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Physical Doping Nanocomposites with Carbon Nanostructures with High Electron Affinity

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Abstract: The fundamental scientific problem for micro- and nanoelectronics has been solved – methods for creating and investigating properties of physically doped materials with spatially inhomogeneous structure at the micro- and nanometer scale have been developed. For the application of functional nanocomposite film coatings based on carbides of various transition metals structured by nanocarbon, for the first time in the world we developed a new technique for their plasma deposition on a substrate without the use of reaction gases (hydrocarbons such as propane, acetylene, etc.). We have created nanostructured film materials, including those with increased strength and wear resistance, heterogeneous at the nanoscale, physically doped with nanostructures - quantum traps for free electrons. We learned how to simultaneously spray (in a plasma of a stationary magnetron discharge) carbides and graphite from a special mosaic target (carbide + carbon) made mechanically Based on the analysis of experimental work, we have formulated the foundations of cumulative quantum mechanics capable of describing the unlimited cumulation of the ψ-function of a quantum particle to the center in hollow spherically and cylindrically symmetric nanoscale quantum resonators.

Keywords: Physical alloying, Allotropic carbon nanostructures, Coefficient of dry friction, Wear and temperature resistance of nanocomposites, Charged layer.

1. Introduction

Nanostructured carbon materials raise interest due to their unique properties. They are tens of times more durable and ductile and have improved luminescent characteristics, etc. [1-13]. To create the modern devices, it is highly important to make use of the high-temperature materials based on compounds of the transition metals of IV-VI periodic system group with nitrogen, boron, silicon and carbon.

There is a special place for carbides with a high melting temperature from 2580 ºC for molybdenum semicarbide to 3880 ºC for tantalum carbide, up to 31 GPa hardness, wear resistance, corrosion resistance, resistance to molten metals, low vapor pressure and low evaporation rate. In addition, they also possess some specific electrical and thermal properties and can be used as materials in the heating elements of high-temperature furnaces, thermocouples and thermionic device cathodes, etc. Among the new materials, special attention is paid to film materials, which have recently been widely used to modify the working surfaces of machines and mechanisms, significantly increasing the service characteristics of most parts and metalworking tools. Enhanced properties of the surface layers of the parts' material and improved contact conditions of their functioning result in an increase in terms of the machine operation and, accordingly, in huge savings in materials and energy [8].

We first developed methods for creating and investigating properties of physically doped materials with spatially inhomogeneous structure at the micro- and nanometer scale have been developed. For the application of functional nanocomposite film coatings based on carbides of various transition metals structured by nanocarbon, for the first time in the world we developed a new technique for their plasma deposition on a substrate without the use of reaction gases (hydrocarbons such as propane, acetylene, etc.). We have created nanostructured film materials, including those with increased strength and wear resistance, heterogeneous at the nanoscale, physically doped with nanostructures - quantum traps for free electrons. We learned how to simultaneously spray (in a plasma of a stationary magnetron discharge) carbides and graphite from a special mosaic target (carbide + carbon) made mechanically.

2. Concepts of the Polarization Mechanism and Experimental Techniques for the Physical Doping of Nanocomposites

2.1. The use of Allotropic Forms of Nanocarbon: Fullerenes and Graphene

At present, in the scientific literature, clear ideas about the mechanisms leading to the appearance of unique properties of such nanostructured physical alloying composites are found only in works [3, 4]. In [3], during the physical doping of copper with carbon nanostructures, the behavior of 2-component nanocomposites in metallurgically non-interacting materials (carbon and copper) was studied. In [4] we have analytically investigated a possibility of hardening and modifying properties of plasma metallization composite coating (nanocomposite materials) by creating spatial nanolayers of space charge on the nanocrystals surface by using nanostructures made of carbon allotropic forms with a high electron affinity - fullerenes (Fig. 1). All carbon nanostructures have a great electron affinity. Fullerenes, nanotubes, and other nano-structures of the allotropic carbon forms with a high electron affinity can be used as free electrons traps that generate a negative charged nanolayer on the surface of the hardened material. These nanostructures (modifiers) attach or capture free electrons and thus charge the crystals of the modifiable material with positive charge (Fig. 1). The Coulomb forces are determined at the level of nanoscale, they are long-range. Therefore, the formation of nanoclusters or nanostructures capable of capturing electrons with resonant energy (traps for free electrons) can substantially modify the macro properties of nanocomposites. This effect (physical alloying of nanostructured materials [3, 4]) may result in the development and production of new materials for various industries [8, 10, 11, 13].

