INVESTIGATION OF THE PRODUCTION PROCESS OF TWO-LAYER POWDER PERMEABLE MATERIALS BY THE ION-PLASMA SPUTTERING METHOD

ИССЛЕДОВАНИЕ ПРОЦЕССА ПОЛУЧЕНИЯ ДВУХСЛОЙНЫХ ПОРОШКОВЫХ ПРОНИЦАЕМЫХ МАТЕРИАЛОВ МЕТОДОМ ИОННО-ПЛАЗМЕННОГО НАПЫЛЕНИЯ

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Abstract *The investigation results of the production process of powder permeable materials (PPM) by forming thin permeable layers by means of ion-plasma sputtering method in a vacuum with the use of removable agents have been presented. The method makes it possible to obtain a continuous coating on the surface of the porous substrate. The layer formation on the surface of the porous substrate is provided by the use of the removable agent. After its removal, the layer sputtered on its surface remains an independent unit in the structure of the two-layer permeable material. The coating applied to the substrate has an open porosity.*

KEYWORDS: POWDER PERMEABLE MATERIALS, ION-PLASMA SPUTTERING IN VACUUM, REMOVABLE AGENT, PROPERTIES

1. Introduction

Reduction of the thickness of a fine-dispersed layer of two-layer powder permeable materials (PPM) leads to a decrease of their hydraulic resistance and, accordingly, increases the efficiency of use [1, 2].
One of the methods that make it possible to produce double-layer PPMs is to apply thin permeable coatings to the porous powder substrate by ion-plasma sputtering method in a vacuum [3-5]. However, the significant dependence of the pore size of the thin permeable layer on the pore size of the substrate and the columnar nature of the coating (Fig. 1) do not encourage the formation of structures with a complex of properties that one would expect from this method.

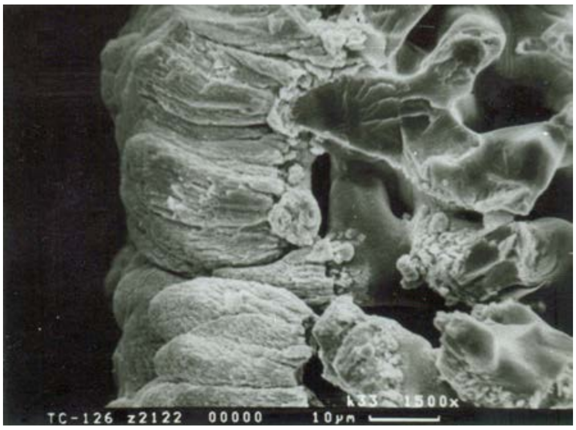


Fig.1 The structure of the PPM produced by ion-plasma sputtering method in a vacuum without a removable agent

The purpose of this work is to study the production process of ion-plasma sputtering method in a vacuum using removable agents.

2. Materials

The samples were produced in the form of disks with a diameter of 30 and a thickness of 3 mm. A study of the structure of porous materials was carried out using a high-resolution scanning electron microscope "Mira" of Tescan company (Czech Republic) (Fig. 2); the characteristics were determined by standard methods (average pore size according to GOST 26849-86, permeability coefficient in accordance with GOST 25283-93, porosity according to GOST 18898-89).

Fig. 2 A high-resolution scanning electron microscope "Mira-3" of Tescan company (Czech Republic)

Initially, a porous substrate was made from a tin-phosphorous bronze powder with particle sizes (minus 630 + 400) μm by a free-filling sintering method, then its surface pores were filled with a removable agent – NaCl powder with a grain size composition (minus 40 + 20) μm on one side of the substrate. To ensure better adhesion of the particles of the removed agent to each other and to the base material, a 5% solution of carboxymethylcellulose (CMC) in water was used as the binder. The ratio of CMC in a mixture of NaCl-CMC was 4% (volumetric). Then a copper coating with a thickness of 35 μm was applied on the side of the removable agent by the ion-plasma sputtering method in a vacuum on a vacuum plating machine ННВ-6.6-И1. Then NaCl was removed and the average pore size and permeability coefficient of the produced sample were determined. The machine for the application of vacuum functional coatings ННВ-6.6-И1 is shown in Figure 3.

Fig.3 A vacuum machine ННВ-6.6-И1 for the application of vacuum composite functional coatings

3. Results and discussions

The choice of materials of the removable agent and binder is due to the fact that the object treated by ion-plasma flows in a vacuum should give stability (resistance to decomposition, no gas evolution, etc.) at temperatures up to 200 °C. It was confirmed by the study of the behavior of the NaCl-CMC composition at different temperatures in air. The porous structure of NaCl-CMC is shown in Fig. 4.

