

Magnetic hydride of carbon

S.S. Agafonov¹, G.I. Borisov¹, I.F. Kokin¹, S.A. Lushnikov², N.N. Parshin¹, and V.A. Somenkov¹

¹*"Kurchatov Institute", Moscow, Russia*

²*Lomonosov State University, Moscow, Russia*

At studying interaction of hydrogen and amorphous fullerites under pressure over 10^7 Pa and temperature over 400°C , we have found out crystal hydride phase, containing about 4%(mass) of hydrogen (approximate composition C_2H).

Samples of this phase have been studied using neutron and X-ray diffraction. We observe graphite-like hexagonal crystal lattice with characteristic parameters $a \approx 2a_{\text{gr}}$, $c \approx c_{\text{gr}}$ (alike intercalates of metals). This phase possesses ferromagnetic properties. Magnetic susceptibility linearly increases with temperature. Coercitive force is rather high ($H_c > 800$ Oe).

Some of samples, according to the neutron activation analysis, contain trace amounts of nickel, and they possess stability in magnetic properties for 20 months, therefore the stable magnetism is probably influenced by impurities and their interaction with carbon.

Interaction of deuterium and amorphous fullerites gives the ferromagnetic phase with essentially differed structure and other magnetic properties.

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Superconductivity in new fullerene composites

V.I. Berezkin¹ and V.V. Popov²

¹Scientific Research Center for Ecological Safety RAS, St.Petersburg, 197110 Russia

²Ioffe Physical-Technical Institute RAS, St.Petersburg, 194021 Russia

As earlier reported [1], a new family of fullerene materials is synthesized. The materials are binary and triple chemical compounds of C₆₀ with carbon matrix.

For synthesis, mixtures of polycrystalline \tilde{N}_{60} powders with different hydrocarbon couplers and doping materials are treated with high pressures and high temperatures. When pressure is applied, molecules of heterocompounds penetrate into \tilde{N}_{60} lattice. Then at elevated temperatures hydrocarbons and other materials are decomposed, volatile matters (hydrogen and others) go away. As a result, C₆₀ molecules or their blocks are connected not directly, as in polymers, but by means of carbon bridges. Doping elements are firmly built into a structure too. Preliminary preparation of initial compositions, the synthesis, sample investigations all perform in the air. Synthesis duration is few minutes. The resulting samples are strong enough and insoluble. Halogens, their mixtures, and Na were used as acceptor and donor impurities. In both doped and undoped samples, weak and extended by temperature Meissner effect is observed.

On doping with Na, a superconductor is obtained. The initial mixture of \tilde{N}_{60} with naphthalene and sodium azide at molecular ratio $1\tilde{N}_{60}:6C_{10}H_8:3.5NaN_3$ is subjected to synthesis at pressure $P=8$ GPa and temperature $T=670^{\circ}N$. In such a situation, superconducting state occur at $\hat{O} \approx 15 \hat{E}$, and it is not affected by the air (at least during one year). Habitual phase transition is absent. Gradual decrease of electrical conductivity down to zero with temperature reduction is observed. At $\hat{O} > 15 \hat{E}$, a mixed current (supercurrent and current of normal quasi-particles) is proposed to exist [2]. For this reason and because of other circumstances, composites are believed to hold much promise for high temperature superconductivity. Instead of phonon mechanism, interaction of conduction electrons with the π -electron system of \tilde{N}_{60} molecule is proposed for the formation of Cooper pairs.

The described technology was applied to fullerenes for the first time. In itself the technology is rather simple and simultaneously flexible. One can vary a composition and synthesis conditions. Doping elements can be included in initial mixtures both directly or by means of decomposing chemical substances. Fullerene \tilde{N}_{70} , higher fullerenes, nanotubes and other nanoparticles can be used. So, the suggested mode of synthesis may be interesting for nanotechnologies.

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Electro-magnetic properties of iron- and cobalt-fullerene clusters

N.V. Bulina^{*}, E.A. Grehova⁺, G.A. Glushenko^{*}, L.A. Chekanova^{*},
E.A. Denisova^{*}, and G.N. Churilov

^{*}*Kirensky Institute of Physic SB RAS, 660036 Krasnoyarsk, Russia*

⁺*Polytechnic Institute of Siberian Federal University, 660074 Krasnoyarsk, Russia*

A great interest to investigations of metal nanoparticles is due to the revealing of new possibilities of their application in different fields of science and technology. It is known that owing to large surface square, nanoparticles incline to aggregate and form large particles, which do not have unique nanoparticles properties. Stabilization of nanoparticles can be realized by fullerenes having large surface activity. These molecules can prohibit aggregation.