These phenomena are associated with the quantum-size effects of polarization capture of electrons by carbon nanostructures [3, 4, 8, 10, 11] (Fig. 1). With such alloying, the properties of the surface of spatially charged nanocrystals also change. This leads to 11 quantum-dimensional effects of nanocomposites appearing in the mesosphere [13]. Here are a few of them.

1. The separation of charges in the nanocomposite leads to Coulomb levitation of positively charged nanocrystals relative to each other and prevents the recrystallization of physically doped positively charged nanocrystals in the composite (Fig. 1(b)) [1-4, 8, 10].

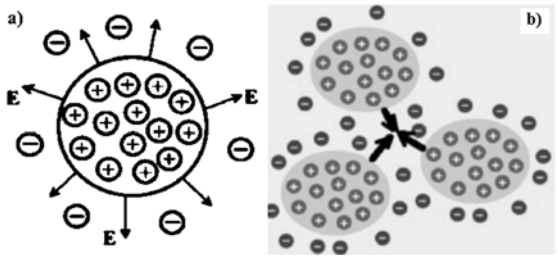


Fig. 1. The scheme of physical doping of nanocrystals with quantum resonators for de Broglie waves of electrons [4].
(**a**) The charge structuring is caused by the capture of electrons by traps-quantum resonators. "+"–a positively charged nanocrystal; " - " – a quantum resonator that physically alloys the nanocrystal. As the concentration of traps increases, the electric field of the nanocrystal and the energy of electrons in its region increases. This increases the efficiency of phosphors.
(**b**) The arrows show the Coulomb compression forces due to the structuring of the volume charge.

In this article, we will use drawings to illustrate the main achievements of our works [1-4, 8, 10-13] (Fig. 1-5). We have discovered the possibility of the formation of endo electrons in fullerene molecules due to their polarization capture of free electrons with resonant energies. This idea is fully consistent with experimentation [15-18].

2. According to the review [18], a single C_{60} molecule can capture up to 6 electrons in experiments. In our experiments [10], according to indirect data, we observed 3 own resonant energy levels of electron capture in the inner cavity of fullerenes, which corresponds to up to 6 electrons per C_{60} molecule. We can see this from the **Vysikaylo' concentration-quantum-size effect** of the second type [1, 4, 10] (Fig. 3). Using this effect, we can restore the first energy level of a hollow quantum resonator-C_{60} of the order of 0.24 eV. This value coincides well with experimental data [14-16] and theory (CQM) [4].

3. In [4] we have proposed a foundation of cumulative quantum mechanics (QCM) that allows one to describe the resonance cos-waves with the $\psi_{n-1/2}$ function of an electron ($\psi_{n-1/2}(r) \sim \cos(k_{n-1/2}r)/r^k$) unlimited (with $k \neq 0$) in the nanoresonator center in **hollow** quantum nanoresonators with any type of

symmetry (plane – k = 0, spherical – k = 1, and cylindrical – k = 0.5). **Irregular in the center of a resonator, the cos solutions are regularized in the resonator center by the geometric normalization coefficient** corresponding to the symmetry type and being $\chi(r) = 2^k\pi^{1/2}r^k$, at k ≠ 0 (if k = 0, then χ = 1).

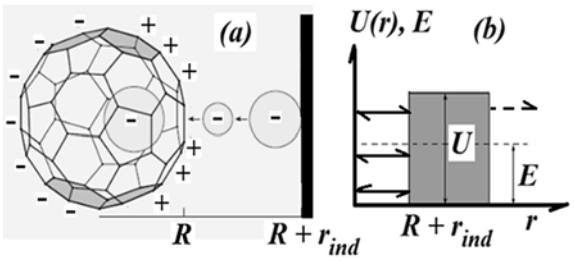


Fig. 2. The scheme of the cumulative polarization electron capture with the resonant energy from 0.24 to 20 eV into a hollow $C_{60,70}$ molecules [4]. The endoion radius (the location of reflecting «mirror» $R_i = (R_{C60,\,C70} + r_{ind})$.
(**a**) The 4D space-time process of formation of a standing de Broglie wave in a polarizing quantum resonator.
(**b**) The diagram of a metastable (qvasi-open) quantum particle with the polarization mirror (of finite size), which captures the electron with energy $E > 0$ into the polarization trap of the characteristic size $R + r_{ind}$. The polarization mirror is darkend. This problem is the first Helmholtz boundary value problem [14, p. 515].

