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Production of Copper Electroerosion Nanopowders from Wastes in Kerosene Medium

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This article describes the parameters of copper powder materials production from wastes of electrical copper wire using electroerosion dispersion method in kerosene medium. The results of the percentage of the different fractions of the produced copper powder and the study of the shapes of the resulted copper particles are presented.

Keywords: Copper wastes, Electroerosion dispersion, Copper nanopowder, Parameters of powdering of electroerosion dispersion process, Particle-size distribution of copper powder, Copper powder particle shape.

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1. INTRODUCTION

Currently, copper nanopowders are widely used as additives for manufacturing components by powder metallurgy and other purposes, mainly in electrical, instrument-making, machine-building, chemical and aviation industries, as well as in nanotechnology [1].

Nowadays, there are many methods allowing manufacturing ultradispersed powders from metals. Among the variety of these methods it is particularly important to find relatively simple, cost-effective and environmentally friendly processes for the synthesis of ultradispersed materials. In recent years, the chosen method of electroerosion dispersion is becoming one of the most promising. This method allows manufacturing powder from almost any current-conducting metal [2].

However, the widespread use of the method of electroerosion dispersion is hindered by the lack of literature reference material on the optimization of the parameters of powdering and resulting copper powders properties. For the widespread use of this method extensive theoretical and experimental studies are required.

Therefore, the goal of this research is to study the parameters of powdering of the process of production of copper powder materials by electroerosion dispersion from electrical copper wire wastes in kerosene medium and the study of the particle size distribution and the shape of the copper powder particles.

2. MATERIALLY AND METHODS

The process of copper powders production is carried out on the unit for producing nanopowders from current-conducting materials (Patent 2449859, Russian Federation, C2, B22F9/14). This unit comprises electroerosion dispersion reactor for current-conducting materials put into it, the voltage regulator and the pulse generator [3].

For copper powder production by electroerosion dispersion copper wire wastes were used. The wire was put into the reactor filled with kerosene as working liquid; the process was carried out by varying the electrical parameters: the electrodes voltage, the frequency of the pulse generator and the capacitance of the discharge capacitors. The destruction of the copper wire occurred as a result of the local impact of the short-duration electrical discharges between the electrodes.

3. EXPERIMENTAL RESULTS AND DISCATIONS

When producing powders by electroerosion dispersion the main controlled parameters of powdering process are the average powder particles size (particle size distribution), the productivity of the process and the chemical composition of the powder. The first two parameters can be changed within a wide range (changing the electrical parameters of the process), whereas the chemical composition of the powder depends on the initial chemical composition of the dispersible material and the chemical composition of the used working liquid [4].

The production rate of the electroerosion dispersion process can be divided into weight output and quantitative outcome. Weight output is expressed by the weight of the powder produced per time unit, and depends on the average weight of the powder particles (which in turn depends on the average size of the powder particles) and their quantity. Quantitative outcome is also expressed by the weight / mass of the powder produced per time unit, but depends only on the powder particle count, i.e. weight output can be increased by increasing the average powder particle size and increasing the resulted powder particle count; and quantitative outcome can be increased only by increasing the resulted powder particle count. It is obviously the quantitative outcome that is important when producing powders with a given size of particles [4].

Figure 1 shows the graph of dependence of the weight of the resulted copper powder produced in the kerosene medium on the pulse generator operating frequency when the voltage across the electrodes of the reactor $U = 220$ V and the capacitance of the discharge capacitors $C = 45.5$ μF.

Experiment proved that there is directly proportional dependence of the weight of copper powder on the time between pulses in the range of up to 100 Hz. Further increase of frequency decreases the powdering. It is obvious that by means of increasing the pulse generator operating frequency it is possible to increase the quantitative outcome of electroerosion dispersion process, but this increase is limited by the time of charge and discharge of discharge capacitors and the speed of charging and discharging thyristor switches.

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Pulse energy can be changed either by changing the capacitance of the discharge capacitors, or by changing the reactor electrodes voltage.

