 23.52 cm^2. In examining the surfaces of the sensor materials microscopically, 243 microcraters total were observed, of which 161 were found on the aluminum and copper alloy samples. Figure 6 shows the size distribution of the microcraters according to material. The shape of the curve is similar for the different materials except that the titanium alloy showed a large number of very small impacts on the order of 2-3 µm.

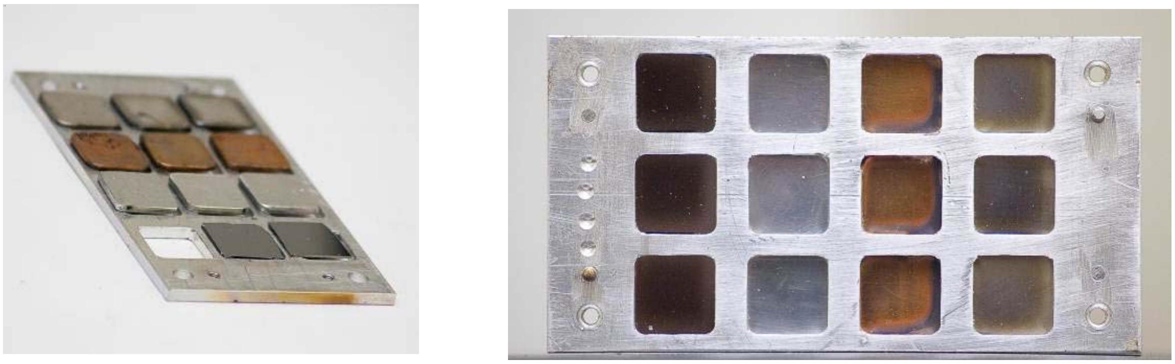


Fig. 5 Micrometeoroid Sensor After Removal from Panel #2

In addition to performing microscopy on the material samples, the exposed surfaces of the panel #2 hardware structure (727.34 cm^2 in area) were examined. Figure 7 shows the distribution of particle sizes for the Komplast hardware structure itself. In this case, 25 microcraters were observed, which is a much lower impact concentration than observed on the sensor materials themselves.. Such a difference in the number of detected microcraters on the panel hardware surface, which is many times larger in area than the sensor sample surfaces, is explained by the

Al
Cu
Si
Ti
Total

Fig. 6 Distribution of Detected Microcraters as a Function of Diameter.

fact that the panel hardware surfaces were not polished or otherwise treated prior to launch, since they were not initially part of the experimental investigation. Therefore, in order to remove this effect from the influence on the study of the number of microcrater defects, it was decided to include only craters with distinctive crater-like characteristics. These craters were 34 to 1000 µm in size.

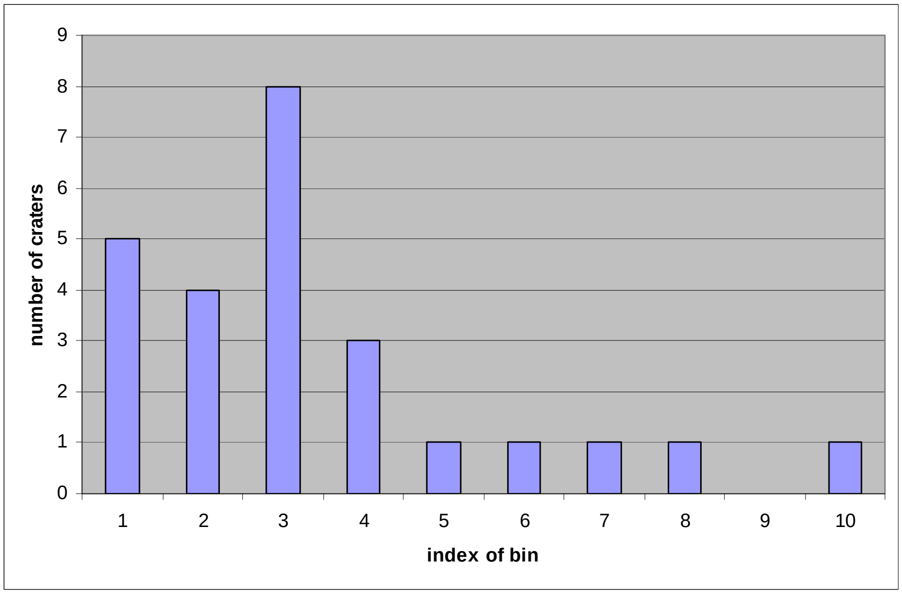


Fig. 7 Distribution of Craters Detected on Panel #2 Surface into Sizes. Spacing is 100 μm