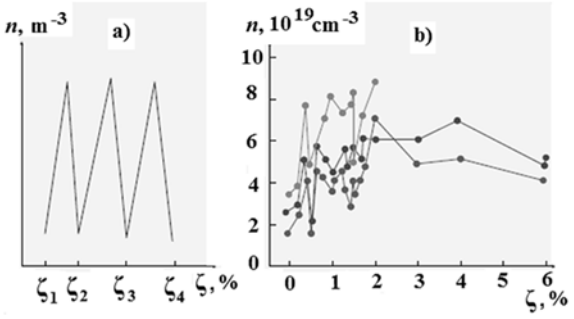


Fig. 3. The Vysikaylo'concentration-quantum-size effect of the second type:
(a) – the manifestation of the quantum-size effect in macroscopic parameters of the nanocomposite, due to polarization capture of electrons by polarized hollow molecules [4, 10]. A characteristic dependence of the nanocomposite parameters, for example, the concentration of ions or electrons n on the volume content of C_{60} quantum resonators in the composite. The profiles shift with a change in the characteristic radius of the nanocrystallites, forming with a relative concentration of traps a quantum-sized pair that changes the parameters of the nanostructured composite in the mesomir [4, 10];
(b) – the results of experimental measurements of the resonance profiles of the electron concentration with a change in the relative concentration of traps upon doping with C_{60} fullerenes of nanocrystals of semiconductors (thermoelectrics) at various temperatures (from 295 to 77 K). The characteristic radius of nanocrystallites after annealing is $R \approx 17$ nm [10].

The stratification of the probability of finding the particle in the quantum nanoresonator volume is similarly determined by the energy of a particle or a full set of squares of the corresponding quantum numbers $((n\text{-}1/2)^2$ for cos-waves and n^2 for sin-waves) for any type of resonator symmetry.

4. Based on this idea, we can solve the following problems (by physical doping of nanocomposites):

1) The appearance of cracks in fuel cells (TVEL) [11];

2) Swelling of fuel elements during their operation at nuclear power plants;

3) The appearance of cracks and roughness in engineering products.

These problems can be solved by adding fullerenes to the nanocomposite - spherical symmetrical traps for free electrons that actively participate in the growth of cracks and swelling of materials under load. We have already experimentally developed ways to increase (by physical alloying):

1) The strength of copper [3] and aluminum products [10] up to 10 times, up to 10 GPA;

2) The intensities of phosphors at times, the generation of electric fields in the region of positively charged crystallites of a phosphor can reach up to 10^{11} V/m [4];

3) The efficiency of thermoelectric by 30 % [10];

4) The long-term functioning of nanocomposites without recrystallization at times [8, 13];

5) The increase of conductivity up to 10^{10} [13] in silicone (siloxane, polysiloxanes, organic silicon) compounds.

The processes of physical doping of nanostructured (meta-) materials have been investigated. On the basis of the author's formulated cumulative quantum mechanics (QCM) [4], we describe:

1) Two types of interference and diffraction (in the center) in hollow quantum resonators for the de Broglie waves of electrons (Fig. 2, Fig. 4);

2) Ten types of the Vysikaylo' quantum-dimensional effects due to the polarization capture of electrons in the cavity of quantum resonators [4, 13]. The first type of interference and, accordingly, diffraction in the resonator center corresponds to the de Broglie-Fresnel interference (sin-waves ψ_n with a wave node in the center of the resonator (Fig. 4)) and is used to describe the cumulation of electrons in an atom with an atomic nucleus in the center.

5. The second type of diffraction is called the **Vysikaylo – de Broglie – Fraunhofer' diffraction** with the antinode of the electron de Broglie wave intensity in the center of a hollow resonator, wherein the $\psi_{n\text{-}1/2}$ functions of the electron infinitely cumulate by a polarization «mirror» towards the center of a hollow quantum spherical or cylindrically symmetric resonator ($\psi_{n\text{-}1/2}(r) \sim \cos(k_{n\text{-}1/2}\, r)/r^k$). It is shown that cos-solutions irregular in the resonator center, are regularized for any wave phenomena by the geometric coefficient (Fig. 4 (*b*)). It is proved in the framework of CQM that, alongside with the classical energy spectrum for asymmetric ψ_n functions (sin-waves (overtones)) with $E_n \sim n^2$, for **hollow** quantum resonators, there exist and are realized in experiments the quantum resonances for $\psi_{n\text{-}1/2}(r)$ – functions (cos-

waves (the principal tone) [14]) **with $E_{n-1/2} \sim (n-1/2)^2$**. The spectrum of energy states, localized by the barrier, with $E_n>0$ (a partially open quantum dot, line or well), as in the case of $E_n<0$ (a closed quantum dot, line or well), is determined by the effective internal sizes of the box ($R+r_{ind}$) with polarization forces effectively acting at a distance of r_{ind} from the molecule. The comparisons of the results of analytical results with the experimental observations proves convincingly the validity of the CQM application in describing the quantum-size effects in the case of physical doping of metamaterials.