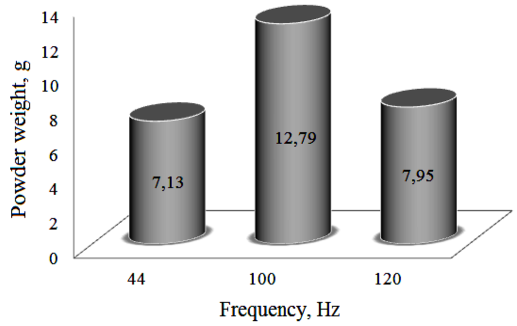
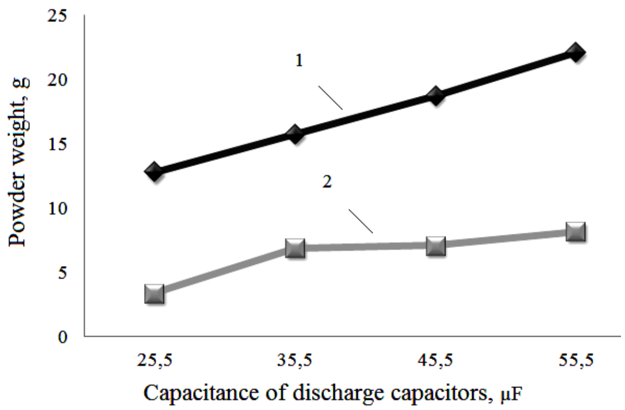


Fig. 1 – The dependence of the weight of the resulted copper powder on the operating frequency of the electroerosion dispersion unit ($U = 220$, $C = 45.5$ μF)

Figure 2 shows the relationship between the productivity of the process of powder production and the capacitance of the discharge capacitors. Experiment proved that there is directly proportional dependence of the weight of resulted copper powder on the capacitance of the discharge capacitors at different values of the time between pulses.

Figure 3 shows the graphs of the dependence of the productivity of the process of powder production on the reactor electrodes voltage of the electroerosion dispersion unit. Experiment the proved the dependence of the weight of the resulting powder on the electrodes voltage.



1 – ν = 100 Hz; 2 – ν = 44 Hz

Fig 2 – The dependence of the weight of the resulted copper powder on the capacitance of discharge capacitors ($U = 220$ V)

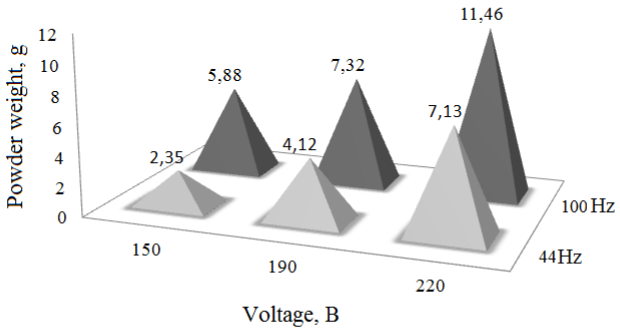


Fig. 3 – The dependence of the weight of the resulted copper powder on the reactor electrodes voltage ($C = 45.5$ μF)

Table 1 – The results of the study of the percentage of different fractions of copper powder

№	Particlesize		Contentof a fraction, %	№	Particlesize		Contentof a fraction, %
	x Low [μm]	x High [μm]			x Low [μm]	x High [μm]	
1	0,1	0,109	0,02	40	3,42	3,74	0,72
2	0,109	0,12	0	41	3,74	4,08	0,69
3	0,12	0,131	0	42	4,08	4,48	0,71
4	0,131	0,144	0	43	4,48	4,9	0,77
5	0,144	0,157	0,01	44	4,9	5,36	0,91
6	0,157	0,172	0,03	45	5,36	5,88	1,1
7	0,172	0,188	0,05	46	5,88	6,42	1,35
8	0,188	0,206	0,09	47	6,42	7,04	1,65
9	0,206	0,226	0,13	48	7,04	7,7	1,98
10	0,226	0,248	0,18	49	7,7	8,44	2,31
11	0,248	0,27	0,23	50	8,44	9,24	2,6
12	0,27	0,296	0,28	51	9,24	10,1	2,8
13	0,296	0,324	0,34	52	10,1	11,06	2,85
14	0,324	0,356	0,39	53	11,06	12,12	2,71
15	0,356	0,388	0,44	54	12,12	13,26	2,35
16	0,388	0,426	0,48	55	13,26	14,52	1,81
17	0,426	0,466	0,5	56	14,52	15,9	1,18
18	0,466	0,51	0,52	57	15,9	17,4	0,64
19	0,51	0,558	0,53	58	17,4	19,04	0,37
20	0,558	0,612	0,53	59	19,04	20,8	0,55
21	0,612	0,67	0,52	60	20,8	22,8	1,27
22	0,67	0,732	0,5	61	22,8	25	2,46
23	0,732	0,802	0,48	62	25	27,4	3,92
24	0,802	0,878	0,47	63	27,4	30	5,31
25	0,878	0,96	0,46	64	30	32,8	6,28

