MAGNETIZATION OF DIAMOND-GRAPHENE FLAKES COMPOSITES

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Magnetic properties of composites from nanodiamond and pyrocarbon (NDC) with the factor γ = mass ratio of sp2/sp3 phases have been studied. Solid bulk porous NDC is made as described in [1]. NDC is semiconductor with the electrical conductivity has changed by 12 orders of magnitude that are controlled by the ratio γ from 0 to 80 % [2]. NDC has intrinsic paramagnetic properties that are permanent for all values of γ [3].

Taking into attention the recent analysis of experimental errors in the observation of nanoscale magnetism [4] we report here the results detailed study the magnetization of NDC by a few methods: wide-angle X-ray diffraction, EPR, Mossbauer, Raman and FTIR spectroscopy. Magnetic measurement was made on the different type of magnetometers (vibration, SQUID, PPMS). The bulk magnetization and ^{13}C NMR spin-lattice relaxation of nanodiamond powder samples have been studied [5] and nonaromatic core-shell structural model of nanodiamond particles has been proposed recently [6].

The total magnetization of NDC can be explained in terms of contributions from (1) the temperature independent different diamagnetic and paramagnetic effects of nanodiamond and graphene flakes $\chi_{\sum}$, (2) the strong temperature dependent paramagnetic effect of unpaired electrons of nanodiamond and tetrahedral Fe-centers into nanodiamond structure, and (3) ferromagnetic-like contributions from magnetic impurities M_{ferro}. The results are shown in the figures 1 and 2 and table 1.

Main our result is following: NDC is magnetic semiconductor with phantom doping by Fe of nanodiamond. The principal possibilities of doping by Cr and S using porous structure of NDC have been illustrated here in the first time.

Recent synthesis of luminescence nanodiamonds from carbon black of 99.9 % purity [7] shows useful method to delete impurities naturally present in detonation nanodiamond.

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Figures:

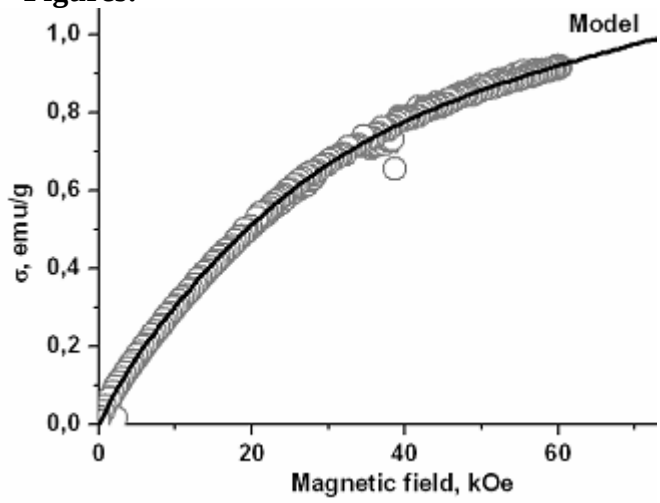

Fig. 1. Magnetization of NDC sample #1.

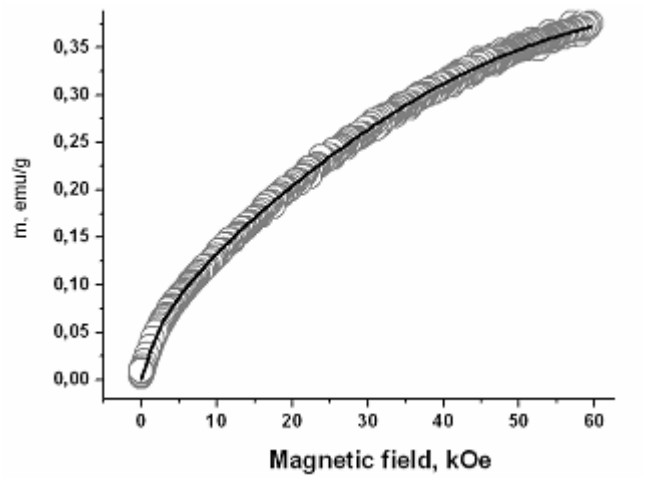

Fig. 2. Magnetization of NDC sample #7.

Table 1 – The results of magnetic measurement of diamond-graphene flakes composites

#	γ, %	H, Oe	T, K	Doped by	M_{ferro}, emu/g	N, spin/g	N/N_m	g	spin	χ_Σ
1	0	var	4,2	Fe*	0,05	3,00E+19	1600	4,4	0,5	4,37E-06
2	10	var	4,2	Fe	0,1	5,46E+19	835,16	2	0,5	-1,58E-06
3	20	var	4,2	Fe	0,1	5,81E+19	719,80	2	0,5	-2,14E-06
4	20	500	var	Cr		4,50E+19	261,38	2	0,5	2,40E-06
5	30	var	4,2	Fe	0,08	5,46E+19	706,67	2	0,5	-1,55E-06
6	40	var	4,2	Fe	0,07	6,60E+19	543,12	2	0,5	-2,00E-06
7	40	var	4,2	Fe	0,04	6,95E+19	515,77	2	0,5	-2,33E-06
8	40	500	var	S		3,60E+19	995,72	2	0,5	-1,20E-07
9	50	var	2	Fe	-	2,00E+20	167,28	2	0,5	1,52E-05
10	60	500	var	SiO_2**		9,26E+18	3388,28	2	0,5	4,30E-07
11	80	var	4,2	Fe	0,04	6,58E+19	423,85	2	0,5	-3,85E-06

Notes: *There are Fe < 0.4% in all samples except #1 where Fe < 4.3 mass %.
**NDC where nanodiamond was substituted by SiO_2 completely.