Figure 8 shows a comparison of the calculated distribution of crater size versus number of yearly microparticle impacts per square meter with the ORDEM2000 model data. The calculations assume a crater diameter equal to 4 diameters of the impact particle. The Komplast experiment shows that the distribution of the craters and low velocity particles within a spacing of 5–50 μm differs by approximately 2-3 orders of magnitude from the data of the existing ORDEM2000 model of natural and artificial origin flux microparticles in the ISS orbit. The difference between the Komplast microparticle results and the current ORDEM2000 model for particles smaller than 50 μm requires further investigation. First, a more precise definition of the origin of the detected particles should be derived using information about the ISS surface structure and orientation.

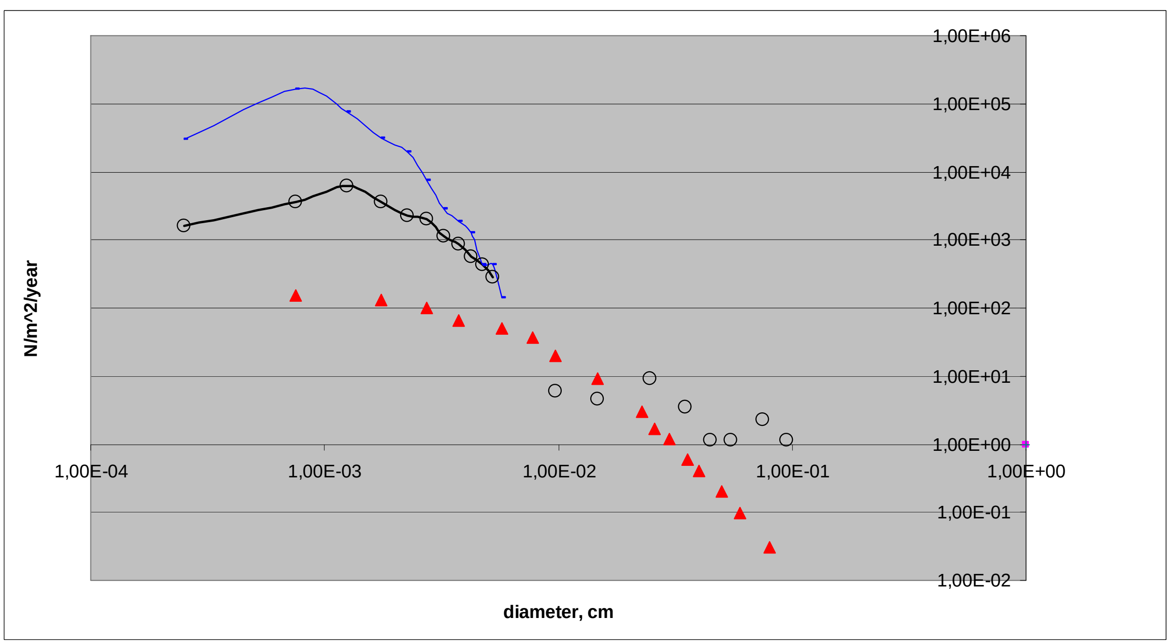
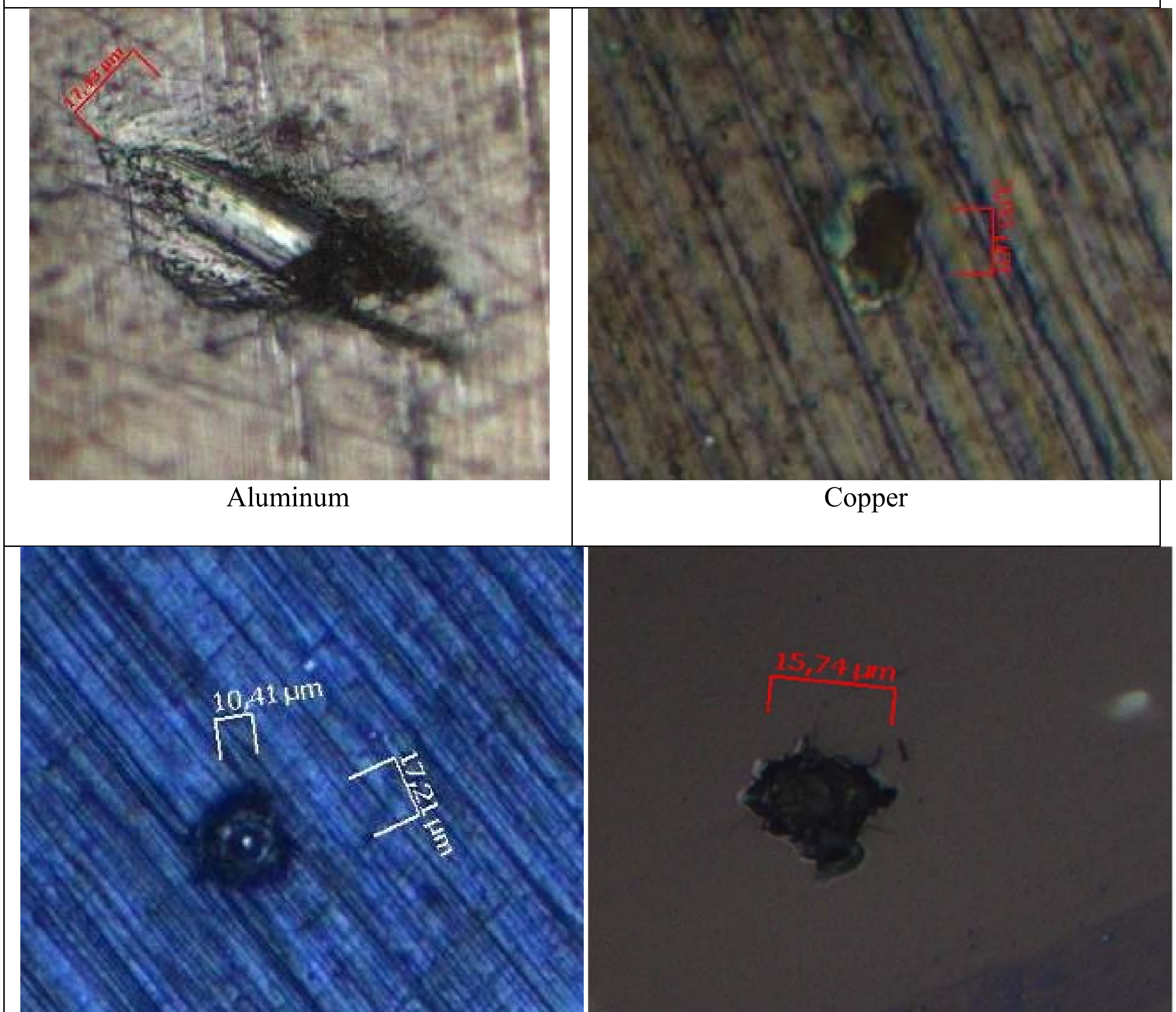


