Processing of metallization technology aluminum oxide ceramics for electro-vacuum devices elements and power electronics devices

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Abstract. In this journal are considered the results of processing titanium film deposition technology on the aluminum oxide substrate. The results of measuring the characteristics of adhesives are given.

Electro vacuum devices producing by the domestic industry are contained in the structure of metal-ceramic compound elements. These compounds are required for strength, vacuum tightness, sustainability to temperature changes. At the moment, these connections are performed on the basic of thick film technology.

Thin films technology ensures generally the absence of the several types of thick film technologies and on the other indicator surpasses them. Transition to thin film technology for creating the basis soldering elements of vacuum devices and power modules will be reduced the percentages of rejects and will be improved the quality of these connections.

Since 2016 at Bauman Moscow State Technological University has been taken modernization of laboratory apparatus for processing thin film coating technology into vacuum. Modernization was made in laboratory’s stand with the magnetron spraying method for thin film deposition on simples of aluminum oxide ceramics. The modernization process consisted of the mounting of gas and magnetron system, which provided the technology base for processing the development of thin film coating.

Special flange was designed and manufactured for apparatus of magnetron system. Cooling water continuously supplied to magnetron system along a close circuit and we have been used that cooling system for prevention of overheating and its demagnetization. However, the cooling system is realized so that was cooled magnets, but the target of magnetron by itself was not cooled and the process was heated temperature about 900 °C. Figure 1 shows an external view of the apparatus after completion of the modernization.

After completion the apparatus of installation work we were made the series of experiments for film deposition. We have been used titanium as the target material (cathode), and the corundum ceramics was used as the substrate material.

During the experiments of coatings deposition, the target was trained for 5 min before starting of the deposition. It was the sign, after the training time for target (cathode) 5 min was sharply increased the current with its subsequent stabilization. At the same time with the cleaning target (cathode) was...
heated temperature to 800 °C, and then after this condition deposition to substrate have been made from the hot cathode.

Figure 1. An external view of the laboratory apparatus after modernization.

We have been conducted the preliminary research and defined the range of gas flow and the range of power. From this research we have got thin films without visual defects. For titanium substrate these values are: gas flow 30 sccm, the range of power from 350 to 420 W, the range of current are from 520 to 600 mA. In these regimes, a series of experiments was conducted to deposit titanium films on an aluminum oxide substrate. In the following table 1 show the regimes of films deposition for power stabilization.

| No | Gas flow Q, sccm | Power P, W | Chamber pressure ρ, mbar | Voltage U, V | Current I, mA | Deposition time t, min |
|----|------------------|------------|--------------------------|-------------|--------------|----------------------|
| 1  | 30               | 350        | 4.3·10⁻²                 | 630–673     | 550–510      | 5                    |
| 2  | 30               | 385        | 4.4·10⁻²                 | 690–750     | 570–530      | 5                    |
| 3  | 30               | 420        | 4.3·10⁻²                 | 745–770     | 580–510      | 5                    |

There were 9 experimental researches and each mode was reproduced 3 times. Before the deposition the polished substrate was treated with isopropyl alcohol in an ultrasonic bath. The deposition time was 300 s for each simple film. The film thickness was measured with the scanning probe microscope Solver NEXT after the etching steps with hydrofluoric acid (figure 2).

Figure 2. Scanning surface and measuring thickness of film.
By the thickness of the film and the time of deposition by an indirect way, the average film deposition rate was calculated. The calculating results of deposition rate are shown in figure 3.

![Figure 3](image1.png)

**Figure 3.** Results of calculating the rate of titanium film deposition.

The samples of films were tested the values of adhesion with the net cut incision method and the separation method. In the first case, samples were scratched two opposite directions, and in the second, a glued fungus broke off from the film. The devices for measuring the values of adhesion by each of methods are shown in figure 4.

![Figure 4](image2.png)

**Figure 4.** Adhesive measuring devices (to the left side is the net cut incision method and the right side is force separating method).

All samples of films was shows the highest values of adhesion. The measuring of the net cut incision method is 5 B, and the measuring of force separating method is from 5.5 to 8 MPa, at that the destruction occurred on the glue, which the fungus was glued to the surface coating. Consequently the real values of adhesion not less than the values of following table 2. For further work, measurements of adhesion will be used the method of force separation with soldered funguses, in order to avoid the destruction of the fungus-coating connection.

**Table 2.** Results of measurement adhesion for titanium films by two methods.

| No | Power $P$, W | Values of adhesion by net cut incision method | Values of adhesion by force separating method | Note |
|----|-------------|---------------------------------------------|---------------------------------------------|------|
| 1  | 350         | 5 B                                        | 5.5 N/mm$^2$                                | Destruction has occurs at the joint of glue onto surface films |
| 2  | 385         | 5 B                                        | 8 N/mm$^2$                                  |      |
| 3  | 420         | 5 B                                        | 6 N/mm$^2$                                  |      |

These results which describes in the upper table suggest that the possibility of using the selected regimes for deposition sublayer of titanium under the materials which uses for soldering components (copper, tin-gold, etc.).
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