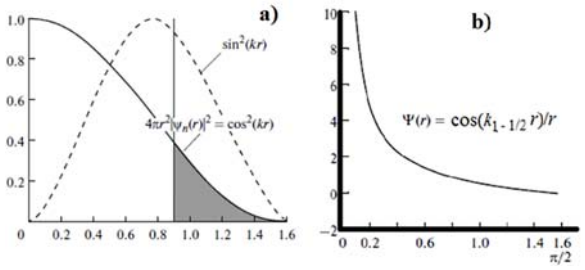
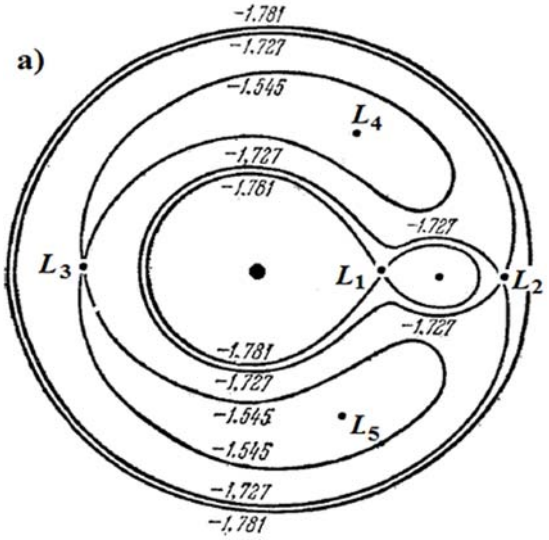


Fig. 4. (a) The probability $4\pi r^2|\psi_n(r)|^2 dr$ to find an electron in the region of a hollow spherically simmetric molecule versus the distence to its center for half-resonance (with E_{cos1}) is denoted by the solid graph and for the wave-resonance (with E_{sin1}) by the dotted graph. The relative probability of finding an electron at 1/2 resonance outside the C_{60} shell is obscured. **(b)** The $\psi_{cos1} - \cos(k_{1-1/2}r)/r$ function of the electron versus the distance to the hollow molecule center (r - in radians).

6. In nanocomposites, the pair of "eigenfunction ψ_n – self – eigenenergy E_n" describing the quantum state in the nanoworld noted by the number n, in the mesoworld of nanocomposites by physically doped with traps is replaced by two nanoworld parameters: **the nanocrystal diameter D and the relative concentration of the modifier** (traps, e.g. C_{60}) ζ_n. In [4] the self-assembly of hollow allotropic carbon forms on resonant electrons is discussed (Fig. 3).

7. An important quantum-dimensional effect is the **cumulation of electron fluxes at libration points between positively charged nanostructures** (Fig. 5).

This effect has so far been studied in gas-discharge plasma in [12] and it has not been studied in sufficient detail in nanocomposites (Fig. 1(*b*)). This cumulative quantum-dimensional effect, due to the capture of free electrons with resonant energy in a quantum resonator and the formation of positively charged nanocrystals of the doped material, can be used to control the conductivity, thermal conductivity and other properties of nanocomposites. The formation of cumulation (libration) points L_1 of electron fluxes by long-range electric potentials for positively charged nano-and Femto-structures and their systems (Fig. 1(*b*) and Fig. 6) becomes clear to us from Fig. 5.



