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PENETRATION OF THE MATERIAL OF PARTICLES FROM A HIGH-VELOCITY FLUX IN COLLISION WITH A STEEL OBSTACLE TO LARGE DEPTHS

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Experimental data on the punching of steel obstacles of thickness ≈200 mm are given, which show that, in collision and penetration, the particle and obstacle materials go out onto the rear side of the obstacle in the form of thin jets and their interaction with the package of electronic elements is responsible for the degradation of these elements located behind the obstacle.

The fact that the effect of superdeep penetration of the material of particles from a high-velocity flux in collision with a metal obstacle exists is considered to be experimentally proved by different methods at present [1]. The following basic facts have been established. The penetration depth is a value of $\geq 10^2$–10^4 of the diameter of the particles (strikers) producing the flux which acts on the obstacle. No open porosity, i.e., no hollow channel left by the penetrating material of a particle, is formed, but its material is recorded at investigated depths of 250 to 300 mm. A completely or partially collapsed channel, i.e., a track revealed by chemical or electrochemical etching, is formed in penetration. The detected track of the striker in the form of a characteristically shaped remnant has a diameter larger than the diameter of the etched channel and contains just a certain percent of the particle material (we recorded from ≈0.1 to 40%, where the lower limit is governed by the resolution of the recorder), i.e., depends on the obstacle material, the striker, and the depth under study. We also note that the initial diameter of the thrown particles is always smaller than the diameter of the remnant and their mutual correlation has not been established.

In the course of studying the process of superdeep penetration, we have developed a procedure for recording the penetrating material of particles, once they have gone out onto the rear side of the obstacle, from the "traces" of interaction with foils placed in this obstacle at a certain depth [2, 3]. Also, this procedure allows consideration of other problems related to superdeep penetration and unsolvable by direct methods of study of the treated obstacle material. By employing the fundamental principle of this procedure one can also place other materials or objects behind the obstacle. In particular, we have investigated the action of the penetrating material of particles leaving the obstacle on its rear side on electronic elements (integrated circuits) placed behind the obstacle [4].

This work seeks to show the validity of the statement that the reason for the failure of integrated circuits located behind a 200-mm-thick obstacle in its collision with a high-velocity particle flux is the punching of the obstacle by individual particles and their action on the integrated circuits.

Figures 1–3 give photographs of variously shaped "traces" of damage to the surface of copper foils and a glass plate which have been placed in the obstacle at a depth of 200 mm and have been treated by a high-velocity flux of silicon-carbide particles with an average diameter of 63 μm. The foil thickness was 10 μm. The bagged foils were staffed with a thin tracing paper of thickness ~30 μm. The flux was formed by compressing the powder-containing cumulative hollow by explosion products. The scheme of formation of the particle flux and treatment of the obstacle has been described in [2, 3]. Foil numbers No. 2 (Fig. 1) and No. 25 (Fig. 2) denote that these are the second and twenty-fifth foils from the rear side of the obstacle from a bag of 30 pieces. The photographs were taken on a Com-Scan scanning microscope with an x-ray micrographic attachment (England) and a Polivar optical microscope (Austria) (Figs. 2c and 3b).

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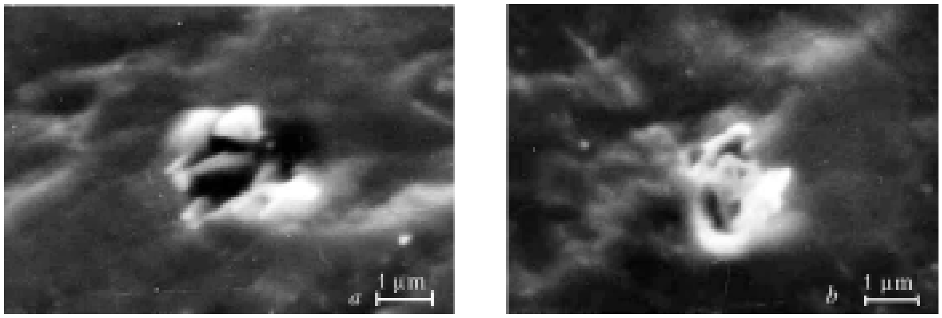

Fig. 1. Remnants of the striker in the form of a "small jet" in foil No. 2.

