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# ON SUPERDEEP PENETRATION OF A MULTIPARTICLE FLUX AND DAMAGE OF ELECTRONIC ELEMENTS POSITIONED BEHIND AN OBSTACLE

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*Tracks of the material of microparticles interacting with a metallic obstacle and a detector positioned behind it are presented. The experimental data obtained show that the degree of damage of microcircuits positioned behind an obstacle depends on the material of the particles acting on it.*

One of the problems facing the designers of launching space vehicles with a long period of work in outer space is the protection of a space vehicle from the action of not only various cosmic bodies and dust bunches — micrometeoroids — but also small particles of artificial origin — the so-called cosmic debris. This problem has become especially pressing in the last 10–15 years in connection with the increased activities of man in outer space. According to the available data, the density of the flux of particles with cross-sectional dimensions of less than 10 μm in low, near-earth orbits (at an altitude of 300–1000 km) is two to three times larger than the density of the micrometeoroid flux [1, 2]. Because of this, the study of the process of interaction of microparticle fluxes with an obstacle, modeling a collision of the body of a space vehicle with microparticles of relatively low velocities (~3–5 km/sec), seems to be urgent.

As numerous theoretical and experimental data on impact interactions show, the depth of penetration of a striker into an obstacle depends on the physical-mechanical properties of its material and the material of the obstacle and does not exceed two or three sizes of the striker. However, in experiments on the impact of a microparticle flux formed by an explosion with a steel obstacle conducted at the Scientific-Research Institute of Pulsed Processes as early as 1974, it had been established that the material of ejected particles of diameter 3–200 μm can penetrate into a steel obstacle to an anomalously large depth, equal to $10^2$–$10^4$ times their initial sizes [3]. This phenomenon has been called the effect of superdeep penetration. It has been revealed that, in the case of such a penetration, the channel left behind a striker closes and an open porosity is not formed. This channel (track) becomes seen only after chemical or electrochemical pickling of microsections of the obstacle.

Figure 1 shows a photograph of a microsection cut from a steel obstacle parallel to a flux of lead particles striking the obstacle, made on an electron scanning microscope. In this photograph, we can see the material of a particle embedded in the obstacle.

Figure 2 shows a microsection cut from a steel obstacle perpendicularly to a SiC-particle flux, subjected to electrochemical pickling. It has been experimentally established that the material of a striking particle penetrates through the obstacle and comes out of the back of it in the form of a thin jet possessing a high penetrating power (energy) [4]. Figure 3 shows a photograph with a track of the action of a particle (jet) on a glass plate positioned behind a steel obstacle of thickness 200 mm subjected to a flux of particles of a mixture of silicon carbide with nickel. It should also be noted that the penetration of particles through a stack of ~40 copper and aluminum foils of thickness

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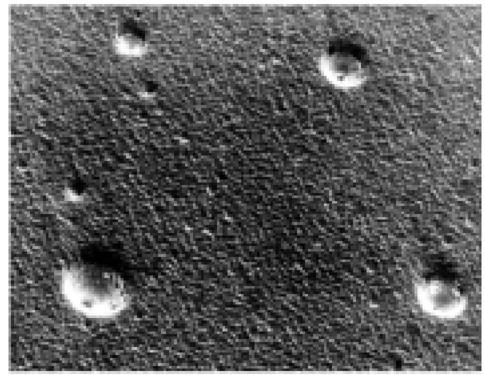
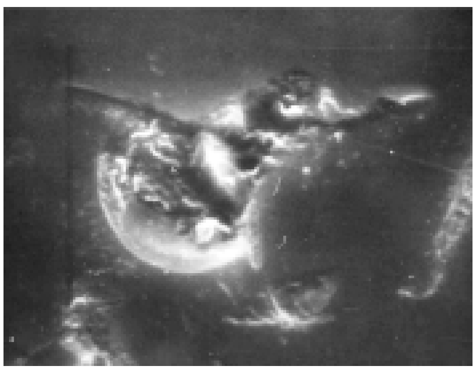


Fig. 1. Remainder of lead in the steel obstacle. ×2000.

Fig. 2. Microsection of a steel sample of dimension 40 × 13 subjected to electrochemical pickling. ×100.