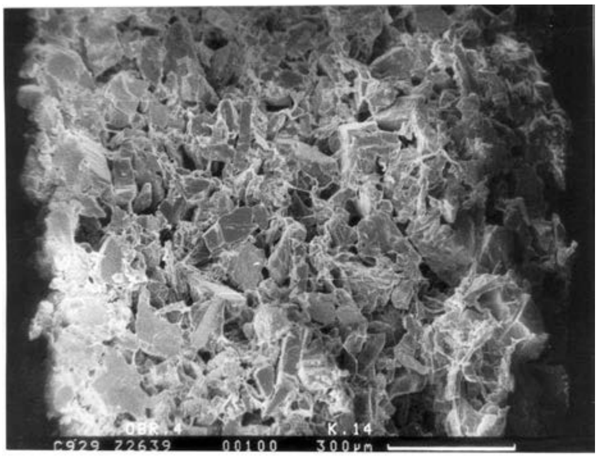


Fig. 4 The porous structure of NaCl-CMC

The main requirement for the composition of NaCl-CMC is the presence of through porosity in its structure and, accordingly, on the surface, otherwise the production of the effective two-layer PPMs by the method being developed will be problematic. Analysis of the structure of the obtained composition confirms the presence of through porosity (Fig. 4). In addition, to confirm the possibility of using the selected removable agent when a thin permeable layer was produced from the NaCl-CMC composition by the ion-plasma sputtering method in a vacuum with free-filling molding into a mold, a substrate was prepared which was coated with a thin layer of copper by means of ion-plasma sputtering and brittle fractures of the produced sample were investigated (Fig. 5-7).

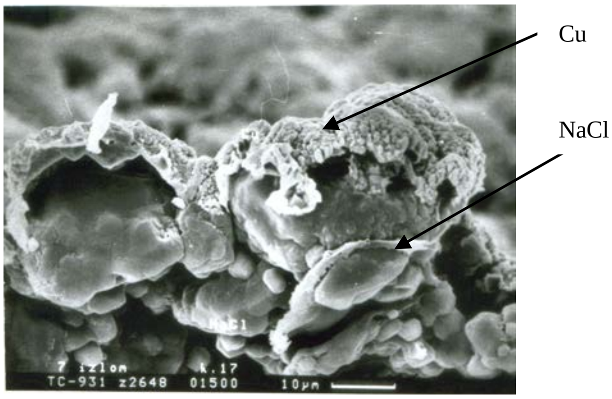
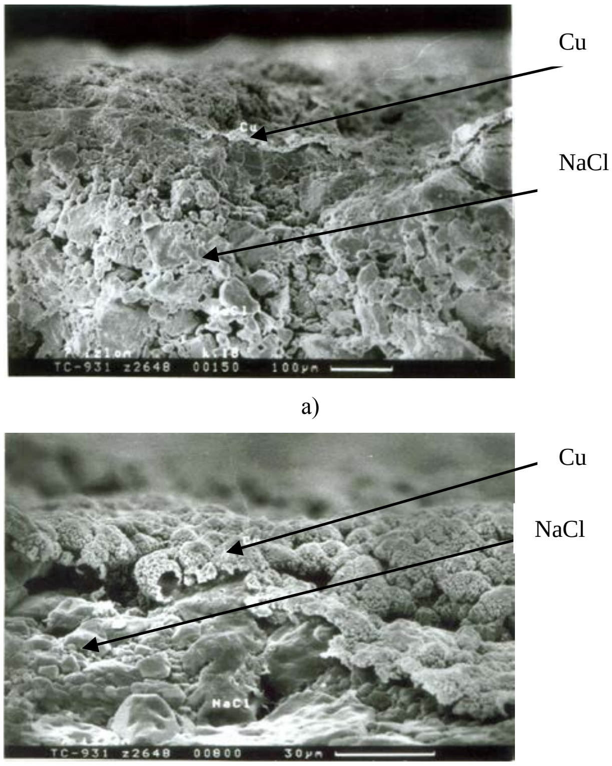


