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## Influence of addition of exommodified carbon nanospheres on the structuration in ethanol motor fuels

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*The work is devoted to elucidation of a general mechanism of action of exommodified carbon nanospheres (CNOs – Brn nanoions) on different physicochemical and chemotological properties of ethanol motor fuels. The formation of supramolecular solvate groups in organic media is explained by the participation of different forces of intermolecular interaction, the main of which are polarization and orientation, as well as donor-acceptor forces of interaction of nanospheres with the environment.*

*The concept of creation in an organic medium of solvation formations - domains, the size of which, determined by the method of photon correlation laser spectroscopy, varies from 21 to 1000 nm, depending on the chemical nature of the solvent - is proposed and substantiated. For ethanol, the size of such formations was ~ 400 nm, which significantly exceeds the size of individual particles of the additive. It is established that to improve the operational characteristics of ethanol fuel it is enough to introduce low concentrations ( $10^{-3}$  -  $10^{-2}$  %, wt.) of synthesized brominated nanoparticles.*

*It is shown that the change of the microheterogeneous structure of fuels affects the change of its physicochemical and operational characteristics: the dielectric constant and hydrophobicity of the medium decrease, the saturated vapor pressure increases, which improves the starting properties of the fuel; hydrophobization of the environment helps to reduce the corrosive properties of ethanol fuel per unit, as a result of which additional introduction of a corrosion inhibitor is not required; the bearing capacity of the fuel in the presence of brominated nanoparticles increases by 1.5 times compared to the base fuel with a corresponding decrease in damage to the metal surface of the friction pairs.*

*It is the rearrangement of the secondary supramolecular structure of fuels in the presence of brominated carbon nanospheres that explains the multifunctionality of their influence on the physicochemical and chemotological properties of ethanol motor fuels.*

**Keywords:** ethanol fuel, carbon nanoscale spheroidal clusters; physico-chemical, performance and ecological properties of the fuel.

### Introduction

In recent decades, ethanol fuels with an ethanol content of 75–85 % have become widespread in the world. Their advantages, in addition to environmental friendliness, are high anti-knock properties, ease of disposal in contact with soil or water. In addition, the use of alternative ethanol fuels helps to reduce the consumption of petroleum gasoline. The availability of different raw materials for ethanol production in Ukraine makes it possible to consider high-ethanol fuels as promising substitutes for petroleum gasoline. Until recently, blended alcohol-based fuels were not competitors to pure petroleum motor fuels due to a number of shortcomings, including unsatisfactory starting, anti-corrosion, lubricating properties, as well as reduced calorific value, which lead to increased fuel consumption. Overcoming these shortcomings and creating a fuel that meets the requirements of modern standards is an urgent scientific and applied task.

As we found [1-3], the chemotological properties of liquid motor fuels can be significantly changed by adding carbon nanospheres, which are effective at concentrations of 0.01–0.001 %, wt. - 10-100 times lower than the concentration of marketable additives of traditional action.

To date, no final explanation has been found for the experimental fact of improving the wear, starting and corrosion properties of fuels and fuel mixtures in the presence of nanosized additives. For the most part, the effect of such additives on the anti-wear properties of fuels and lubricants is explained by changes in the mechanical properties of hard metal contact surfaces due to their chemical interaction with additive molecules and the creation of the so-called intermediate (third) phase [4-6]. In liquid fuels, nanocarbon additives have a multifunctional effect and, unlike commercial additives, do not increase, but, on the contrary, significantly reduce the content of toxic substances in the emissions of engines during combustion. This paper is devoted to

elucidating the reasons for the multifunctional action of exommodified carbon nanospheres on the properties of ethanol motor fuels.

### Materials and Methods

Carbon nanospheres of the fulleroid type - nano onions (CNOs) [7] - were obtained by using high-frequency discharge-pulse method [8] on the installation of plasma chemical synthesis at an output voltage of 4 kV in the frequency range of 20 - 25 kHz using electrodes made of pure tungsten and propane-butane mixture as a raw material.

Increasing the solubility of the synthesized carbon nanostructures in organic solvents was achieved by bromination in the presence of excess liquid bromine. Selection of brominated nano onions from the synthesis products was carried out by extraction with organic solvents followed by drying.

