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A porous materials production with an electric discharge sintering

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ABSTRACT

A short review of a porous materials production from the powders of titanium, niobium and tantalum with a high-voltage discharge current is presented. The experimental dependences of bending strength, porosity, specific electrical resistance, radial and axial shrinkage from the sizes of particles of the examined powders and from the parameters of the electric discharge are given. The maximum correlations of the diameters and the length of the experimental samples of porous powders are stated. The examples of perspective applications of produced porous materials in the manufactured articles of electronics and medicine are shown.

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1. Introduction

A direct electric current passing through the powder is the most simple and economical method of producing powder materials. The first patent on using a direct electric current to heat the powder of the hard alloy during hot pressing was obtained in 1933 [1]. In 1944 for the first time the use of alternating current of industrial frequency with a mechanical pressure sintering powders of copper, brass, bronze and aluminum was proposed [2]. In 1955 for the first time the use of equipment for spot welding capacitor powders by sintering under external pressure was described [3]. A wide range of the electrical parameters of the impact on the powder causes a large number of these methods collectively called «an electric current sintering» [4]. The existing methods for the direct influence of the electric current have a number of features allowing them to be used successfully for powder materials of different densities. Common to all of these methods is that the consolidation of the particles takes place in a closed matrix compression molding and discharges DC or a pulsed electric current generating heat passing through the powder. As a result of the electric current effect, there is an intensive mass transfer in the solid phase at the contact areas between the neighboring particles of the powder. Furthermore, the surface of the powder particles in the contact zone can be melted which is accompanied by a more intensive mass transfer. The result is a rapid consolidation of the particles throughout the volume of the powder. Depending on the magnitude of the compacting pressure and the range of values of the electrical parameters (the nature, the amplitude and the duration of the flow of the electric current), the consolidation process may proceed in different ways. This widely varies the structure and properties of the resulting powder materials. Methods of consolidating the powder with an electric current can in many cases dispense with the usage of protective gas or vacuum, and combine molding and sintering of powder performs in a single operation.

One of the significant trends of the powder metallurgy is a porous material production, the efficiency and the field of application of which are defined by their pore structure capable of passing liquids and gases through itself [5].

The most propagation is due to the application of porous materials as filters used for the separation of gases and liquids from foreign admixtures, for the transportation of liquids in pore channels under the effect of capillary forces in capillary pumps, heat pipes wicks, evaporators, condensers, as fire blocks and noise suppressers and in many other cases.

The porous materials are produced from the powders of metals, oxide and nitride ceramics, glasses, polymers and other materials. Each of these materials has a unique set of characteristics and properties and can be used in different fields of engineering. The porous materials produced from the powders of refractory metals – titanium, niobium, tantalum, molybdenum, tungsten and their alloys – have the unique properties of refractoriness, hardness, corrosive stableness, wear resistance and many specific characteristics.

The production of porous materials from the refractory metal powders includes some traditional technological operations of the powder metallurgy: a preparation of the initial powder including dissemination and mixing with pore-forming substances; a forming of intermediates as a rule, under pressure applied; a sintering and an additional

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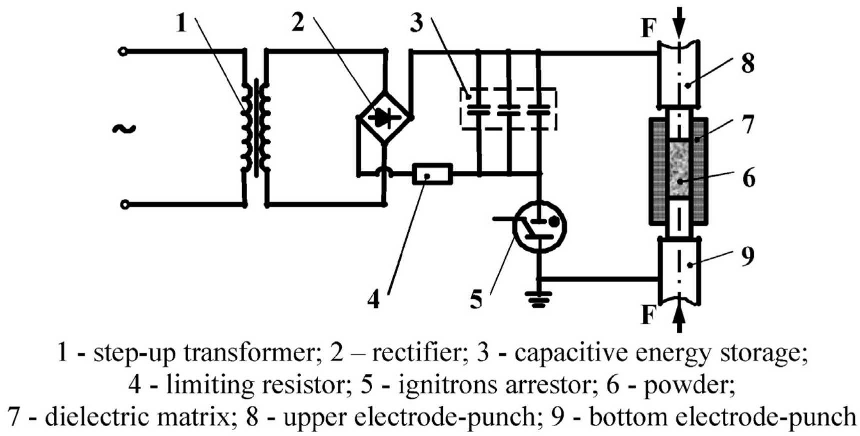

Fig. 1. A scheme of the experimental setup 1 — step-up transformer; 2 — rectifier; 3 — capacitive energy storage; 4 — limiting resistor; 5 — ignitrons arrestor; 6 — powder; 7 — dielectric matrix; 8 — upper electrode-punch; 9 — bottom electrode-punch.