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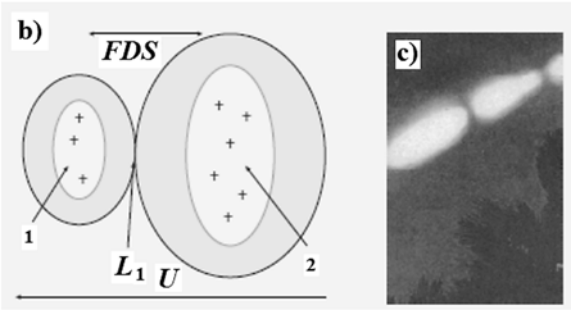

Fig. 5. Schemes of cumulative-dissipative structures:
(**a**) – this is a cross section of surfaces of equal potential (taking into account the centrifugal potential) in the Roche' model in the orbital plane of a double gravitational system. The Roche surface scheme consists of two closed cavities surrounding both material points (two stars or stars and planets, for example, the Sun-a massive point on the left) and Jupiter-a massive point on the right) and having a common point L_1. The points of libration and cumulation of Lagrange-Euler $L_{2\text{-}5}$ are due to the interference of long-range non-local gravitational and centrifugal potentials or to the inertia of gravitational bodies (term $m(\boldsymbol{V}\cdot\nabla\boldsymbol{V})$ in the momentum transfer equation).

(b) – cross-section of equal potentials according to the Vysikaylo-Roche' model [12] in the cross-section plane of two positively charged plasma structures. Equipotential surfaces consist of two closed cavities 1 and 2, for example, two positively charged 3D finite plasma structures: a cathode spot 1, for example, on the left, and a positive column 2 on the right (or two positively charged strata) and having a common point L_1 – the point of accumulation of electron flows (L_1 – the point of accumulation of electron flows or focus for electrons); U – external drop of potential, the electrons in it move from point 1 to point 2;
(c) – a vivid illustration of long-range convective nonlocality is clear lightning with points of cumulation of electron fluxes and Faraday dark spaces (FDS) between luminous, positively charged plasmoids [12].

8. **Coulomb melting** of nanofullerite (fullerene nanocrystals) occurs when k electrons are captured by fullerene molecules in fullerite. In a fullerite crystal, C_{60} molecules are bound together by weak Van der Waals' forces. The binding energy of a single fullerene molecule in a fullerite nanocrystal does not exceed 1.6 eV. The potential energy of the Coulomb interaction of two negative ions in fullerite with k electrons is about $1.4 \cdot k^2$ eV (the average distance between fullerenes in fullerite is $D \approx 1$ nm). Therefore, the capture of several electrons from a nanocrystal physically doped with fullerenes leads to Coulomb scattering of fullerite nanostructures and coating of a positively charged doped nanocrystal with a monolayer of negatively charged fullerenes (see Fig. 1(*b*)) [4, 10, 12, 13]. One fullerene C_{60} molecule can capture up to 6 electrons [10, 18].

Note that neither nanotubes, because of their entanglement, nor nanographens, because of their strength, can have this property of breaking up into strictly nanometer structures. In experiments, this property of fullerites allowed us to create nanocomposite materials with unique functional and strength properties when the thermoelectrics [10], copper [19] and aluminum [9] are physically doped with C_{60}. However, the most significant progress in improving the strength properties was observed in the physical alloying of transition metal carbides [8]. The theory in [1-3] predicts the possibility of increasing the microhardness to 100 GPA.

9. As a **quantum-dimensional effect of Fermi gas counteraction to compression** of nanocomposites physically doped with nanocarbon structures, we present the reaction of electrons trapped in the trap to external action on the trap and the entire nanocomposite material (Fig. 2). In this case, the electrons already at the size $D = 2(R+r_{ind})$ from the physically doped nanocrystal traps counteract the external influence, preserving the physically doped material from destruction; R – the radius of the trap; r_{ind} – the characteristic induction size to which the electron exits the trap. In experiments, this effect was observed when metal products were coated with graphene sheets and was used to explain the properties of white dwarfs in astrophysics by Frankel' and earlier in Fowler's works. It turns out that any electrons localized in the Coulomb well in any quantum resonators with sizes from 10^{-15} m (in this case, the role of electrons is played by negative mesons [4]) up to 10^{26} m have dual properties to focus and counteract compression.

10. In this paper, we study the interaction of 3 nanocomponents in a nanostructured material - a physically doped carbide with nanocarbon (Fig. 6).