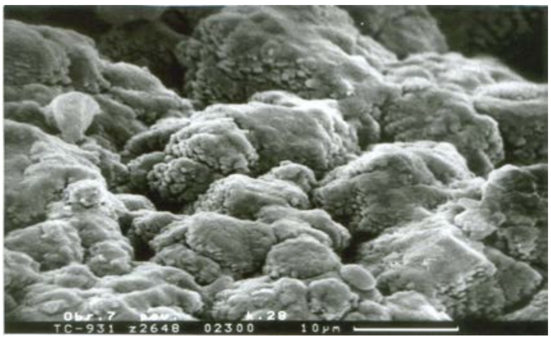
Fig. 5 The configuration of the coating on the removable agent, × 1500



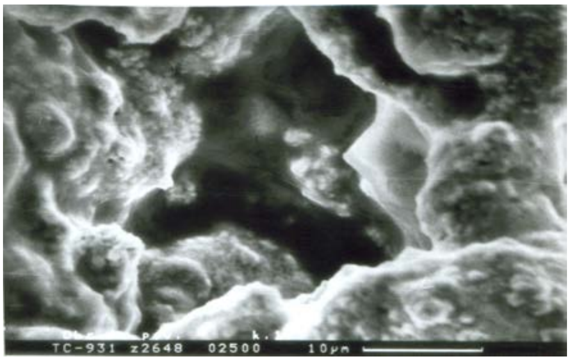
b)

Fig. 6 Copper coating on the NaCl-CMC composition at various magnifications, x: a) × 150;) × 800

Figure 5 shows the configuration of the coating of individual particles of the removable agent with the sputtered material (copper), which repeats their shape. Figure 6 illustrates the presence of a thin continuous sputtered layer of copper on the surface of the substrate at various magnifications. Figure 7 confirms the presence of open pores on the surface of the substrate.



a)



b)

Fig. 7. Pore channels on the surface of the substrate produced from the NaCl-CMC composition, after applying a layer of copper at various magnifications: a) $\times 2300$; b) $\times 2500$

Analysis of images of brittle fractures obtained by the proposed method, experimental samples of two-layer PPMs and their surface on the side of the sputtered layer (Fig. 8-13) makes it possible to define that:

a) the proposed method makes it possible to obtain a thin continuous coating on the surface of the porous substrate (Fig. 8);

b) the creation of a thin layer on the surface of the porous substrate is primarily provided by the use of a removable agent: the images of the sample surface in the cracking site at the fracture (Fig. 9) and the fracture at the sites where the removable agent was sputtered (Fig. 10) show that after removal of the removable agent, the layer sputtered on its surface remains an independent unit in the structure of a two-layer PPM, sufficiently tightly bound to the porous substrate;

c) the coating sputtered on the substrate has an open porosity (Fig. 11);

d) the particles of the sputtered layer have a good contact with the substrate particles (Fig. 12) and with each other (Fig. 13).

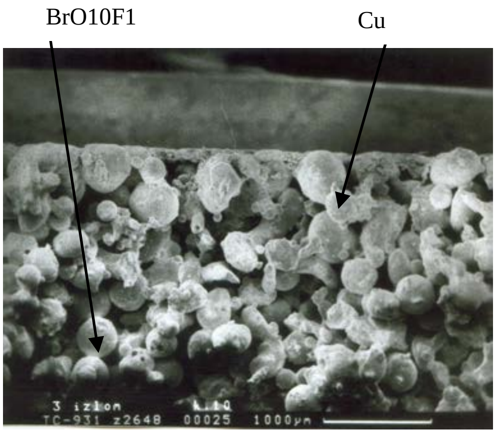


Fig. 8 Structure of a two-layer PPM, $\times 025$

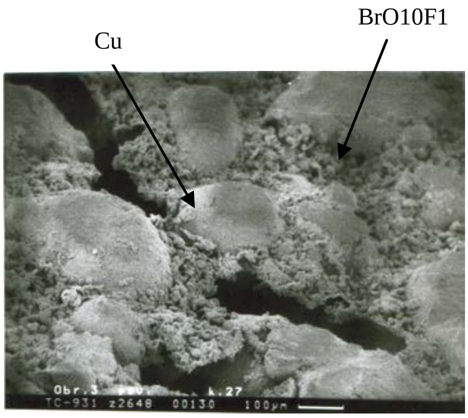
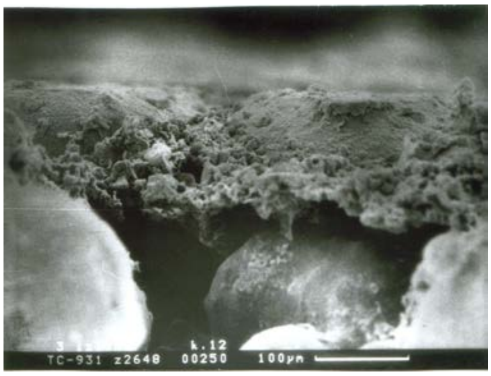


