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INFLUENCE OF A FLUX OF HIGH-VELOCITY MICROPARTICLES ON THE PARAMETERS OF INTEGRATED CIRCUITS PLACED BEHIND A THICK-WALLED OBSTACLE

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Experimental data showing that on collision of a flux of high-velocity microparticles (which is close to the fluxes of space particles in parameters) with a thick-walled metal obstacle we have failure of integrated circuits placed behind this obstacle have been given.

The existence in space of microparticle fluxes with parameters close to the parameters of the flux in experiments [1] is known from [2, 3]. Their origin can be both natural — dust bunches ejected from the surface of the moon when large meteorites fall on it or arriving from deep space — and artificial, i.e., it can be a result of human activity in space. In particular, these can also be fragments of the products of explosion of spacecraft elements — the so-called "space debris." The amount of such "products" grows every year in an uncontrolled manner, in practice, and represents an actual threat of collision with spacecraft operating in space [3].

In [1], we have reported on experiments in which a variation in the electrical parameters of the integrated circuits of a fast-acting complementary MOS logic, placed behind a thick-walled (100–200 mm) steel metal obstacle on which a flux (formed by explosion energy) of high-velocity silicon-carbide microparticles is acting, has been recorded. The variations attained values causing the total failure of an integrated circuit (IC).

In [4], it has been shown that the particle material, penetrating into an obstacle, emerges on its rear side and interacts with a detector placed behind this obstacle to leave a "track" analogous to the high-velocity action of the striker whose residual velocity is high and whose diameter is small (~1 μm). On the basis of the character of the "track," it is assumed that the striker has the form of a jet and the action of the striker on the integrated circuit located in place of the detector is the reason for the variation in the parameters of the integrated circuit.

It is clear that when a spacecraft encounters in space a small-particle flux whose parameters will coincide with or will be close to the parameters of the flux (velocity ~1000 m/sec and density ~1 g/cm^3) obtained in our experiments, we can have a breakdown of the body of the spacecraft and the action on electronic elements with an analogous effect, i.e., their failure. In this case, the spacecraft will not be depressurized. The present work seeks to determine the reasons why an integrated circuit fails under the action of a high-velocity particle flux on the obstacle.

Experimental Procedure. We placed the integrated circuits to be tested in a container with a 200-mm-thick front wall as an obstacle and carried out measures preventing their collision with the container walls, just as in the experiments in [1, 4]. The integrated circuits had a cermet case. We measured all the electrical parameters of the microcircuits before the experiments. The flux colliding with the obstacle was formed by compression by an aluminum cummulative lens with microparticles, the products of detonation of an explosive [5]. A mixture of nickel, aluminum, and copper with a particle size of 10 to 40 μm was employed as the microparticles. After the action of the particle flux, the integrated circuits were removed from the container and visually monitored to determine mechanical damage because of vibrations and possible collisions with the walls of the container's frame. Once the electrical parameters had been measured, the chips were removed from the case. The chip surface was investigated with an INM100 Leica optical microscope and an S-806 Hitachi scanning electron microscope with an x-ray microanalyzer.

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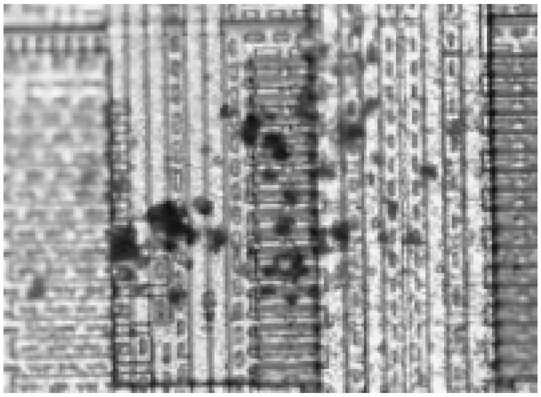

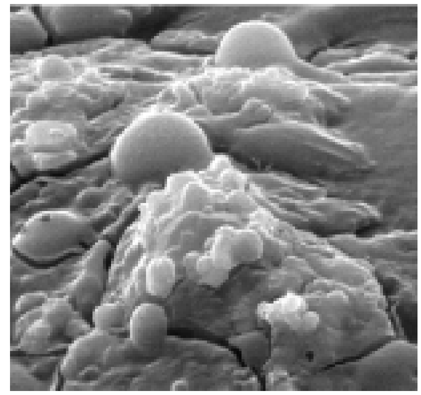

Fig. 1. Surface of the chip of an open integrated circuit after its treatment with a microparticle flux. ×200.

Fig. 2. Picture of the observed inclusions, obtained with a scanning electron microscope. ×8000.

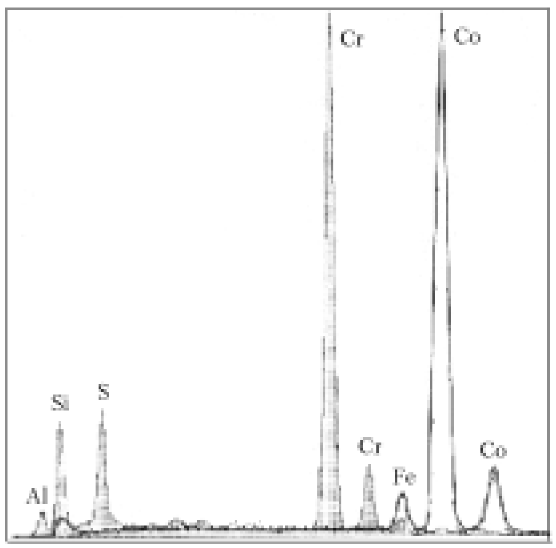

Fig. 3. Composition of the inclusion on the integrated-circuit chip.

Investigation Results. The cases of the integrated circuits had no visible mechanical damage after the action of the flux of high-velocity microparticles. The measurements of the electrical parameters of the microcircuits showed that 40 to 60% of them had values beyond the permissible standards.

On the surface of the integrated-circuit chips, we have found imperfections in the appearance, shown in Fig. 1. These imperfections represent black point inclusions. Figure 2 is a picture of the detected inclusions, obtained with the electron microscope. Figure 3 gives the data of an analysis of the composition of one inclusion observed.

Discussion of the Results and Conclusions. From the results obtained it follows that after the action of the flux of high-velocity particles, we have mechanical damage to the surface layers of the chip and the formation of point inclusions. The latter contain chemical elements that are absent in the composition of materials employed in the manufacture of the integrated-circuit chip — aluminum, sulfur, cobalt, and chromium. We have not detected nickel and copper entering into the composition of the powder. Cobalt is contained in the material of the cover of the integrated circuit's case, whereas chromium is contained in the material of the protective coating of the chip applied in the process of assembly of an IC. Sulfur is a product of detonation of the explosive. Consequently, we can infer that selective penetration of aluminum and sulfur occurs from the flux colliding with the obstacle. Based on the data of [1] and those given above, we can draw the following conclusions:

1. On collision of a flux of high-velocity particles with a thick-walled metal obstacle, we observe the formation of point inclusions and mechanical damage to the surface of the chip of an integrated circuit placed behind the obstacle.

2. A consequence of the action is the values of the electrical parameters going beyond the permissible standards and even failure of the integrated circuits.

3. The selective presence of chemical elements from the composition of the detonation products and the microparticle powder in the composition of the point inclusions has been noted.

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