Fig. 8 Comparison of Komplast Yearly Microparticle Impacts with ORDEM2000 Model Data

In addition, more detailed statistical data processing is necessary for a better description of these "minute events."

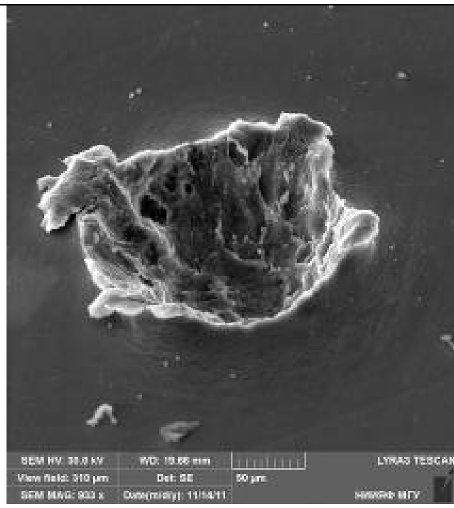
Shown in figures 9 and 10 are some of the optical and scanning electron microscope images obtained, both of the craters that were produced on the samples by high velocity microparticles and the low velocity particles that were observed to be embedded in the sample surfaces.



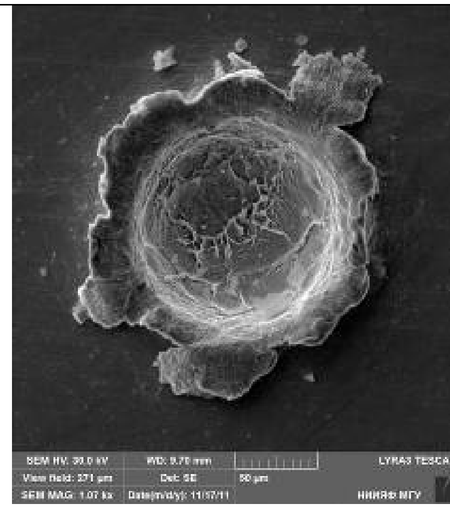
Aluminum | Copper

Titanium | Silicon

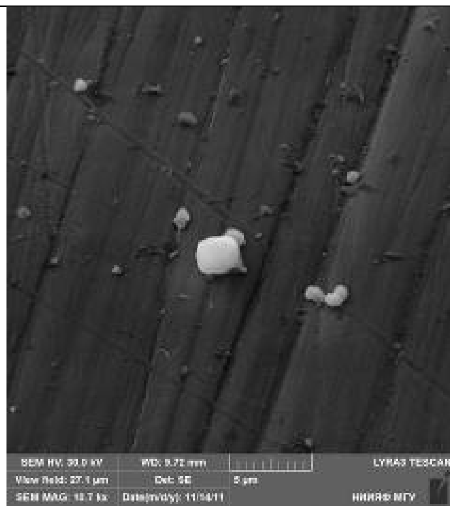
Fig. 9 Optical Microscope Images of Material Surfaces



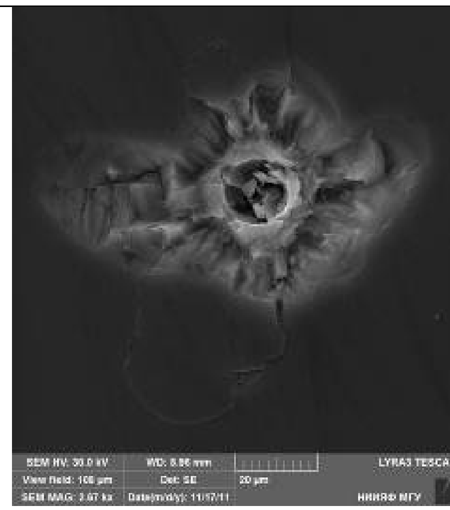
Aluminum



Copper



Titanium



Silicon

Fig.10 Scanning Electron Microscope Images of Microcraters

Figure 11 shows a photograph of a low velocity microparticle that was found embedded in one of the material samples. The elemental composition of the substance was also determined by energy dispersive spectroscopy, and indicates that it is a SiO_2 microparticle. This data permits the particle to be distinguished from naturally-originating space particles and identifies it with human-generated space debris. Figure 12 shows a photograph of another low velocity microparticle that was found embedded in the titanium sample and the chemical analysis allowed it to be identified as CrO_x.