26	0,96	1,052	0,46	65	32,8	35,8	6,58
27	1,052	1,152	0,47	66	35,8	39,2	6,21
28	1,152	1,26	0,51	67	39,2	43	5,34
29	1,26	1,38	0,56	68	43	47	4,29
30	1,38	1,51	0,63	69	47	51,6	3,31
31	1,51	1,654	0,7	70	51,6	56,4	2,52
32	1,654	1,81	0,78	71	56,4	61,8	1,92
33	1,81	1,982	0,85	72	61,8	67,6	1,41
34	1,982	2,18	0,89	73	67,6	74	0,95
35	2,18	2,38	0,92	74	74	81	0,55
36	2,38	2,6	0,91	75	81	88,8	0,24
37	2,6	2,84	0,88	76	88,8	97,2	0,07
38	2,84	3,12	0,83	77	97,2	106,4	0,01
39	3,12	3,42	0,77	78	106,4	116,4	0

Figure 3 shows the graphs of the dependence of the productivity of the process of powder production on the pulse energy of the electroerosion dispersion unit. These graphs were obtained both changing the capacitance of the discharge capacitors at constant reactor electrodes voltage and changing the electrode voltage at permanent capacitance.

Having analyzed the obtained relationships, it is possible to conclude that the weight of the resulted copper powder is directly proportional to the pulse energy (the energy of capacitors discharge). This explains the quadratic dependence of the weight of the resulted copper powder on the voltage and the linear dependence of the weight of the resulted copper powder on capacitors capacity.

Thus, it can be noted that, on the other conditions being equal, weight output of the electroerosion dispersion process can be controlled by changing the capacitance of discharge capacitors and the source voltage of the electroerosion dispersion unit, and the quantitative outcome of the process can be controlled by changing the operating frequency of the electroerosion dispersion unit.

It is known that depending on the powder particle size and their shape the properties of the resulting powder and the properties of the powder-based material will change. Therefore, the resulting powder was evaporated and the distribution of the resulting particles was analyzed according to the size using a laser particle size analyzer "Analysette 22 NanoTec", because laser diffraction has several important advantages, such as short analysis time, good reproducibility and accuracy, simple calibration, large measurement range and high flexibility.

The results of particle size measurements are presented in Table 1. It has been found that the average particle size is 23.65 μm. The fractions of the powder in the range up to 960 nm are highlighted. The content of nanofractions in the analyzed copper powder is 7.18 %.

To study the shapes of the resulted copper particles micrographs were made using scanning electron microscope "QUANTA 600 FEG" (Fig. 4). It has been found that the powder produced by the electroerosion dispersion method from copper wastes mainly consists of the particles of regular spherical shape (or elliptical) with inclusions of the particles of irregular (conglomerates) and fragmentation shapes.

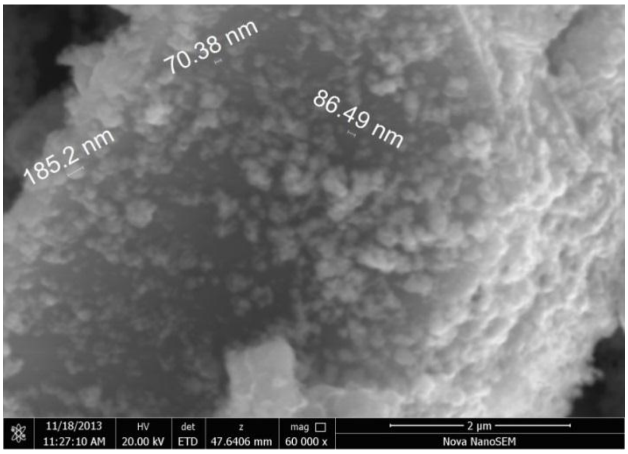


Fig. 4 – Themicrography of the particles of copper electroerosion powder

Based on the obtained results it can be said that the copper powders produced using electroerosion dispersion can be used for waste processing into nanopowders at low costs and without adverse effects on the environment.

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