Structure and properties of onion-like carbon produced via annealing of nanodiamond.

V.L. Kuznetsov, Yu.V. Butenko, A.L. Chuvilin, A.V. Okotrub[1], L.G. Bulusheva[1], A.I. Romanenko[1]
Boreskov Institute of Catalysis SB RAS, Lavrentieva 5, Novosibirsk 630090, RUSSIA.
[1]Institute of Inorganic Chemistry SB RAS, Lavrentieva 3, Novosibirsk 630090, RUSSIA.

We were the first to demonstrate the large-scale production of onion-like carbon (OLC) and graphite/diamond nanocomposites with different ratios of closed curved graphitic shells and nanodiamond cores (with controlled sp^2/sp^3 ratio) by vacuum annealing of nanodiamonds (ND) at temperatures of 1400-2140 K[1,2] (see Fig.1). Transformation of diamond nanoparticles to onion-like particles was also observed under the electron beam irradiation[3].

X-ray fluorescence spectroscopy investigation of OLC and graphite/diamond nanocomposites produced at various temperatures of ND annealing detected the enhanced density of weekly bonding states in the former material. Quantum-chemical semiempirical AM1 calculations on the carbon cages showed such enhancement is more likely explained by the occurrence of dandling bonds in an internal carbon cage, which may significantly modify the chemical and physical properties of OLC compared to the polyhedral graphitic particles prepared on the final stage of ND annealing at temperature of 2100 K. The holes in OLC may cause unusual effects in its transport, magnetic and optic properties. The origin of such defects accompanying the OLC formation can be explained in terms of deficit of diamond carbon atoms in the diamond/graphite interface to form perfect fullerene-like shells during ND annealing. We proposed that the sphericity of onions produced by ND annealing at the intermediate temperature (1400–1900 K) can be explained by the formation of holed structure of onion shells[4].

The electrical resistivity of annealed ND is characteristic of systems with localized electrons and can be described in terms of variable hopping-length hopping conductivity. Measurements of temperature dependence of electrical resistivity and magnetoresistivity of carbon nanoparticles with different graphitization degrees was used for estimation of conduction carrier concentration and a length of free path of carriers. The free path length of electrons within OLC particles is comparable with the size of graphitic fragments within holed structure of single onion (l ~ 12±2 Å). When their holed structure is annealed with the formation of hollow polygonized structures the free path length of the electron increases up to 18±2 Å. The size localization length of current carriers is comparable with the size aggregates of OLC particles. Within the aggregates onions are linked to each other with defect graphite-like sheets and C-C bonds[5].

OLC and graphite/diamond nano-composites produced via annealing of ND can be considered as perspective materials for electrochemical electrodes and supercapacitors due to the presence of accessible mesopores and high surface area.

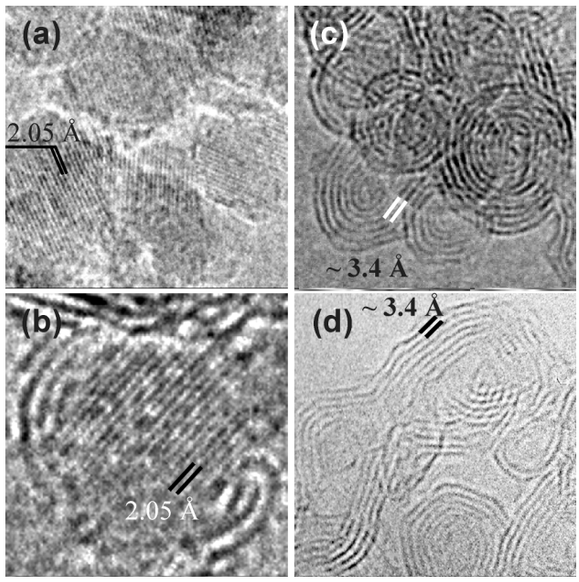

Fig. 1. HRTEM micrographs of ND samples annealed under vacuum at (a) 1170, (b) 1600, (c) 1800, (d) 2140 K.

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