The electrical capacity of the capacitor with ethanolic solutions of brominated carbon nanospheres between the covers (distance 1 cm) was measured using an AC bridge under the following conditions: generator frequency 1000 Hz, electrical resistance in stores 500 Ohm, store capacity  $C_0 = 0$ , voltmeter measurement limit - 10 V.

The refractive index was determined on an IRF-454 B2M refractometer at a temperature of 20 °C at the operating wavelength of the sodium atom spectrum line  $\lambda = 589.3$  nm.

The method of dynamic coherent scattering of laser light (Malvern Zetasizer Nano S light scattering analyzer) was used to experimentally estimate the size of the domains formed by the molecules of the dispersion medium around the brominated carbon nanospheres.

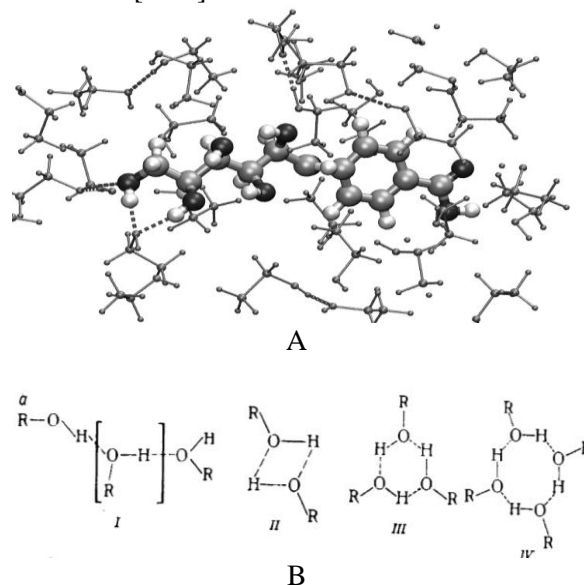
To assess the corrosion effects of ethanol fuel E-85, a test method on a copper plate according to GOST 6321 (ISO 2160-85) was used. The essence of the method is to keep the copper plate in the tested fuel at elevated temperature and record the change in its appearance, which characterizes the corrosive effect of the fuel. Evaluation of test results is performed visually depending on the degree of copper plate damage.

Indicator of the critical load of the solution to the scuffing, which is the maximum value of the load at which there is no metal contact (scuff) by friction in the test liquid of standardized metal balls made of high-strength low alloy steel for bearings (microhardness 64-66 HRC, roughness parameter  $R_a < 0, 25 \mu\text{m}$ ), was evaluated on a four-ball friction machine according to the method described in ASTM D 2266-01.

### Results and discussion

The modern idea of the structure of substances in the liquid state is based on the assertion of the existence in the structure of various hierarchical structures that are

not characteristic of the gaseous and solid states. Such spatially ordered objects in liquids include solid or localized in some objects hydrogen skeletons from fires, stable associative molecules and short-lived groupings of molecules [9-11].



**Fig. 1.** Three-dimensional dynamic secondary structure in the liquid phase of ethanol (A) and the main elements of the secondary structure of ethanol due to intermolecular hydrogen bonds (B) [11]: I - linear associate; II - cyclic dimer; III - cyclic trimer; IV— cyclic tetramer.

Dissolution of brominated carbon nanospheres CNOs –  $\text{Br}_n$  in organic solvents is accompanied by solvation of added molecules by molecules of the medium with the participation of different forces of intermolecular interaction, which are based on Coulomb interaction forces between electrons and nuclei of solvent and solute molecules. To describe the intermolecular interaction between the components of dilute solutions, the general equation of Van der Waals is acceptable [12]:

$$E = -1/r^6 \left\{ \frac{2}{3} \cdot \mu_1^2 \mu_2^2 / kT + (\mu_1^2 \alpha_2 + \mu_2^2 \alpha_1) + 3\alpha_1 \alpha_2 \cdot I_1 I_2 / (I_1 + I_2) \right\} \quad (1)$$

where E is the energy of intermolecular interaction solvent (1) - solute (2);

r is the distance between the centres of the interacting molecules;

$\mu_1$  and  $\mu_2$  are dipole moments,

$\alpha_1$  and  $\alpha_2$  are polarization,

$I_1$  and  $I_2$  are the ionization potentials of solvent and solute molecules, respectively.

