Magnetic Resonance Study of Fullerene-Like Glassy Carbon

A.I. Shames[1], A.M. Panich[1], E.W. Prilutskiy[2], E.A. Katz [3]

[1] Department of Physics, Ben-Gurion University of the Negev, Be'er -Sheva 84105, Israel
[2] Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Krzhizhanovski Str. 3, Kiev, 03142 Ukraine
[3] Dept. of Solar Energy and Environmental Physics, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer, 84990 Israel

Recent High Resolution Transmission Electron Microscopy study revealed that the glass-like carbon (GC) samples, produced by a multi-step carbonization of sucrose at which the highest temperature of the heat treatment was only 450-650°C, show well defined multi-shell fullerene-like (or onion-like) structure. These samples were studied by means of Electron Magnetic Resonance (EMR) and Nuclear Magnetic Resonance (NMR).

EMR study unambiguously demonstrate that the GC samples are magnetic ones. There are two sources of magnetism observed: extrinsic magnetism due to para- and ferromagnetic impurities entrapped during the GC synthesis and intrinsic magnetism due to the dangling bonds in carbon system. The EMR signal of carbon centered paramagnetic defects has Lorentzian line shape and 2.0030 ± 0.0001. Its line width as well as spin-lattice relaxation time were found to be extremely sensitive to ambient conditions such as partial oxygen pressure and humidity. The latter facts allows proposing this GC as a proper working substance for the EMR oxymetry. The total amount of carbon originated paramagnetic defects exceeds 2×10^{19} spin/g. The intrinsic magnetism obeys the Curie law below 400K down to 130K. It was suggested that carbon originated paramagnetic defects exist in all layers of imperfect fullerene(onion)-like particle and clisterize around breaches in the graphene shits which are large enough allowing oxygen to penetrate freely through these particles.

Room temperature ^{13}C NMR spectrum of these samples [B_0 = 8.0196 T, $\nu(^{13}C)$ = 85.85 MHz] shows a complicated line which may be fit by a superposition of two broad lines and two weak narrow peaks. The most intensive component (σ = 179 ppm) belongs to sp^2 carbons. Another components (~ 200 ppm, 54 ppm and 13 ppm) are attributed to some carboxyl (COOH) or carbonyl (C=O) groups, CH and CH_2 groups and sp^3 carbons. ^{13}H NMR spectrum shows superposition of broad and narrow lines corresponding to rigid and mobile hydrogens. T_1 and T_2 relaxation times have been measured and discussed within the model of system containing intrinsic paramagnetic centers, as it was found by EMR.