Our investigations showed that Fe and Co nanoparticles, covered by carbon shell, form clusters like $nF \cdot mM$, where F – fullerene, \dot{I} – atom of Fe or Co. The clusters are formed at mixing of the nanoparticles and benzene fullerene solution under ultrasonic waves (22 kHz frequency). The dependence of obtained cluster amount on the time of ultrasonic treatment has been investigated. It was found that for Fe nanoparticles the maximal concentration (0.74%) of Fe in the fullerene mixture have been detected after 3 min. treatment. In the case of Co the maximal concentration was 0.28 % after 10 min. treatment.

Investigations, carried out by ferromagnetic resonance and magnitometry indicated that metal nanoparticles had spherical forms and consisted of superparamagnetic and ferromagnetic phases in cases of the both metals. As for iron, superparamagnetic part had particle size less than 160Å, their amount was equal to 94%. As for cobalt, one had size less than 50Å and amount was 96%.

In such clusters metal atoms and fullerenes are associated by Van der Waals forces. Creation process of these structures can be described as following: fullerene clusters destroyed under ultrasonic waves, than, after shutdown the influence, combined again trapping metal nanoparticles. Differences in effective time of the treatment as well as different maximal metal concentration in fullerenes point out on essential role of nanoparticles properties.

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NMR study of ferromagnetic rhombohedral C₆₀ polymer

M. Gu, Y. Yu, L. Zhang, X. Xu, S. Wang, and X. Xu

*National Laboratory of Solid State Microstructures, Nanjing University, Nanjing 210093,
People's Republic China*

We have prepared a batch of C₆₀ polymer under the high-temperature and high-pressure condition of 973 K and 5 GPa, and the polymer was confirmed to be rhombohedral phase by XRD method. The weak ferromagnetism has also been detected by SQUID method at 1.8 K for this sample. Its coercive field and saturation magnetization are about 110 Oe and 4.0×10^{-6} (emu/g), respectively. We have further acquired the ¹H, ¹³C MAS and ¹H-¹³C CP/MAS NMR spectra of the sample. We observed a broad resonance peak of hydrogen, and several ¹³C resonance peaks under the condition of ¹H-¹³C cross-polarization. By analysis of these NMR spectra, we found that this sample was partly hydrogenated, and the hydrogen atoms are bonded with carbon atoms of C₆₀ ball. The C-H bonds would be possibly to replace some of inherited C-C sp³ bonds between the C₆₀ balls. By comparison of the hydrofullerenes reported earlier, we proposed that the origin of the ferromagnetism of our rhombohedral C₆₀ polymer might be due to the existence of hydrogen impurities. The hydrogen might be introduced into the sample during preparation of the C₆₀ polymer under high-temperature and high-pressure condition.

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Oxygen effect on magnetic properties of fullerenes

O.E. Kvyatkovskii* and I.B. Zakharova⁺

*Ioffe Physical-Technical Institute RAS, 194021 St. Petersburg, Russia

⁺State Polytechnic University, 195251 St. Petersburg, Russia

Recently, room temperature ferromagnetism has been reported in oxygenated fullerenes induced by ultraviolet [1-3] or heavy-ion [4] irradiation. The experimental data indicate that the ferromagnetic phase is not produced when the irradiation occurs in high vacuum [1]. In the present paper, we consider the role of oxygen in formation of magnetic properties in fullerenes on the basis of *ab initio* calculations of oxygen energetics in fullerene matrix. The optimized geometry and electronic structure of several molecular complexes $C_{60}O$, $C_{60}O_2$ and $C_{60}-O-C_{60}$ in singlet and triplet spin states are calculated in the framework using DFT/B3LYP method on 3-21G and, partly, 6-31G* levels. It is found that dissociation of intercalated oxygen molecule into pair of exohedrally attached ligands is energetically favorable: $E(O_2)+2E(C_{60})-2E(C_{60}O)=1.48$ eV, where $C_{60}O$ epoxide isomer has singlet ground state. The polymerization of the fullerene matrix due to mono-oxidation is considered. The singly-bonded and conjectured [2+2] cycloaddition mechanisms for $C_{60}-O-C_{60}$ formation from $C_{60}O$ and C_{60} are examined by *ab initio* calculations. The applicability of the spin-transfer model [5] of ferromagnetism in doped polymerized fullerenes for the magnetic irradiated material is discussed. The work is supported by the Russian Foundation for Basic Research (Grants 05-02-17779 and 06-02-17305).

