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RESEARCH OF THE PROPERTIES OF CARBON NANOMATERIALS OBTAINED BY ELECTRIC ARC METHOD

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Keywords: carbon, nanotechnology, arc discharge, nanomaterial, graphene.

Introduction. Carbon is one of the most common elements and continues to amaze with its variety of forms. It is the basis for living nature, fossils and millions of organic compounds. Carbon has a unique variety of compounds, incomparable to other elements of the Periodic Table. Even in the form of a simple substance, carbon is the leader in the variety of forms. The emergence of graphene is a striking example of this diversity, which has given new impetus to nanotechnology [1,2].

Graphene is a nanoscale two-dimensional crystalline nanostructure consisting of carbon particles arranged in a hexagonal or honeycomb lattice. It is accepted as a basic building block for other forms of carbon such as fullerenes, carbon nanotubes and graphite layers. It was previously thought that such a material could not exist due to its thermodynamic instability, but in 2004 Andre Geim and Kostya Novoselov [3,4] were able to extract graphene from graphite using ordinary adhesive tape. Their discovery led to an explosion in graphene research due to its amazing properties. For this work they were awarded the Nobel Prize in Physics in 2010, and since then interest in graphene has been growing rapidly, which is reflected in an increase in publications on this topic [5-7].

The purpose of this work is the synthesis of carbon graphene-like nanomaterials using the electric arc discharge method from coal and the study of their physicochemical and electrophysical properties.

Experimental part. In the proposed method for producing graphene and graphene- containing materials includes the following stages: preparation of raw materials, inflation and filling of the reactor with inert gas, arc discharge at 100 A, 75 V, collection of the product.

In this study, graphene-containing nanomaterials were synthesized from activated carbon obtained from coal from the Shubarkol deposits, grade D, by carbonization and activation. The resulting carbon material has the following characteristics (%):*Wr*–1.10;*Ad*– 10.17;*Vdaf*–8.59.

The essence of the method is the thermal spraying of a carbon electrode in the plasma of an arc discharge burning in an inert gas atmosphere. To obtain graphene, the process of electric arc discharge of Shubarkol activated carbon was carried out in an inert atmosphere of nitrogen; the current strength at a constant voltage of 75 V was 100 A in a quartz reactor.

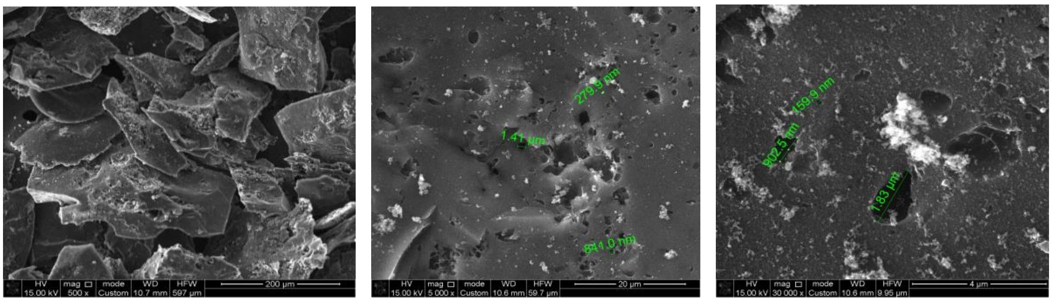
The study of the structure and dimension of carbon nanomaterials was carried out using energy-dispersive X-ray spectroscopy on a device *SEM (Quanta 3D 200i)*with attachment for energy dispersive analysis from *EDAX*.

The type of carbon modification was studied using Raman spectroscopy using the Raman scattering (RS) method. Raman spectra of samples were recorded using a scanning probe microscope*Integra Spectra*, using a laser with a radiation wavelength of 473 nm.

Determination of electrophysical characteristics (dielectric constantε, electrical resistance*R*) were carried out by measuring electrical capacity samples on a serial device *LCR-800* (meter*L*,*C*,*R*) at an operating frequency of 1 kHz with a base error of

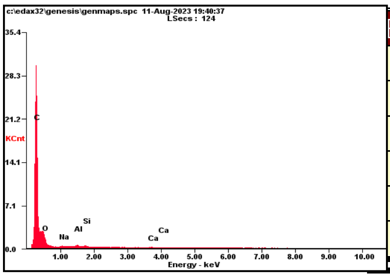
0.05-0.1% continuously, in dry air, in thermostatic mode with a holding time of 3 minutes at each fixed temperature.