We believe that the theory of physical doping of carbides with carbon nanostructures does not differ significantly from the theory of physical alloying of copper nanocomposites, built in [1-3]. In the study of composites on the basis of transition metal carbides, we confine ourselves to the experimental results and when discussing them we will rely on the theory [1-3]. Our design of a target made it possible to intensively cool it in the magnetron body and spray its parts (carbide + carbon) simultaneously with a high power density of a constant plasma discharge - in the range of values from 40 W/cm^2 to 125 W/cm^2. Such sputtering with a change in the power or relative surface areas of various parts of the target (carbon and carbide) made it possible to change the average density of carbide, metal, and carbon in a nanostructured (nanocarbon and metal nanostructures) coating. The changed relative density of various components of the nanocomposite (nanostructures of carbide, metal, and carbon in the form of graphite) significantly affected the physical properties of the nanocomposite coating. We have proposed the new method for creating multiphase nanostructured composite plasma film coatings (based on transition metal carbides) with high hardness of 30 GPa, a low friction coefficient to dry of 0.13–0.16, with high heat resistance up to 3000 °C and thermal stability in the nanocrystalline state for more than 1200 °C designed. We consider the experimental results study of the physical alloying of carbides as a result of joint magnetron sputtering of transition metal carbides and graphite. We reveal the synergetic effect essence of negatively charged traps for electrons on the modification of the physically alloying crystals properties as a function of the dopant concentration [1-4].

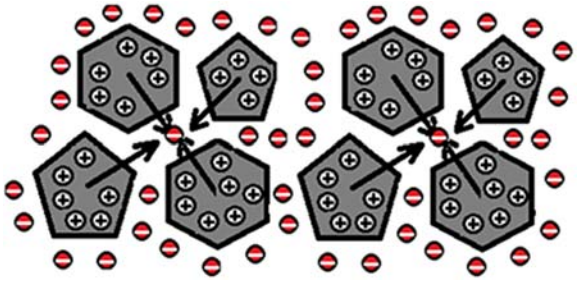

Fig. 6. The scheme of **physical** doping of nanocomposites (gray nanocrystals with "+") by carbon nanostructures (circles with "-"). Carbon nanostructures have an affinity for free electrons and are charged with a negative charge ("-"). The arrows indicate the direction of the Coulomb forces that compress the nanostructured polarized composite. Circles with the minus sign inside are the nanostructures with the captured electron. Circles with the positive sign inside correspond to a positive ion in the positive nanocrystal. Hexagons - MeC (nanostructures of carbide metal - Me). Pentagons - Me (nanostructures of metal).

2.2. The Physical Doping of Self-healing Borosiloxane Matrices with Carbon Nanotubes

For many modern materials used in electronics, space technology, automotive and many other areas, self-healing is relevant. One of the most promising oligomeric substances to create self-healing materials are borosiloxane. They combine unusual properties: fluidity at a long time and elasticity at a short time of

application of external load. This is due to the presence of intermolecular hydrogen bonds and donor-acceptor interactions between boron and oxygen atoms of neighboring molecules. Thus, with application of an external load in borosiloxane formed hydroclasters. It has been experimentally shown that doping of borosiloxanes with multi-wall carbon nanotubes affects the hydroclaster structure of borosiloxanes, changing its characteristics. When the concentration of nanotubes increases, quantum-dimensional effects begin to appear, which affects the reduction of fluidity and increase of elasticity due to Coulomb strengthening of intermolecular bonds in borosiloxane hydroclasters (the first effect) and an increase in brittleness (the fourth effect). As the concentration of nanotubes increases, the electrical resistance of borosiloxane materials decreases (**the eleventh effect**). Thus, legira borosilicone carbon nanostructures, it is possible to manage the whole complex of characteristics of materials. This is especially important when developing self-healing materials with specified and controlled characteristics, where the speed of self-healing, positioning the place of self-healing, as well as the presence of a physical mechanism for stimulating self-healing is important [1-3].

By varying the concentration of carbon nanotubes, it is possible to obtain materials with different rheological parameters and, accordingly, self-healing. By applying an electric current to the doped section of the borosiloxane self-healing coating, it is possible to increase the fluidity due to heating caused by the current of electrons in a medium with an electrical resistance of a given range. These parameters can be controlled not only by changing the concentration, but also by changing the degree of dispergation. The dispergation process in borosiloxanes can be intensified due to the possibility of using mixing in the modes of brittle and viscous destruction when creating a self-healing composite material.

3. Discussion of the Model of Hollow Quantum Resonators

The model of a hollow quantum resonator (Fig. 2) requires certain explanations and conclusions. As Schrödinger taught: "Isolated knowledge obtained by a group of specialists in a narrow field does not represent any value, it is only valuable in synthesis with all other knowledge." The main hypothesis in new quantum mechanics (de Broglie's hypothesis) is that quantum particles behave like waves. Fig. 7 illustrates the transition of a cos-wave to a rising drop in a hollow wave resonator. These experiments served as the basis in [4] to formulate the foundations of cumulative quantum mechanics for describing the behavior of quantum particles in hollow quantum resonators (Fig. 2).