Equation (1) includes orientational (first term), polarization (second term) and dispersion (third term) forces of intermolecular interaction.

Electrostatic interaction forces play a major role in the formation of the primary solvate shell, which consists of solvent molecules strongly bound to the solute molecule [13, 14].

By the method of dynamic coherent scattering of laser light, we experimentally determined the region of coherent scattering, which corresponds to the size of structural groups formed by brominated carbon nanospheres CNOs – Br<sub>n</sub> in the environment of chemically different organic solvents (Table 1) [14-16].

According to the above data, the size of the domains formed by solvation of the added CNOs – Br<sub>n</sub> nanospheres in the investigated solvents is different and varies from 21 to 1000 nm. For ethanol, this size is ~ 400 nm, which is much larger than the size of individual additive particles (5 - 40 nm) [17]. Table 1 also shows the reference values of dipole moments ( $\mu$ ), dielectric constant ( $\epsilon$ ) and the acceptor number of the investigated solvents. The parameters  $\epsilon$  and  $\mu$  are related by the Debye equation [18]:

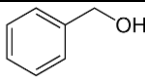
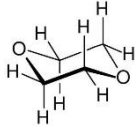
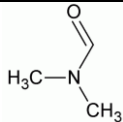
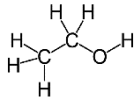

$$(\epsilon-1)/(\epsilon+2) = 4\pi N_1/3 * (\alpha_0 + 3\mu^2/3kT) \quad (2)$$

where  $\epsilon$  is the dielectric constant of the medium,  
 $\mu$  is the intrinsic dipole moment of the molecule,  
 $\alpha_0$  is the polarization of the molecule,  
 $N_1$  is the number of molecules in 1 cm<sup>3</sup>,  
 $k$  is the Boltzmann constant,

T is absolute temperature.

As can be seen from the above data, a clear relationship between the size of the domain formed by the dissolution of CNOs – Br<sub>n</sub> nanospheres, dielectric constant and dipole moment is not observed. These dependences are complex because the dipole moment of a molecule is a vector sum of the dipole moments of the groups of which it consists. The corresponding correlations are more characteristic of systems of simple molecules with a small content of polar groups. However, according to the data in table 1, the determined volume of the domain correlates well with the acceptor number of the solvent in the series: dioxane - dimethylformamide - ethanol: the value of the latter increases in the same direction as the size of the domain CNOs – Br<sub>n</sub> - solvent. This dependence suggests that donor-acceptor interaction forces are involved in the formation of domains, where the electron donor is a brominated onion molecule containing a system of conjugated double bonds and an electronegative substituent, and the acceptor is a solvent molecule. It is significant that solvent molecules with high electron density (benzyl alcohol, dioxane), which are good electron donors, block the formation of stable bonds with CNOs – Br<sub>n</sub>. The low values of the size of the domains obtained in the latter environments are also explained by the peculiarities of the geometric configuration of their molecules, which complicates their intermolecular interaction with solute molecules.

Table 1. Experimentally determined domain sizes from solvated CNOs – Br<sub>n</sub> nanospheres in different media and some physicochemical properties of the corresponding solvents

Solvent	Structural formula	Domain size, nm	Dipole moment ( $\mu$ , D)	Dielectric constant ( $\epsilon$ )	Acceptor number
Benzyl alcohol		21	1,71	13,5	
Dioxane		28	0,0	2,2	10,8
<i>N, N</i> -dimethylformamide		220	3,8	36,7	16
Ethanol		400	1,68	25,2	37,9
<i>N</i> -methyl-pyrrolidone		950	4,06	34,9	13,3