Fig. *9 Cracking at the fracture site of the experimental sample*



a)

b)

Fig. 10 Fractogram of the brittle fracture of the experimental sample in the region of the removable agent at various magnifications: a) $\times 250$; b) $\times 300$

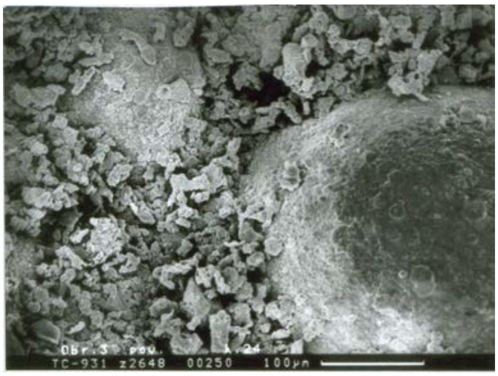


Fig. 11 Surface of the experimental sample when the thin permeable layer is applied

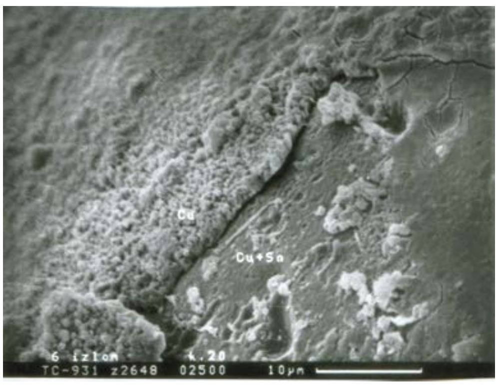


Fig. 12 The boundary line between the sputtered layer and the substrate particle at the site of brittle fracture

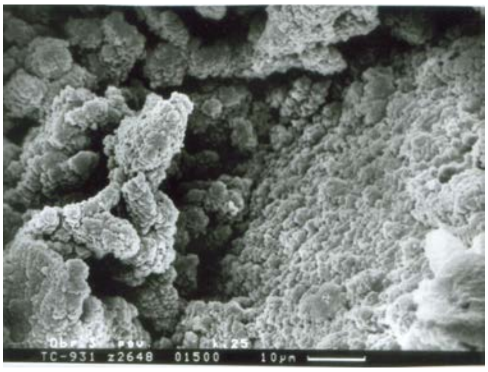


Fig. 13 The coating on the substrate particle (on the right) and on the removable agent (on the left)

The properties of the experimental samples of two-layer PPMs and also the properties of the analogue samples are given in Table 1.

Table 1 – Properties of two-layer experimental samples and analog samples

PPM Characteristics	PPM process					
	Ion-plasma sputtering in vacuum using a removable agent		Powder molding of various fractions		Ion-plasma sputtering in vacuum without a removable agents	
	The particle size of a removable agent, µm		Particle size of fine-dispersed layer, µm		The particle size of the substrate powder, µm	
	(minus 40+20)		(minus 200+ 160)	(minus 160+ 125)	(minus 630+400)	(minus 400+315)
	The particle size of the substrate powder, µm		The particle size of the substrate powder, µm			
	(minus 630+400)	(minus 400+315)	(minus 630+400)	(minus 400+315)		
Porosity, P, %	42	41	40	38	43	41
$d_{\text{п макс}}$, µm	63	49	60	42	220	140
$d_{\text{п ср}}$, µm	38	27	38	27	170	120
k, m^2, $\times 10^{13}$	364	350	197	172	1400	900

Analysis of the experimental data presented in the table enables to state that ion-plasma sputtering in a vacuum with the removable agents makes it possible to produce two-layer PPMs with an increased complex of properties: the permeability coefficient at the specified average pore size of such materials can reach values by 1.85-2, 0 times higher in comparison with two-layer PPMs, produced by the method of powder molding of different fractions.

4. Conclusion

The process of applying of ion-plasma coatings on porous substrates using a removable agent was studied. It has been experimentally confirmed that the proposed method makes it possible to produce a thin continuous coating on the surface of the porous substrate. The formation of a thin layer on the surface of the porous substrate is primarily provided by the use of the removable agent. After its removal the sputtered layer remains an independent unit in the structure of the two-layer PPM, sufficiently tightly bound to the porous substrate. The coating sputtered on the substrate has an open porosity. The particles of the sputtered layer have good contact with the substrate particles and with each other.

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