Here we present the main provisions of cumulative quantum mechanics:

1. We claim that on the atomic nucleus or proton in the hydrogen atom there is a quantum reflection of the cumulating (focusing) standing de Broglie wave of electrons of the shell to the nucleus. As we first pointed out, taking into account such a quantum structure impervious to de Broglie waves of electrons (a proton or an atomic nucleus in the center of an atom) requires setting the boundary condition in the center of the quantum resonator on the ψ-function of the de Broglie wave of the electron $\psi(0) = 0$. This quantum boundary condition leads to the presence in the hydrogen atom of only sin waves with asymmetric ψ_n functions and with the spectrum $E_n \sim n^{-2}$. All other requirements about the limitation of the ψ-function or its first or second derivative, according to the QCM, are superfluous and erroneous. This is proved in experiments with electron capture into the inner cavity of fullerenes and nanotubes and the formation of endoelectrons in hollow nanostructures with a resonance spectrum of $E_{n-1/2} \sim (n\text{-}1/2)^{\pm 2}$ [1, 4, 15-17].

Fig. 7. The formation of a back-moving drop during cumulation (focusing), reflected from the walls of a cylindrical symmetric resonator with a liquid when a drop falls on the liquid surface. It is cos waves, in contrast to sin waves, that accumulate energy, mass and momentum to the center of the hollow acoustic resonator.

2. When switching to spherically symmetric and cylindrically symmetric resonators, one should take into account the normalizing geometric coefficients that regularize the probability of finding a particle in the layer. This is often forgotten in textbooks on quantum mechanics. For this reason, some solutions of the Schrodinger equations (the first Helmholtz boundary value problem) are thrown out for no reason.

3. As we have shown, in accordance with the de Broglie hypothesis, the Eigen spectra of quantum hollow resonators in QCM do not differ from each other for all three types of symmetry: spherical, cylindrical and planar, and they are determined by the characteristic size of the quantum resonator.

4. As we have proved analytically (and compared with experiments on the example of electron capture C_{60}, C_{70}) in quantum hollow resonators with any type of symmetry, standing de Broglie waves of electrons with half the wavelength are possible.

5. For hollow quantum resonators, a new class of solutions with a proper energy spectrum of $E_{n-1/2} \sim (n\text{-}1/2)^{\pm 2}$ has appeared for potential wells " -", and for structures with potential barriers "+". This is how the degeneracy of the main quantum level in sin and cos waves in hollow quantum resonators appeared.

6. In hollow quantum resonators, transitions with the corresponding resonance spectrum are possible not only between sin waves, but also all transitions between the cos and sin states of de Broglie waves.

7. The de Broglie hypothesis indicates that when applied, it should be carried out a complete transfer of mathematical models from areas well studied in the field of natural sciences, which are not sufficiently studied. It is necessary to investigate the entire spectrum of similar phenomena, and not be limited to only particular solutions. So in wave physics, such phenomena as cavitation and sonoluminescence in acoustic resonators have long been known. These phenomena are caused by the accumulation of wave energy to the center of the acoustic resonator (see Fig. 7). In this paper, we point out the phenomena of unlimited cumulation of $\psi_{n-1/2}$-functions of quantum particles in hollow quantum resonators with spherical and cylindrical symmetries.

An excursion into the history of the creation of a new quantum mechanics [4] shows that the process of cognition is difficult, endless, and all modifiable models of the objects under study that arise in this process, even only in the field of nanoworld, require constant verification by experimental research and all the knowledge obtained in other fields of science. New models should not so much be cleaned from a number of solutions, looking for features at individual points, for example, in the center of a quantum hollow resonator with a 1/0-type feature for $\psi_{n-1/2}$-functions that do not carry physical meaning, but rather check the resulting solutions by carefully thought-out experiments experimentally establishing their own spectrum of hollow spherically symmetric quantum nanoscale resonators C_{60} and C_{70}.