Results. Scanning electron microscope analysis results. The carbon material formed in the reactor showed the formation of flocculent carbon particles, possibly graphene-like materials(Fig. 1).



a) b) c)

Figure 1 SEM image of samples obtained by electric arc method discharge:
(a) x500; (b) x5000; (c) 30000 A



Element	Wt%	At%
C	87.21	90.40
O	11.75	9.15
Na	0.25	0.13
Al	0.36	0.16
Si	0.19	0.08
Ca	0.25	0.08

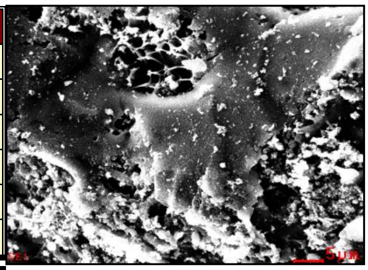
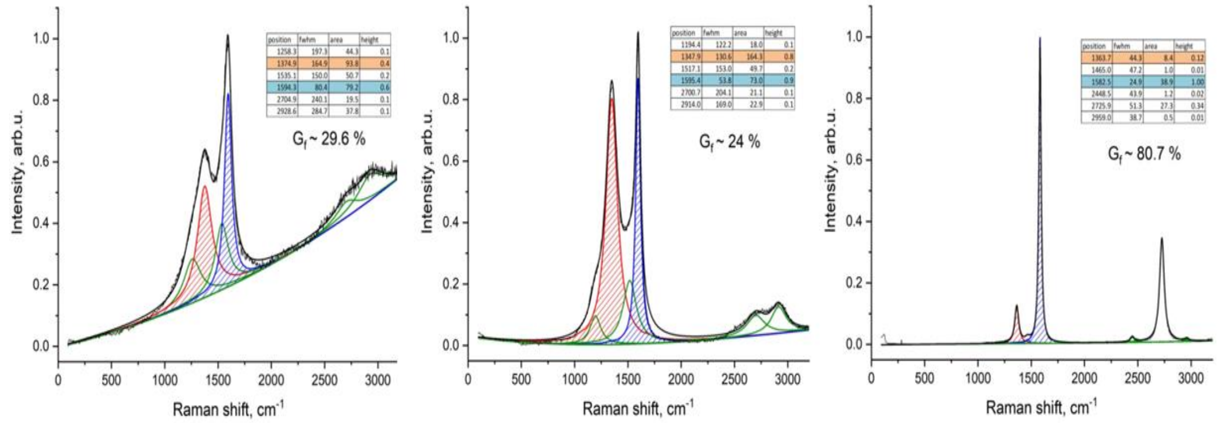


Figure 2 Elemental composition of carbon material formed in the reactor

The elemental composition of the porous carbon material after electric arc processing is: carbon, oxygen, sodium, aluminum, silicon and calcium.

The Raman spectrum of the original Shubarkol coal shows a signal with characteristic peaks D and G (1374.9 and 1594.3 cm-1). The D band is a disordered band associated with structural defects and amorphous carbon, while the G band corresponds to in-plane coupling of sp2 carbon atoms. The broad D-band peak indicates that the sample contains a relatively large amount of disordered structure and defects. The degree of graphitization is Gf=29.6% . According to the ratios I(D)/I(G)=0.67; I(G)/I(D)=1.5; I(G)/I(2D)=6; I(2D)/I(G)=0.17, we can say that there is no graphene and the original coal has different degrees of defectiveness, which indicates the quality of the material. After the activation process of Shubarkol coal, the degree of graphitization decreased to Gf=24%, but at the same time the peaks are 1363.7 cm-1(D); 1582.5 cm-1(G); 2725.9 cm-1(2D); increased their intensity and based on the proportions I(D)/I(G)=0.89; It can be argued that the absence of graphene and activated carbon have a high degree of defectiveness due to the appearance of meso- and macropores.