Table 1
Technical characteristics of the unit “Impulse-BM”.

The name of the characteristic	The value
A maximum energy of the accumulator, kJ	32
A maximum capacity of the accumulator, μF	1800
A range of voltage, kV	1…5.9
A maximum intrinsic frequency of a discharge, kHz	20
A maximum effort of pressing, kN	5

processing of sintered intermediates (under pressure, mechanical, chemical-thermal processing and others) [6,7].

As for the powders of refractory metals especially with a spherical shape of particles it is typical to have a low compression rate and formability, the inclination to exfoliation during compression. The external surface of compressing has a closed porosity due to a friction against the walls of a press-form. The addition of pore-forming and connecting substances brings foreign admixtures and significantly complicates a technological process of the porous material production. Thus, a development of technologies considering and excluding the above mentioned limitations is very urgent.

The production of porous materials with an electric discharge sintering from the powders of refractory metals is considered as very perspective for the development of such technologies. An electric discharge sintering (EDS) is one of the electric current sintering methods. The investigations of the possibility of using the powerful current pulses arising from the discharge of a high-voltage capacitor for powder sintering for the first time began in the late 1970s and in early 1980s [8,9]. The EDS essentially differs from the other methods of consolidating the direct influence of the electric current with a more powerful heat over a shorter time interval (10^{-4} - 10^{-3} s). The EDS major advantage is the achievement of very high temperatures (10^3–10^4 K) of contacts between the powder particles while maintaining low temperatures within the particles themselves [10]. An important feature of EDS is a manifestation of the pinch effect [11], which occurs when the powder is passed through high-current transient electrical discharges. The resulting radial force from its own electromagnetic field reduces the size of the resulting product (shrinkage) in the direction perpendicular to the transmitted current. The theoretical aspects of a contact formation at EDS and the assessment resulting from the pinch effect of the radial pressure are considered in detail in the papers [12,13].

Table 2
Characteristics of the starting powders.

Powder	Particle size, μm	Pycnometric density, kg/m^3	The specific surface area, m^2/kg	Micro-hardness, MPa	Bulk density, kg/m^3	Tap density, kg/m^3	Form factor, FF	Fluidity, s
Titan	160–200	4490	8.14	206.2	2710	2920	0.98	27
	315–400	4510	4.91	181.4	2670	2820	0.96	32
Niobium	40–63	8570	25.0	167.2	3700	3920	0.60	23
	10–63	8570	42.5	155.2	3510	3704	0.60	21
	10–40	8570	55.5	127.6	3010	3175	0.65	20
Tantalum	5–40	16,600	45.3	184.4	7520	7730	0.65	22
	3–30	16,600	70.0	210.7	6840	7080	0.63	24

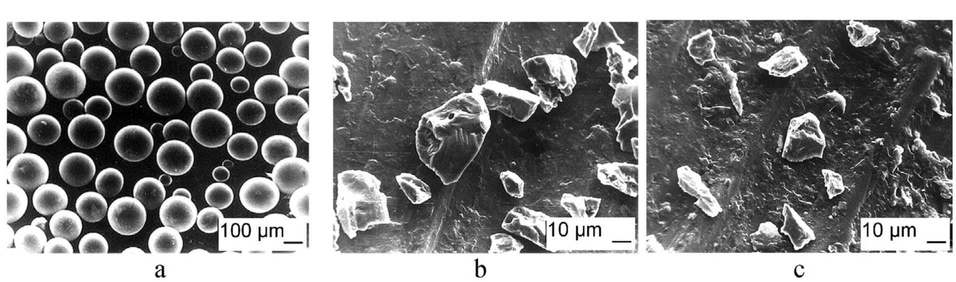

Fig. 2. Topogramms of powder particles: a — titanium, b — niobium, c — tantalum.

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