The quantum rebound, which is expressed in the statement of the boundary condition at the center of the hydrogen atom for the ψ-function $\psi(0) = 0$, was not considered in the framework of the new quantum mechanics by Dirac. This condition $\psi\ (0) = 0$ due to the presence of an atomic nucleus in the center of the atom, which explains the absence of cos waves (symmetric with respect to the center of the resonator) in the spectrum of the hydrogen atom, as the main condition for quantum (wave) rebound, is put forward only in the framework of the QCM in [4]. The Comparison of experimental [15-17] and theoretical works [1, 3, 4] proved that, for analytic and numerical modeling of polarization interaction between the external electron and polarizing hollow molecules, for example, fullerenes C_{60} and C_{70}, it is possible to use the Gamow mathematical models formulated to describe the passage of α–particles through a potential barrier of an atomic nucleus. The modified model is based on the Schrodinger equation and the de Broglie hypothesis, a new quantum theory. By comparison with experiments, it is proved that the application of the old quantum Bohr model of the hydrogen atom does not describe the phenomena of polarization capture of an electron (the formation of a negative ion with an endoelectron) and leads to errors in the description of phenomena in cumulative-dissipative quantum structures.

4. Conclusions

The technological process used in this work is a breakthrough. First, in it, using our technique, it is possible to spray any materials from one target, setting their concentration by a simple ratio of the areas in the zone of maximum target erosion. Secondly, any physical alloying carbides (Fig. 6) can be obtained by a simple joint sputtering of metal and graphite without feeding explosive gases into the working volume of the chamber. Third, by controlling the sputtering mode (plasma discharge power density), it is possible to change the structure and phase composition (free amorphized graphite content) in a wide range and thereby control the properties of the most important performance characteristics of composite coatings based on carbides (hardness, wear resistance, friction coefficient, etc.).

The method of physical doping, developed by the authors, has no world analogues and can be used to solve problems of nanoelectronics and optoelectronics.

In its pure form, carbides have an increased brittleness. To increase their plastic properties, the metal phase is introduced into the composition of carbides and the grain is ground, then they are sintered. In this process, the formation of charged layers does not occur.

In order to preserve fine-grained carbides, we used an original method of physical doping of carbide nanocrystals with carbon nanostructures, which are traps for free electrons, for long-term operation of devices based on them. Structures made of carbon, polarized, pull over a portion of the free electrons of the composite. They themselves are charged negatively, and the nano-crystals of carbides that donated free electrons are charged with a positive charge (Fig. 6). For this reason, positively charged carbide nanocrystals do not recrystallize with time.

Without the formation of layers of space charge (Fig. 1 and Fig. 6), the nanocrystals in the nanocomposites crystallize case of energy loads.

The method allows, under certain conditions (changing the power density of a plasma discharge in the range of values from 40 to 125 W/cm^2), the joint spraying of mosaic targets with different compositions of materials, for example, metal-graphite; graphite-

metal-carbide; carbide metal; carbide metal - graphite and in a wide range to vary equally the composition (the ratio of the areas occupied by the metal, carbide and graphite) and the dispersion of the crystal structure, the change in the discharge power. The carbide coating rates using this stationary discharge method at such sputtering power densities of materials (metal and graphite) are 0.1 to 0.7 μm/min, which is almost an order of magnitude more than with conventional magnetron sputtering (MRSPVD) and vacuum arc spraying (ARC-PVD). In our case, we can get not only carbides, but also other phases, including nanocarbon and metal nanostructures (Fig. 6). This idea is confirmed by the properties and features of the processes of applying a composite coating of metal-carbon, where the metal does not interact metallurgically with carbon. In this case, the coating has a two-phase composition consisting of metal nanostructures and a nanographite phase [2].

The theory of quantum-size effects, developed by us in [4] and tested in [1-3, 6, 7, 11, 13, 19, 20], including these experiments, successfully works for physically doped carbides (Fig. 1, Fig. 6). Thus, in [2, 6, 7, 9, 19], during physical doping of copper and in aluminum, hardening of materials in 10 times, to 10 GPa was obtained, and in the case of carbides in this work, we obtained up to 31 GPa. According to the theory [4], hardening of nano-composites is possible during physical doping with fullerene layers up to 100 GPa.

We have created nanostructured materials, including materials with increased strength and wear resistance, heterogeneous at the nanoscale, physically doped with nanostructures - quantum traps for free electrons. It has been established that the presence of nanographite in the composite significantly improves the toughness and expands the range of possible applications compared to pure carbides. Carbon nanostructures can function as a conductor in the sp^1 – carbine-and sp^2 chain of the planar structure of graphene and graphite, or as a wide-band dielectric with sp^3 bonds − for example, diamond, etc. The first two has the potential to form bonds that are electrically conductive, and sp^3 has heat-insulating properties. These properties suggest that nanostructured composite materials have a powerful potential for their application in transistors and other electronic components [5]. Our research is of special interest to the nuclear industry and rocket production, where high-temperature composites are needed.

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