Gas-phase Method of Production of Metal Nanocrystals Encapsulated in Carbon Shells: Perspectives of Applications

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Nanoparticles encapsulated in carbon shells are of great interest to researchers due to ability of the shell to preserve physico-chemical properties of the metastable core nanoparticles for prolonged period of time. Starting from '90s a variety of methods had been developed for synthesis of fullerenes, carbon nanotubes and metals encapsulated to carbon including most widely used arc-discharge and laser ablation methods. Nanoparticles or clusters of the transition metals (Ni, Fe, Co) introduced to a carbon-containing gas phase act as nucleation centers for the carbon solid phase. If a gas phase containing methane, high molecular weight hydrocarbons or alcohols is thermally activated, such process recently had been called CVD (chemical vapour deposition) method [1]. The novelty of the reported method is in utilizing core metal nanoparticles which are dispersed in the gas-phase rather than placed on a substrate. Metallic clusters concentrated in the vicinity of the metal evaporation zone (in our case, induction overheated droplets at a gas-phase (GP) synthesis) serve as centers of nucleation and growth of the carbon phase. Catalytic decomposition of hydrocarbon molecules at the surface of the generated metal nanoparticles result in formation of the carbon shells preventing metal nanoparticles agglomeration.

We will report on a variety of demonstrated and prospective applications of the nanocomposites based on the metal encapsulated in the carbon (MEC) synthesized by the GP method. Particularly, very encouraging results had been obtained in animal studies on using MEC nanoparticles for cancer treatment. MEC functionalized with specific biopolymers were accumulated with high specificity in the malignant tumors. High therapeutic efficiency had been demonstrated in the treatment of MEC-containing tumor using short pulse laser irradiation. Importantly, MEC biocompatibility studies demonstrated low toxicity of the composites. Perspectives of the applications of MEC in catalytic decomposition of chlorobenzene to less toxic and useful products (benzene, cyclohexane) had been also demonstrated. Highly efficient MEC-assisted hydro-dechlorination of the chlororganic compounds is ecologically safe and economic approach to degrade chlororganic wastes and polychlorinated biphenyls. Development of hydrogen storage materials is one of the hot topics in the energy-related R&D. Here we report on the method of production of the magnesium hydride using nano-catalysts based on Ni and Fe encapsulated to carbon [2]. As compared to known thermohydrogenation of Mg at high pressure (more than 50 atm.) and high temperature (more than 400°C) we suggested novel mechanoactivation process at atmospheric pressure and room temperature for production of the magnesium hydride using GP-produced MEC (Ni@C, Fe@C) allowing synthesis of magnesium hydride with high hydrogen capacity. We will also report on the EMI shielding efficiency of the MEC in infrared and microwaves spectral ranges.

Possibilities of scale-up for manufacturing metal-carbon nanocomposite catalysts of hydrogenation will be also discussed.

We greatly acknowledge Stratonnikova A.A., Losenkova V.B., Konov V.I. (IGP RAN, Moscow) for the investigations of MEC in cancer diagnostic and therapy. We are grateful to Lokteva E.C., Kachevskii S.A., Golubina E.B., Lunin V.V. (Department of Chemistry, MSU, Moscow) for the data on MEC-assisted hydro-dechlorination of the chlorobenzene.

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[2] Yermakov A.E. et al., Patent of Russian Federation- №2007106398/15(006945).