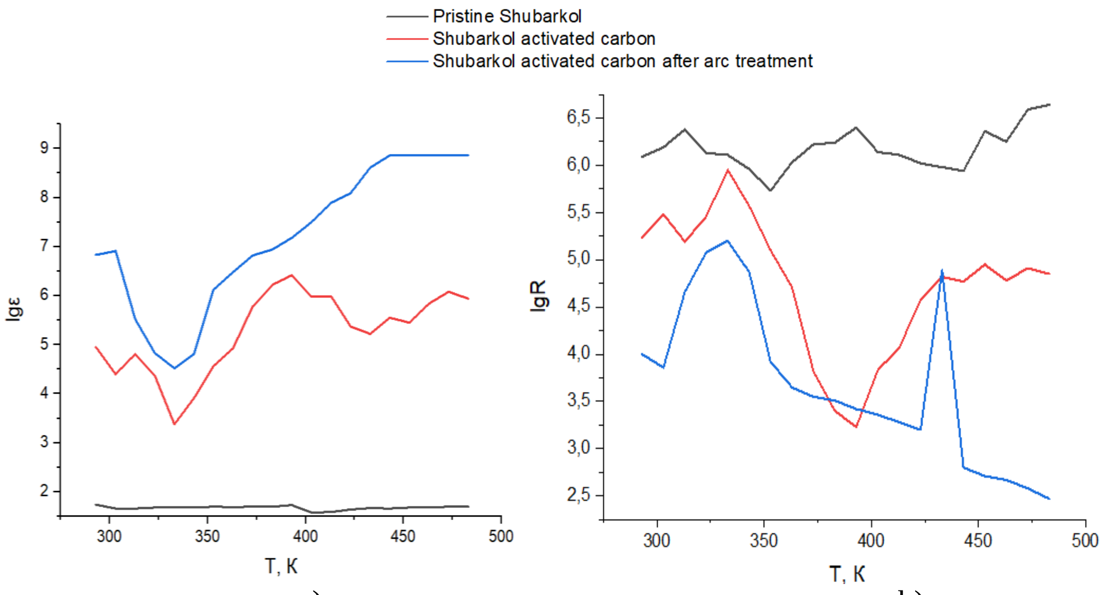
Analysis of the Raman spectrum of the grown graphene layer "Shubarkol" after an arc discharge showed that wider peaks with centers around 1363.7 cm are visible in the spectrum-1(D) and 1582.5 cm-1, caused by graphene (ordered carbon sp2), respectively, and a relatively low and wide peak centered around 2725.9 cm-1, corresponding to the 2D peak. After arc treatment, the Raman spectra show a high degree of graphitization Gf =80.7% and the spectra are similar to the peaks of pure graphene. According to the ratios of these peaks, I(D)/I(G) = 0.12; I(G)/I(D)=8.33; I(G)/I(2D)=2.94; I(2D)/I(G) = 0.34 it is clear that the resulting materials are of high quality and ordered; in the same way, by proportions we can say that after an arc discharge, multilayer graphene was obtained on the walls of the reactor.



a) b) c)

Figure 3 Raman spectra: a-pristine Shubarkol coal, b-Shubarkol activated carbon, c-Shubarkol activated carbon after arc treatment

By permeability and electrical resistance, the original coal does not have semiconductor properties, its dielectric constant remains very low over the entire range of temperatures under study, therefore, from an electrical physical point of view, this material is not of interest. Activated carbon "Shubarkol" has mainly average material values. The maximum value of electrical conductivity is achieved at a temperature of 393 K and is 2.62x106at 1 kHz. A study of the dependence of electrical resistance on temperature shows that in the range from 293 to 333 K the material has variable conductivity, from 333 to 393 K - semiconductor, from 393 to 453 K - metallic, and from 453 to 483 K - again variable conductivity. After an arc discharge, the material has very high electrical permeability. As shown in Fig. 4 there is a noticeable improvement in the electrical properties. The maximum value of electrical permeability reaches 7.20-108and more at 1 kHz at a temperature of 433-483K and in the same range the material has semiconductor properties. A study of the effect of temperature on the electrical resistance of a material shows that in the range from 293 to 333 K it changes in a variable manner, and when the temperature rises to 333-423 K and again to 433-483 K, semiconductor conductivity appears.