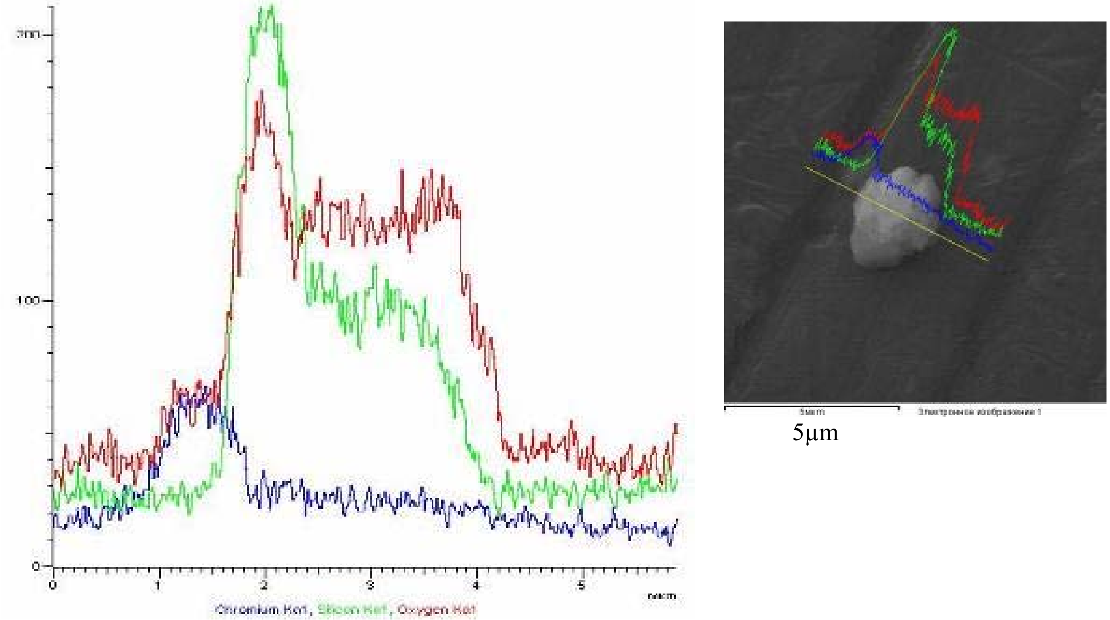


Fig. 11 Low-Velocity SiO_2 Microparticle on Sensor Surface and Its Spectrum

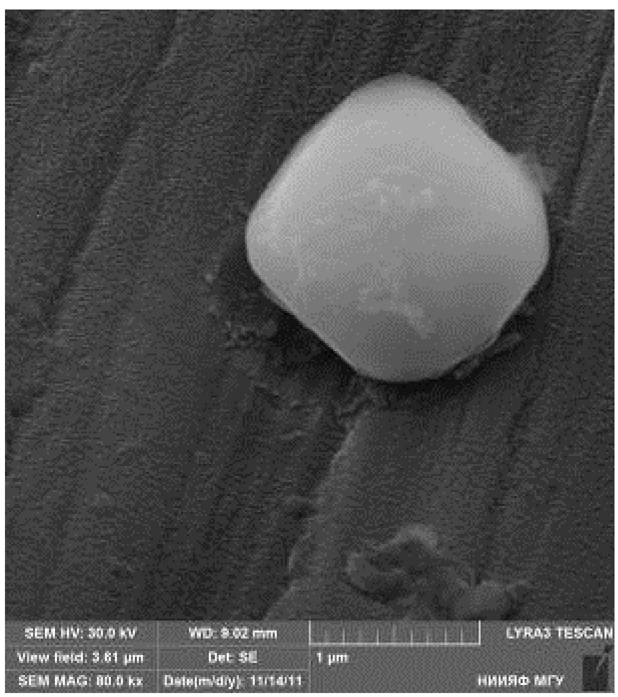
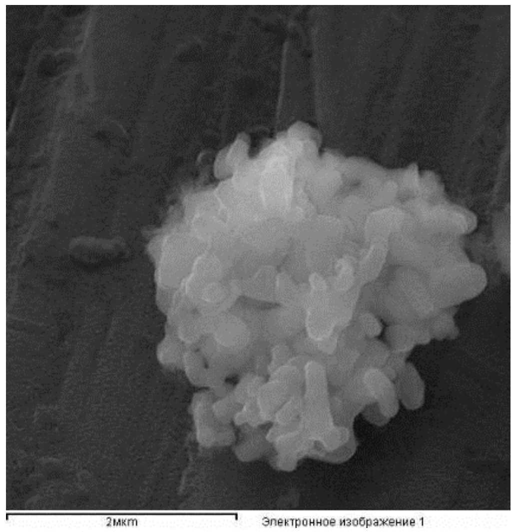


Fig. 12 Low Velocity CrO_x Microparticle on Surface of Titanium Sample

In addition to the craters and particles that could be easily understood, some more complicated and nonhomogenous particles were found in the sample surfaces. The origin of these particles is ambiguous and requires further investigation. One example of these particles that was observed in the titanium sample is shown in figure 13. The energy dispersive spectroscopy results indicated the presence of Zn, Mn, Ti, Al, Si, and O. In past evaluations of impacting particles, this chemistry was associated with spacecraft paint [1].



2μm

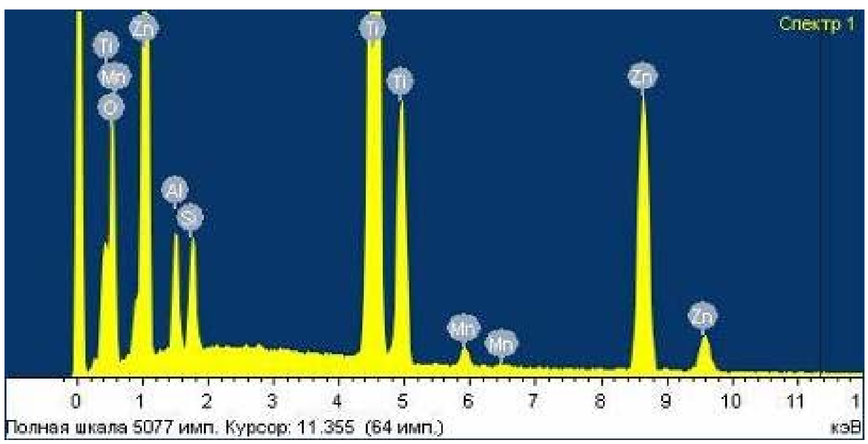


Fig. 13 ZnO MnO_x Particle and Its Spectrum on Ti-alloy Surface

References

1. E.L. Christiansen, J.L. Hyde, R.P. Bernhard, Space Shuttle Debris and Meteoroid Impacts, Advances in Space Research, Vol.34, Issue 5, 2004, pp.1097-1103.