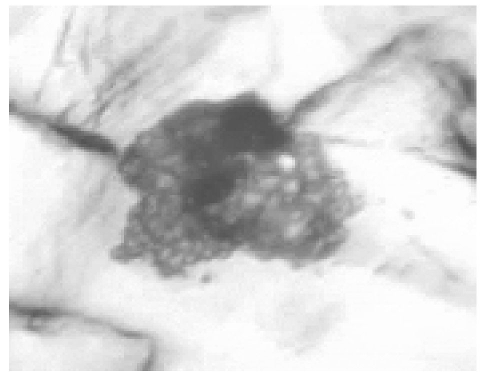


Fig. 3. Glass positioned behind the obstacle of thickness 200 mm. ×500.

Fig. 4. Track of penetration of a copper particle through the 25th aluminum foil. The thickness of the obstacle is 50 mm. ×750.

10 μm each positioned behind a 200-mm obstacle has also been detected. Figure 4 shows a photograph with a track of the action of a copper particle on an aluminum foil. The photograph has been taken on an optical microscope.

The data presented show that a particle flux having certain parameters can penetrate through the body of a space vehicle under certain conditions and act on the electronic elements of the equipment, which very substantially influences its serviceability.

In [5], it was reported for the first time that the electric parameters of electronic elements (microcircuits of a high-speed CMOS logic system) positioned behind a metallic obstacle of thickness 200 mm change when the obstacle is acted upon by a silicon-carbide particle flux having a velocity of the order of 1000 m/sec.

The aim of the present work is to determine, using a flux of nickel particles of size ~30 μm as a model of a dust bunch moving with a velocity of ~1000 m/sec, the effect of the material of a particle flux on the serviceability of microcircuits positioned behind a thick-walled obstacle and compare the data obtained with the data of [5].

In modeling the process of interaction of a particle flux formed by the method developed by us, a microcircuit was positioned in a steel cylindrical chamber one wall of which (frontal) served as the loaded obstacle and the other wall (of the same mass) of which was the base. The microcircuit was protected from displacement in the process of loading and deformation of the obstacle. The design of the chamber in which the microcircuit was positioned completely excluded the penetration of particles from outside. Before and after the experiments, the working, electric parameters of the microcircuits were tested. A particle flux was formed by compression of a cumulative depression, filled with nickel-powder particles by the detonation products of an explosion. The velocity of the particle-flux front was ~1000 m/sec. After the action of a particle flux on a microcircuit through the obstacle of thickness 200 mm, its body was visually examined on an optical microscope. The microcircuits studied had a metal-ceramic and a ceramic body. They were investigated in two positions where their crystal or their back side faced the back of the obstacle.

In the case where the crystal of a microcircuit having a metal-ceramic body faced the back of the obstacle, 27.3% of its tested parameters were changed completely (the voltage measured was equal to the supply voltage — the leads of the circuit were shorted out). The change in 12.1% of the parameters exceeded the admissible value. This points to the fact that the microcircuit failed completely. In the case where the back side of the microcircuit faced the back of the obstacle, i.e., the crystal faced the base of the chamber, the change in 3% of its parameters exceeded the admissible value.

Testing of a microcircuit having a ceramic body has shown that, in the case where the crystal of the circuit faced the back of the obstacle, 62% of its tested parameters failed completely (short circuit). In the case where the back side of the microcircuit faced the back side of the obstacle, the deviation of the tested parameters from the norm was admissible.

The fact that the working parameters of the microcircuit in the ceramic body remained unchanged in the case where its back side faced the back of the obstacle indicates that the material of the penetrated particles did not act on the crystal of the microcircuit and the obstacle did a good job of protecting it in this case. It may also be suggested that, because of the small dimensions of the crystal, the small number of particles penetrating to the indicated depth, and the nonuniformity of the distribution of the particle tracks over the cross section of the obstacle, there is little likehood that a particle from the flux reaches the crystal. However, this result excludes the assumed (debated) variant of the influence of the impact vibrations, arising as a result of the interaction of the particle flux with the obstacle, on the serviceability of the circuit since the placement of the microcircuits behind the obstacle was identical in all the experiments. Comparison of the percentage of electric parameters of the microcircuits, the change in which exceeded the admissible value under the action of Ni and SiC particles [5], shows that plastic-Ni particles penetrate into the obstacle to a larger depth and exert a stronger damaging action on the microcircuits. It is felt that the experimental method proposed for modeling of the processes of collision of cosmic-dust particle fluxes with a space vehicle and the data on the effect of the material of the particles impacting an obstacle on electronic elements positioned behind it can be used for increasing the resistance of electronic elements used in space vehicles to the action of microparticle fluxes.

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