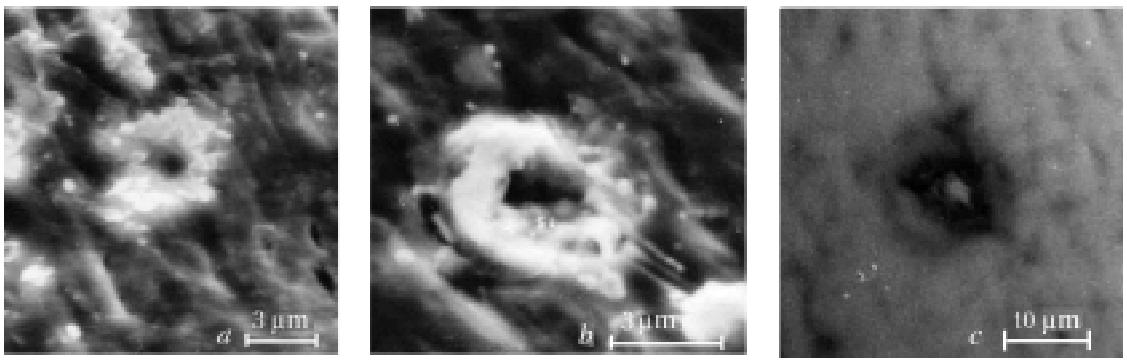

Fig. 2. "Traces" of the material of the striker passed through the obstacle on

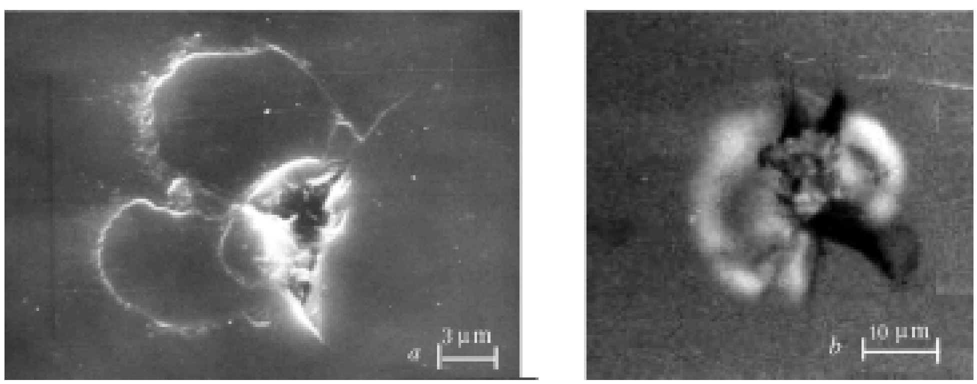

Fig. 3. "Trace" of the impact of the material of the striker passed through the obstacle on glass.

The photographs presented (Figs. 1 and 2) show several forms of the "traces" of interaction of the penetrated striker material with the copper foils. Since the foils are reliably protected against foreign particles of the ground in which the obstacle with enclosed foils or a glass plate is placed, it seems impossible to explain the inclusions on the foils by any other action. An analysis of the obtained pictures of the "traces" confirms the assumption made.

On foil No. 2 (Fig. 1), the striker material penetrated to the indicated depth has the form of a "solidified" jet jammed in the obstacle. Figures 2a and b give typical craters of a shock and of punching of a foil. The crater-like shape of the "traces" can be caused just by a high-velocity shock and it is analogous in form to the shape of the microshock crater produced by the collision of a bullet with a metal obstacle. Hence, the logical and only explanation is that the photographs presented show the "traces" of the interaction of the material of a striker passed through a 200-mm-thick obstacle. In support of this, the x-ray micrographic analysis shows a content of silicon of 21.4% in the inclusion shown in Fig. 1a and of 0.15% in that shown in Fig. 1b, while the content of silicon in the initial foil, determined by the same analysis, is 0.076%. We have recorded 2.3% silicon on the crater shaft (Fig. 2a); the rest is the copper foil. Figure 2b shows the interaction "trace" visible by the optical microscope.

When the glass plate having high hardness and brittleness is placed behind the obstacle, the character of damage also corresponds to a high-velocity shock. The trace of the "small jet" with a diameter of ≈1 μm is clearly seen at the center (Fig. 3a). Using x-ray micrographic analysis, we recorded the traces of iron (absent in glass) on the glass surface in the region of the crater and the traces of calcium, which is possibly removed from the paper interlayer located between the glass and the obstacle. The analogous crater — the "trace" with side chippings — is also clearly seen by the optical microscope (Fig. 3b).

In our opinion, the above data on the character of action of the material of individual particles from a high-velocity flux (which passed through a 200-mm-thick steel obstacle) on glass and a copper foil confirm the assumption made of the reasons why the tested electrical parameters of integrated circuits located behind the particle-flux-treated obstacle change (some of them by 80%) [4]. In this case, we have only local microdamages to the package of an integrated circuit, having an effect on its operating parameters, rather than the total punching of its package and the total failure of it.

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