CARBON NANOCAPSULES WITH A FERROMAGNETIC CORE PRODUCED BY A CATALYTIC DISPROPORTIONATION OF CARBON MONOXIDE

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According to literature data most of the carbon nanotubes, produced by various catalytic methods, are decorated by spherical carbon nanocapsules of a diameter of 5 – 100 nm, with a catalyst metal core [1]. In this paper, we suggest a new concept of production of carbon nanocapsules with a ferromagnetic core by a catalytic disproportionation of carbon monoxide (CO), deposited at the reactor sites spatially separated from the sites of deposition of other products of the process (carbon nanotubes, large carbon onions, amorphous carbon).

A Fe_2O_3 powder of a specific surface area of 15 m^2/g was placed in a Cu crucible and heated up to 540 – 600 ^oC in CO gas flowing through a quartz tube reactor. Products of the reaction were studied by Transmission Electron Microscopy (TEM), High Resolution Transmission Electron Microscopy (HRTEM), Energy Dispersive Spectrum (EDS) analysis and X-Ray Diffractometry (XRD).

Figure 1 shows HRTEM image of two carbon-encapsulated nanoclusters with defect-free crystalline structure. HRTEM micro-diffraction pattern, EDS analysis and XRD revealed that the nanocapsule cores consist of highly crystalline magnetite (Fe_3O_4). Deposition of such nanoparticles, with a diameter of 2 – 10 nm, has been found to occur at cooled parts of the reactor.

A possible mechanism for a formation of the nanostructures is suggested. In particular, we assume that the core-clusters are generated in the active zone of the reaction of carbon monoxide disproportionation, while carbon shells, encapsulating a core, are formed during a diffusion of the latter from the active zone of the reaction, in a CO atmosphere. Indeed, movement of aerosol particles is known to be governed by diffusion rather than gravitation and aerodynamic principles. In our experiment, the aerosol Fe_3O_4 particles have been found to diffuse along the temperature and concentration gradient from the active zone of the reaction in the directions along and even against (!) the gas flow. During their diffusion in a CO atmosphere, these core nanoclustes act as catalysts and instigate the formation of encapsulating carbon shells.

The encapsulating carbon shells of the Fe_3O_4 nano-clusters are stable in air at room temperature, but do not prevent them at high temperatures. Accordingly, these nanoparticles may also act as catalysts for the corresponding production of carbon nanomaterials via carbon monoxide disproportionation. For example, we have demonstrated the corresponding transformation from Fe_3O_4 core to a nanoparticle of a pure Fe with a simultaneous formation of additional encapsulating carbon layers. Figure 2 displays an HRTEM image of such a nanocapsule. One can clearly seen an ~ 10 nm Fe cluster encapsulated by as many as 6 concentric quasi-spherical carbon shells. The distance between the carbon layers are found to be close to that of graphite, 0.34 nm.

References:

1. “Carbon Nanotubes: Synthesis, Structure, Properties and Applications”, M. Dresselhaus, G. Dresselhaus and Ph. Avouris, Eds., Springer-Verlag, Berlin, 2001.

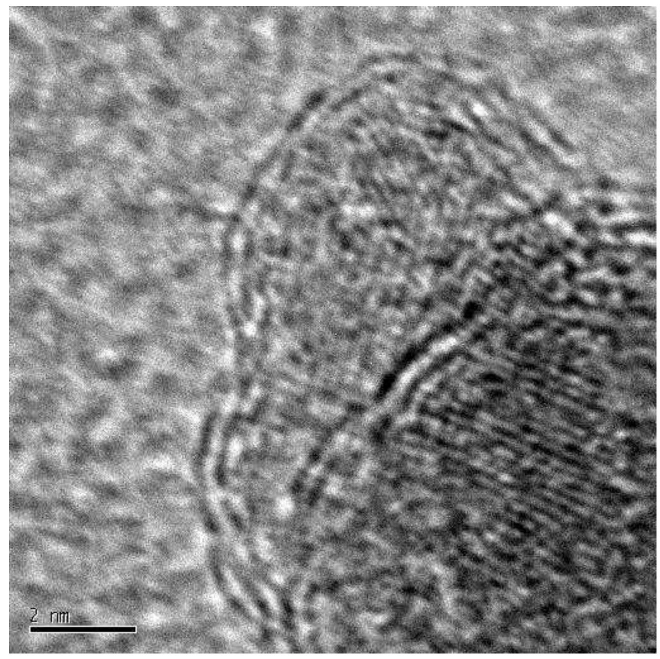

Fig. 1. HRTEM image of two carbon-encapsulated nanoclusters of Fe_3O_4.

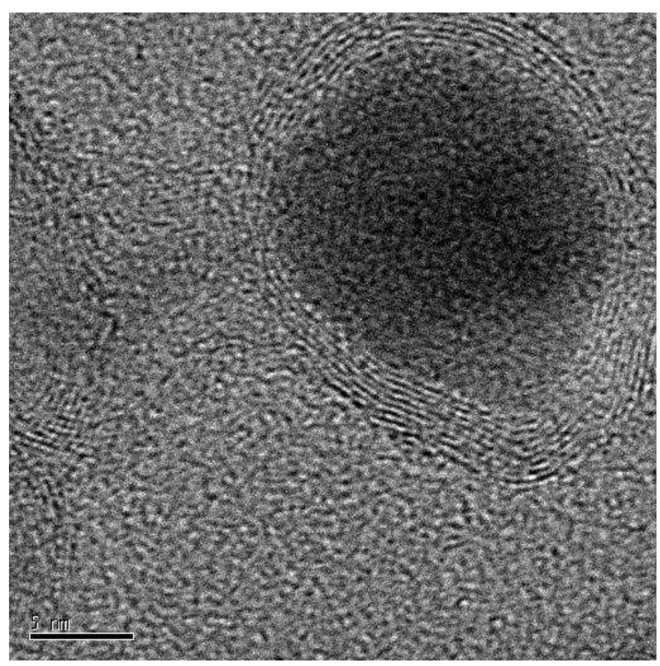

Fig. 2. HRTEM image of a carbon nanocapsule with a Fe core.