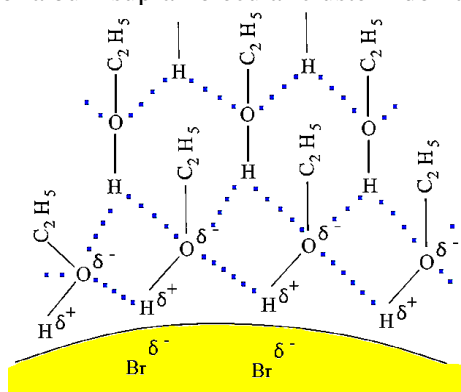


The dielectric constant of the medium (equation 2) as well as the intermolecular interaction of the solvent with the solute (equation 1) significantly depend on the polarization of the interacting molecules. Considering the abnormally high polarization ( $\epsilon$ ) of fullerene and fulleroid structures [19, 20], the influence of this indicator on the solvation of CNOs – Br<sub>n</sub> nanospheres in polar media is the most important. The presence of heteroatoms attached to the outer shell of the framework of the onion molecule causes an increase in the polarization of the molecule compared to the carbon analogue. The study of solvation of exomodified onions with various substituents showed that in ethanol the smallest domains (~ 75 nm) are formed on the basis of oxidized nanocarbon spheres, slightly larger - on the basis of chlorinated (~ 90 nm) and much larger - on the basis of brominated ones (~ 400 nm) (Table 2) [17].

The obtained results correlate with the values of electronic polarization and the radius of the substituent and, to a lesser extent, with the value of the dipole moment of the Ar-X bond (Ar is an aromatic ring, X is a substituent) (Table 2). As the electronic polarization of the substituent increases, the polarization of dissolved ion molecules increases, the value of which is additive to the polarization of individual bonds, and the contribution of the polarization component of the Van der Waals interaction forces to the medium increases. This can explain the increase in the size of solvate structures in ethanol in a number of substituents: OH<sup>-</sup> (O<sup>2-</sup>) – Cl<sup>-</sup> – Br<sup>-</sup>.

When dissolving CNOs – Br<sub>n</sub> ions in ethanol, the scheme shown in Figure 2 gives an idea of the formation of the primary solvate shell, which consists of solvent molecules strongly bound to the solute molecule by electrostatic interaction.

Under the action of the solvent, the C-Br bond, like the whole ion molecule, is polarized with the formation of dipoles, which, in turn, polarize the substrate molecules. The secondary solvate shell is formed due to the electrostatic interaction of primary solvated molecules with solvent molecules with the formation of a bulk supramolecular cluster - domain.



**Fig. 2.** Orientation ordering of ethanol molecules under the action of brominated carbon nanospheres.

Hydrogen bonds play a significant role in ethanol solution. Solvation of dissolved nanoparticles is

accompanied by a change in the electronic structure of both substances in contact. The formation of similar structures was observed in the study of the properties of hydrated C<sub>60</sub> fullerenes [21]. In [22] it is noted that the properties of the boundary water layer formed near hydrophilic surfaces, which has a thickness of tens and hundreds of microns, are so different from bulk water that it can be considered a special aggregate phase of water, whose unusual properties are due to mobile the state of the electrons in this phase. The corresponding changes in the properties of ethanol take place in the solvate shell formed around the CNOs – Br<sub>n</sub> nano ion. The scheme of the supramolecular domain formed in ethanol can be represented as follows (Figure 3).

The formation of an ordered structure of domains with the orientation of hydrocarbon fragments of ethanol molecules outward, and protons - to the center-forming brominated carbon nanospheres - structures the environment and significantly changes the physicochemical and operational characteristics of CNOs – Br<sub>n</sub> solutions compared to pure solvent. Considering the linear relationship [23]:

$$C = \epsilon \epsilon_0 S / d \quad (3)$$

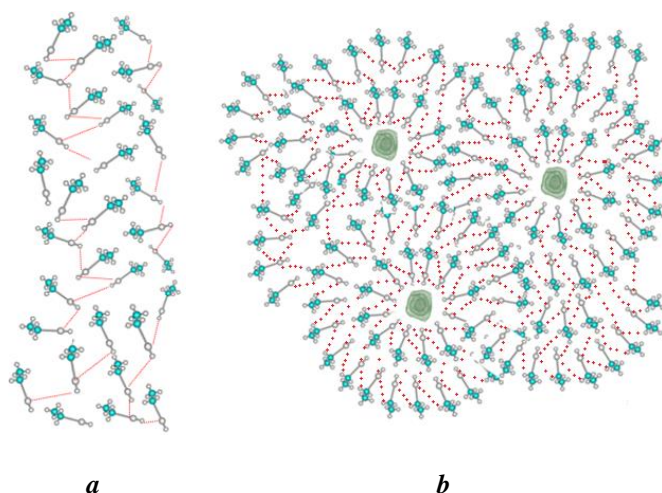
where C is the capacitance of the flat capacitor C, between the covers of which is placed the test solution;