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Study of metallic clusters in carbon nanofoam

B. Ayan⁺, N.D.Khan⁺, A. Mombru[♦], H. Pardo[♦], R. Faccio[♦], T. Makarova^{+*}

⁺ *Umea University, Umea, Sweden*

^{*}*Ioffe Physical-Technical Institute of the RAS, St. Petersburg, Russia*

Universidad de la Republica, Montevideo, Uruguay

Graphite, which is one of the most extensively studied carbonaceous material both experimentally and theoretically has remained the backbone of carbon science. Recently, electronic properties of nanostructure graphite have attracted much attention from researchers and industrialists. An easy way of producing graphite nanofoam by a redox reaction in a closed system between graphite and CuO in the vapour phase was suggested by us earlier. The samples were prepared from pure graphite, or from graphite with the addition of 1–5% boron to the starting reactant. We have found the correlations between the nanostructure of the material and its magnetic properties such as high-temperature diamagnetism and low-temperature paramagnetism. The boron content governs the diamagnetic properties of the material: the more boron in the pristine material, the more diamagnetic is the sample. The value of the Curie constant is also largely determined by the boron content in the material, whereas this constant does not depend on copper and iron concentration in the samples. Moreover, we did not find an expected correlation between the superparamagnetic properties and the iron content: for the same iron concentration we observed different behaviors, from diamagnetic, through superparamagnetic to the overcome of superparamagnetic limit. Wild differences in magnetic and physical structure from the thermal treatment and background gas condition do exist and are important for the formation of metallic clusters incorporated in carbon nanofoam.

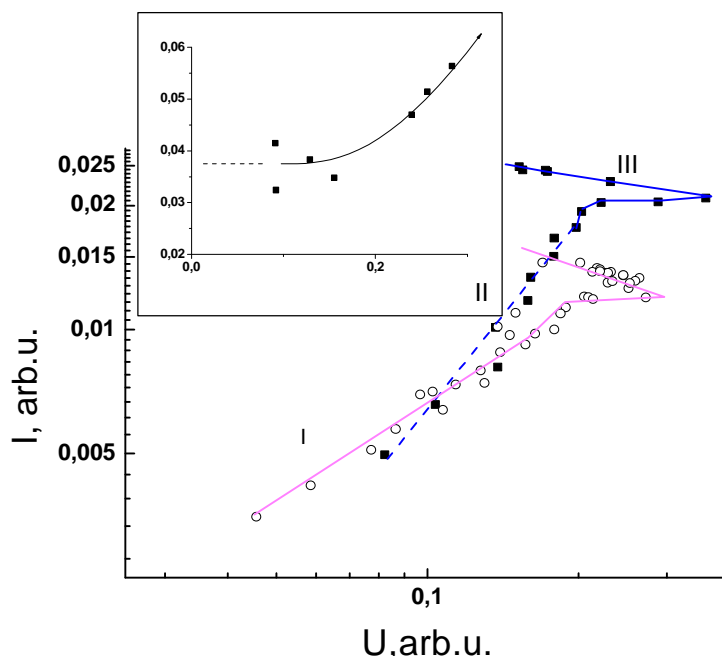
The superconductivity, electrical instabilities and statistical measurements in Cu_nC_{60} polycrystals

A.V. Prikhodko, O.I. Konkov, and I.D. Mishin

St.Petersburg State Polytechnical University, 195251 St.Petersburg, Russia

The complex of studies carried out on Cu_nC_{60} polycrystalline samples, including Meissner measurements, clearly support the existence of a superconducting phase with $T_c > 78\text{K}$ [1]. In this paper we present a detailed study of the nanosecond voltage-current characterization including statistical resistance distribution on above mentioned samples.

The samples that were investigated were in the form of cylinder 2 mm diameter and 0.5 mm thick [2]. Square pulses of 10 ns and 0.4 ns rise time were used for I-V dependence.



Typical I-V curves for the Cu_nC_{60} samples are presented in Fig. As can be seen, I-V curve consists of several line (sections) with different slopes: I-ohmic, II-injection type, III-the instability region. At lower temperatures from 300K (?) to 78K (?) the first section is spreading and the second, third decreases. The detailed shape of I-V curves near $V \sim 0$ in I section (insert) was typical for superconductive state.

It was found that a junction from normal statistical spreading to homogenous of the resistance in III section is the result of sufficient heating of current channel. A possible mechanism for this behavior is considered on the basis of the concepts of percolation network and pinchlike current distributions.

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