FORMATION OF UNIPOLAR ARCS UNDER METEORITE ACTION. O. N. Nikitushkina and L. I. Ivanov, A.A. Baikov Institute of Metallurgy and Material Science RAS, 119991, Moscow, Leninsky pr.,49 (olik-n@yandex.ru; l_ivanov@ultra.imet.ac.ru).

Introduction: One of the problems on development of advanced long terms functioning space vehicles and orbital stations is protection of constructions and individual elements against influence of meteorite flows and various particles of artificial origin, so-called space dust.

The impacts of natural and artificial particles on the surface of spaceships may result in the change of both surface and bulk properties of structural materials. The results of laboratory simulation experiments on the high speed collision of hard micro-particles with metal target [1] show that both craters and so-called micro-crater fields were created. The formation of the micro-crater fields is explained by dissipation of the energy of shock waves arising while collision of supersonic particle with target material which takes place on the structural and phase inhomogeneities of the surface layer. It has been marked [2] that the formation of a crater is accompanied by emission of high-temperature and density plasma which being distributed along the surface of the sample can also damage the surface of the material.

The present work is devoted to investigation of near-crater regions found on the surface of aluminum specimens exposed in the open space.

Experiments and analysis: Two flat aluminium samples with the cross sizes 1×1 cm and thickness of 1 mm prepared for metallography, were located on the external surface of the module "Quantum – 2" of the space station "Mir". The exposition time for the samples was about 1.5 years.

After delivery the specimens back to the laboratory, their surface was investigated by mneans of scanning electron microscope LEO-430i (Leica & Carl Zeiss), equipped with the system of energy dispersion local X-ray spectroscopy analysis LINK-ISIS-300 (Oxford Instruments). The instrument was used for chemical analysis (beginning from oxygen) of zones of interest of the samples.

Results and discussion: Fig. 1 shows one of the craters found on the tested samples. The crater was selected being the most interesting from the point of view of damage of the surface. The crater has the size about 1 mm and may be seen even by a unaided eye. Its depth is approximately equal to thickness of a sample. It should be noted, that the broken fragment with diameter of about 100 microns on the back side of the sample and deflection of a material of the target in area of crater formation have been found out.

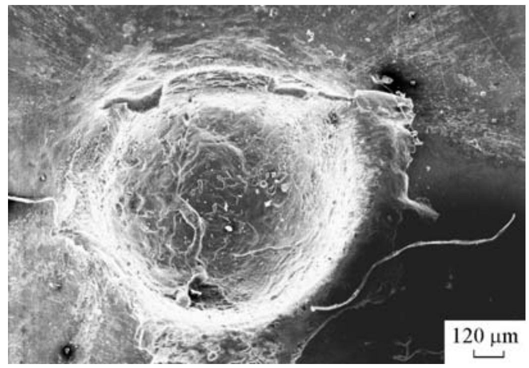

Fig. 1.

One can see the fields of the broken surface structure of material which are distributed as rays out behind a narrow part of the crater breastwork and absent out of its wide part. The extent of these fields from edges of breastwork is about 2 — 3 diameters of the large crater and cover the total area about 3 mm^2. The carried out research of individual elements of those fields shows that they have a complex structure and represent separate microcraters sometimes connected in chains (Fig. 2) linearly departing from the breastwork of the crater. The sizes of microcraters both in such chains and separately located are varied from 1 up to 5 microns.

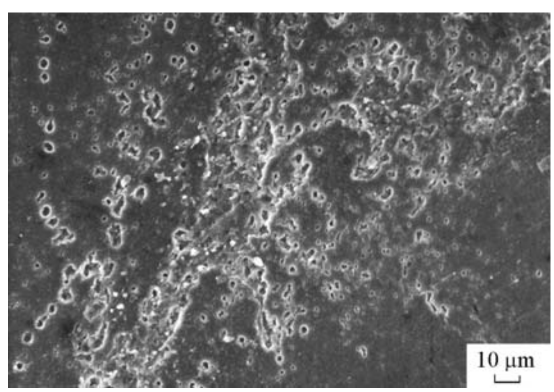

Fig. 2.

As it was shown for the first time [3] the collision of solid bodies having velocity more than 14 km/s results in formation of high-temperature plasma with ion temperature laying in a range of energy of few keVs. In this case a complete or partial evaporation both colliding particle and base material in the zone of impact irrespectively of chemical content of interacting bodies takes place. The high density high-temperature plasma formed at the moment of impact is ejected out the zone of crater as a plume which extends in vacuum in all direction including the direction to the surface of the sample. As a result of plasma interaction with surface in near-crater area is changing of its morphology which is observed as direct lines similar to scratches. The formed radial structure has increased essentially the visible area of destruction.

Similar degradation of a surface under plasma influence was observed in thermonuclear fusion installations. It is connected with formation of so-called unipolar arcs [4]. Since the middle of 70-th years due to development of high resolution methods of diagnostics of a surface it was found that the formation of unipolar arcs is observed in the majority of thermonuclear installations. As a result of formation of unipolar arcs the traces as direct lines similar to scratches (Fig. 3) are retained on a surface. The investigation of formed traces at the high resolution has shown that they consist of the large number of small craters.

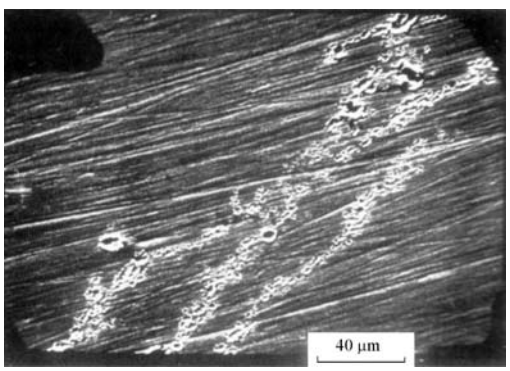

Fig. 3.

The formation of unipolar arcs is caused by significant exceeding of electron flux at the initial moment of discharge in comparison with ion flux due to higher speed of electrons in comparison with speed of ions of plasma. The result is negatively charged surface of a sample respectively to plasma and appearance of a so-called contact potential. If this potential exceeds a threshold needed for ignition of arc, then a cathode spot forms on a surface and this spot is a source of local emission both ions and electrons. Thus, the unipolar arc arises between plasma being the anode and solid material being the cathode. The occurrence of an arc results in sharp reduction of contact potential, extinction of the arc discharge and formation of the crater on the material surface. The size of the formed crater is commensurable with the area of a cathode spot which is small region of dense metal plasma with radius of few micrometers.

Thus under sliding collision of micrometeorite of relative speed more than 14 km/s with a surface of metal the high-temperature high density plasma is formed. This plasma distributed along a surface of a sample resulting in formation of extended surface defects similar to ones that are formed in thermonuclear fusion installations as a result of arising of unipolar arcs on the surface of material.

References:

[1] Nikitushkina O.N. et al. (2001) *Physics and chemistry of material treatment 1*, 48-51. [2] Nikitushkina O.N. et al. (2002) *Physics and chemistry of material treatment, 2*, 21-25. [3] Zeldovich Ya.B., Raizer Yu.P. (1966) M.: Nauka, 686. [4] McCraken G.M. (1980) *J. of Nucl. Mater.*, *93-94*, 3-16.