$\epsilon$  is the dielectric constant of the medium between the plates of the capacitor;

$\epsilon_0$  is dielectric constant of vacuum;

S is the value of the surface area of the capacitor plate (smaller if the opposite plates are uneven);

d is the distance between the plates of the capacitor



**Fig. 3.** Possible secondary supramolecular structure of the liquid phase of ethanol:

a - dynamic continuous network of hydrogen bonds of ethanol molecules [9]; b - ordered islet groupings of ethanol molecules around nanoparticles; ..... - hydrogen bond; [ethanol symbol] - ethanol; [nanoparticle symbol] - CNOsBrn.





Table 2. The effect of the substituent in the structure of exommodified carbon nanospheres on the size of the domain formed in the ethanol medium (additive concentration: 0, 01%, wt.)

Substitute (X)	Domain size in ethanol, A (experiment)	dipole moment of C <sub>6</sub> H <sub>5</sub> -X (μ, D)	The value of the electronic polarization of the ion, A	Ion radius, A
OH <sup>-</sup>	~ 750	1,40	2,04	1,36 (for O <sup>-2</sup> )
Cl <sup>-</sup>	~ 900	1,69	2,96	1,81
Br <sup>-</sup>	~ 4000	1,77	4,16	1,96

Table 3. Anticorrosive properties of ethanol fuel E-85\* in the presence of 0.001% wt. of CNOs-Br<sub>n</sub> additive in comparison with traditional anticorrosive additives (0.01% wt.)

Additive	Corrosion degree
Absent	2a
CNOs-Br <sub>n</sub>	1a
TEPA (tetramethylene polyamine)	1b
THETA (triethylenetetramine)	1a
Monoethanolamine	1b
Diethanolamine	1b
Triethanolamine	2b
Triethylamine	1a

\* E-85 - ethanol fuel (85% ethanol, 15% gasoline A-95)

According to the experimental measurement of C, the effect of the CNOs – Br<sub>n</sub> ion concentration not only on the electrical conductivity but also on the dielectric constant  $\epsilon$  of ethanolic solutions was indirectly estimated. As can be seen from Figure 4, the addition of brominated carbon nanospheres to ethanol is accompanied by a decrease in the electrical capacitance of the capacitor in the range of CNOs – Br<sub>n</sub> concentrations from 0 to 0.001 %, practically does not change from 0.001 to 0.006 % and then increases

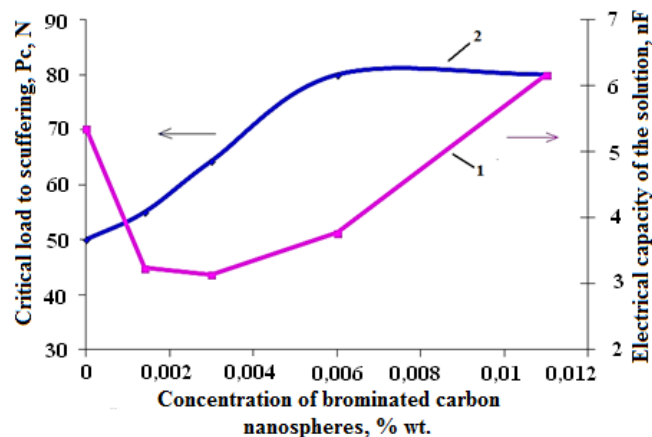


Fig. 4. Concentration change of electric capacitor capacity with ethanol solution of brominated carbon nanospheres between covers (curve 1) and critical load of solution to scuffing (curve 2).

As can be seen from table 3, the introduction of CNOs – Br<sub>n</sub> nanospheres into ethanol fuel at a concentration an order of magnitude lower than traditional corrosion inhibitors (mono-, di-, triethanolamine, triethylamine, TEPA, TETA) exceeds the anticorrosive efficiency of the latter.

The structuring of the solution at low concentrations of the additive improves its anti-wear properties - the critical load of ethanol solution to scuffing increases with increasing concentration of CNOs – Br<sub>n</sub> from 0 to 0.06 % and with a subsequent increase of the latter to 0.01 %, these values do not change (Figure 4).