a) b)

Figure 4 Dependence of dielectric constant (a) and electrical resistance (b) on temperature at a frequency of 1 kHz

Electrical resistance after an arc discharge shows the lowest value compared to the original ones. Based on the electrical data of Shubarkol coal, activation energies were calculated in activated carbon and after arc treatment. Shubarkol activated at a temperature of 333-393 K and 1 kHz imparts activation energy E_{act}=123.26 kJ/mol, and after the arc discharge this figure dropped to E_{act}=55.54 kJ/mol at a temperature of 323-423 K.

Conclusions. Based on Raman spectroscopy data and electrical properties (dielectric constant and electrical resistance), it was shown that the synthesized products have a high degree of graphitization and long-range structural order (2D peak), which indicates the formation of graphene-containing nanomaterials. These results provide a possible route for low-cost mass production of high-quality graphene samples. Electrical resistance (R), electrical capacity (C) and dielectric constant (ε), electrical resistivity (R) graphene-containing materials in the temperature range 293−483 K. After arc treatment, the activation energy decreased, which demonstrates an increase in electrical properties. As a result, we obtained high-quality carbon nanomaterials similar to graphene and with high electrical conductivity properties.

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INFLUENCE OF HYDRODYNAMIC REGIME OF FLOTATION CHARACTERISTICS ON TITANIUM-CONTAINING ORE

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Flotation, as a mineral processing method, is used to separate and concentrate ores by altering the surfaces of minerals to a hydrophobic or hydrophilic condition. That is, the surface is either repelled or attracted towards water. The flotation process was developed commercially early in the 20th century in order to remove very fine mineral particles which had previously gone to waste in gravity separation plants. Flotation has now become the most commonly used process for extracting various minerals from their ore sources. Many studies have suggested selective collectors for flotation, with sodium oleate being one of the more reliable candidates due to its ease of availability and lower cost when compared to other anionic fatty acid collectors.

Ilmenite, the primary titanium source vital for various industries, undergoes crucial processing through flotation. This review aims to systematize technological advancements in ilmenite upgrading. Understanding the fundamental properties of ilmenite and its metallogenic mechanisms is pivotal in selecting beneficiation strategies. Over time, flotation has become indispensable in ilmenite upgrading, with numerous collector types developed for different pH ranges. Surface modification methods have emerged as a prominent research area. Future endeavors should focus on enhancing the floatability of fine ilmenite and effectively recycling historic ilmenite-containing tailings.[6]

The experimental part. To enrich the source ore, a laboratory chamber-type flotation machine with mechanical stirring is used. Ilmenite ore was collected from the Satpayev deposit in the East Kazakhstan region of the Republic of Kazakhstan from 2020 to 2021.

Reagents: sodium oleate, sulfuric acid, foaming agent T-92.

Methodology. The prepared bulk of the enriched ore is placed in the mixing compartment of the flotation chamber and water is poured with a measuring cylinder, fixing the volume. The level of the resulting pulp should be slightly higher than the dividing wall of the chamber.

Then the appropriate reagents are added in the following sequence: pH regulators, collectors, foaming agents. When adding reagents, the agitator and the air supply are switched on each time. After processing the pulp with flotation reagents, the foam pen is turned on using the handle. It is taken to an upright position and at the same time the time of the beginning of flotation is fixed by a stopwatch.

Foam with concentrate is collected by a foam pad into a glass mounted on a table. Foam is removed every 3 minutes into separate glasses so that the progress of the process can be analyzed over time. The duration of the flotation is 9 minutes. The resulting concentrate fractions are filtered under vacuum on a Buchner funnel, dried at a temperature of 100-105 ° C and weighed on a technical scale.

At the end of the work, the foam and mixing are turned off, and the flotation chamber is freed from the “tails”. To do this, move the table to the side by turning the locking screw in one turn, and