### Conclusions

Based on the analysis of research results, it can be stated that the formation of supramolecular solvate groups, the center of which are nanosized carbon clusters of CNOs – Br<sub>n</sub>, in the ethanol medium, occurs with the participation of different in nature forces of intermolecular interaction. The basis of intermolecular interaction is the Coulomb forces of interaction between electrons and nuclei of ethanol molecules and nanoadditives.

Based on the data obtained, it can be concluded that when adding anions to ethanol fuel should work in the range of operating concentrations of 0.001-0.01 wt.% CNOs - Br<sub>n</sub>, where there is no agglomeration of the structures formed in solution.

The influence of microstructural changes in the studied system on its macrophysical properties is revealed and the interrelation between physicochemical

and operational properties of ethanol fuels containing nanocarbon clusters is found [23].

### References

- Polunkin Ye. V., Pylyavs'kyy V. S., Kamenyeva T. M., Shelud'ko Ye. V. Karbonovi sferoyidal'ni polisharuvati nanoklastery yak perspektyvni bahatofunktsional'ni prysadky do motornykh palyv. *Problemy resursu i bezpeky ekspluatatsiyi konstruktsey, sporud ta mashyn.* 2015. 200-205.
- Gaidai O., Bereznitsky Ya., Himach N., Pylyavskiy V., Polunkin Ye. Vplyv prysadok na osnovi nanorozmirnykh sferoyidal'nykh karbonovykh klasteriv na ekspluatatsiyi vlastyivosti etanol'nykh benzyniv. *Problemy khimmotolohiyi. Teoriya ta praktyka ratsional'noho vykorystannya tradytsiynykh i al'ternatyvnykh palyvno-mastylnykh materialiv: monohrafiya.* 2017. 35-42
- Hayday O.A., Himach N.Yu., Pylyavs'kyy V.S., Polunkin Ye. V. Novi pidkhody do stvorennya al'ternatyvnykh motornykh palyv z ponovlyuvanoyi syrovyny. *ScienceRise.* 13-21 <http://dx.doi.org/10.15587/2313-8416.2016.71955>
- Danilov A.M. *Primeneniye prisadok v toplivakh. Spravochnik.* 2010. 368 p
- Kuliyev A.M. *Khimiya i tekhnologiya prisadok k maslam i toplivam. 2-ed.* 1985. 312 p
- Frolova K.V. *Sovremennaya tribologiya: itogi i perspektivy.* 2008. 480 p
- Bartelmess J., Giordani S. Carbon nano-onions (multi-layer fullerenes): chemistry and applications. *Beilstein J. Nanotechnol.* 2014. 1980-1998
- Boguslavskiy L.Z., Nazarova N. S., Vinnichenko D.V., Rud' A.D., Kyryan I.M., Zelinskaya G.M. Sintez nanougleroda vysokochastotnym razryadno-impul'snym metodom. *Nanosystemy, nanomaterialy, nanotekhnolohiyi.* 2012. 159-167
- Tsyvadze A.Yu., Abrosymov V.K., Kyselev M. H. Strukturnaya samoorganizatsiya v rastvorakh i na granitse razdela faz. 2008. *LKI.* 544 p
- Franks F. *Water: A Matrix of Life, 2nd Edition* (London: Royal Society of Chemistry). 2000. 238 p
- Krestov G.A. *Termodinamika protsessov v rastvorakh.* 1984. Leningrad: Khimiya. 272 p
- Raykhardt K. *Rastvoriteli i efekty sredy v organicheskoy khimii.* 1991. Moskva: Mir. 763 p
- Bokris D. *Sovremennyye aspekty elektrokhemii.* 1967. Moskva: Mir. 512 p
- Moskva V.V. *Rastvoriteli v organicheskoy khimii. Sorosovskiy obrazovatel'nyy zhurnal.* 1999. 44-50
- Nikol'skiy B.P. *Spravochnik khimika.* Leningrad: Khimiya. 1966. T.1. 1072 p
- Stepanova T.P., Karpenko Ye.D., Kapralova V.M. Dipol'nyye momenty N-metilpirrolidona v zhidkom sostoyanii i v razbavlenom vodnom rastvore. *Nauchno-tekhnicheskkiye vedomosti SPbGPU. Fiziko-matematicheskkiye nauki.* 2013. 112-117
- Haidai O., Pilyavskiy V., Shelud'ko Ye., Polunkin Ye. Improvement of performance characteristics of ethanol motor fuels through use of additives based on nanoscale carbon clusters. *EUREKA: Physics and Engineering.* 2016. 3-10 <http://dx.doi.org/10.21303/2461-4262.2016.00213>
- Pentina Yu. A. *Fizika i khimiya tverdogo sostoyaniya organicheskikh veshchestv.* Moskva: Mir. 1967. 738 p
- Shchur D.V., Matysyna Z.A., Zahynaychenko S.Yu. *Uglerodnyye nanomaterialy i fazovyye prevrashcheniya v nikh.* Dnepropetrovsk.: Nauka i obrazovaniye. 2007. 680 p
- Sedel'nikova O. V., Bulusheva L. G., Okotrub A.V. Vliyaniye defektov uglerodnoy setki na staticheskuyu polarizuyemost' fullerenov. *Fizika tverdogo tela.* 2009. 815-821
- Shirinkin S.V., Shaposhnikov A.A., Volkova T.O., Andrievskiy G.V., Davydovskiy A.G. Gidratirovannyi fulleren kak instrument dlya ponimaniya roli osobykh strukturnykh svoystv vodnoy sredy zhivogo organizma dlya yego normal'nogo funktsionirovaniya. *Nauchnyye vedomosti BelGU: Yestestvennyye nauki.* 2012. 122-130
- Zheng J.M., Chin W.C., Khijniak E.Jr., Pollack G.H. Surfaces and interfacial water: evidence that hydrophilic surfaces have long-range impact. *Adv. Colloid. Interface. Sci.* 2006. 19-21
- Kovalev P.G., Khliyan M.D. *Fizika (Molekulyarnaya fizika. Elektrodinamika).* Rostov-na-Donu: Izdatel'stvo Rostovskogo universiteta. 1975. 264 p

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## Вплив додавання екзомодифікованих вуглецевих наносфер на структурування в етанольних моторних паливах

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Робота присвячена з'ясуванню загального механізму дії екзомодифікованих вуглецевих наносфер (CNO - Br<sub>n</sub> нано-оніонів) на різні хімічні та фізико-хімічні властивості етанольних моторних палив. Формування надмолекулярних сольватних груп в органічних середовищах пояснюється участю різних сил міжмолекулярної взаємодії, основними з яких є поляризаційні та орієнтаційні, а також донорно-акцепторних сил взаємодії наносфер з навколишнім середовищем. Запропоновано та обґрунтовано концепцію створення в органічному середовищі сольватаційних утворень - доменів, розміри яких, визначені методом фотонно-кореляційної лазерної спектроскопії, варіюються від 21 до 1000 нм залежно від хімічної природи розчинника. Для етанолу розмір таких утворень становив ~ 400 нм, що значно перевищує розмір окремих частинок добавки. Встановлено, що для поліпшення експлуатаційних характеристик етанолового палива достатньо ввести низькі концентрації (10<sup>-3</sup>-10<sup>-2</sup>%, мас.) синтезованих бромованих наночастинок.

Показано, що зміна мікрогетерогенної структури палива впливає на зміну його фізико-хімічних та експлуатаційних характеристик: зменшуються діелектрична проникність та гідрофобність середовища, збільшується тиск насиченої пари, що покращує вихідні властивості палива; гідрофобізація середовища допомагає зменшити корозійні властивості етанольного палива на одиницю, внаслідок чого не потрібне додаткове введення інгібітора корозії; несуча здатність палива в присутності бромованих наночастинок збільшується в 1,5 рази порівняно з базовим паливом з відповідним зменшенням пошкодження металеві поверхні пар тертя.

Саме перегрупування вторинної надмолекулярної структури палив у присутності бромованих вуглецевих наносфер пояснює багатофункціональність їх впливу на фізико-хімічні властивості та хімотологічні характеристики ета-нольних моторних палив.

**Ключові слова:** етанольне паливо; карбонові нанорозмірні сферичні кластери; фізико-хімічні, експлуатаційні та екологічні властивості палива