Review

of the foreign scientific supervisor, d.c.s. Farit Khisamutdinovich Urakaev for the thesis of Zhandos Smagulovich Shalabayev "Solid-phase and liquid-phase preparation of sulfur nanoparticles and their composites: properties study and application fields" submitted for the degree of Doctor of Philosophy (Ph.D.) in the specialty 6D072000 – Chemical Technology of Inorganic Substances

Recently, sulfur-based composite materials are widely used in agriculture, lithium-ion batteries, pharmacy, and many other fields of science and technology. In this regard, the study of properties composite materials is of theoretical and practical interest. Moreover, nowadays preparation of composite nanomaterials is becoming in material science hot topic due to their enhanced physicochemical properties and possibilities than individual nanoparticles. In this dissertation work, sulfur, copper sulfide (CuS) nanoparticles, and nanocomposites based on sulfur, CuS, and alkali-earth metal carbonates have been successfully synthesized using solid-phase and liquid-phase preparation methods at ambient conditions.

The synthesis of cost-effective composite materials based on sulfur nanoparticles via facile, cheap, and environmentally-friendly preparation methods is very important.

In this regard, for the first time, using liquid-phase method sulfur-containing S/MCO_3 (M: Ca, Sr, Ba) have been synthesized via the reaction of carbon dioxide with alkaline earth metal polysulfide at room temperature. In addition, sulfur nanoparticles easily separated from the as-obtained nanocomposite treating it with strong inorganic acid (HCl). In contrast, to separate carbonate nanoparticles, nanocomposite was possessed with hydrazine hydrate dissolving sulfur nanoparticles. Obtained sulfur, alkaline-earth metal carbonate nanoparticles, and nanocomposite material based on them have been investigated for hydrophobic and anti-biological properties. Thus, a cheap and cost-effective method was developed to prepare sulfur-containing nanocomposite and its individual components.

Regarding solid-phase synthesis, using mechanochemical method, CuS nanoparticles have been successfully synthesized. This work for the first time demonstrated the possibility of applying mechanochemistry in the synthesis of CuS nanocrystals with different shapes (spherical and needle-like). It was found that upon introducing sulfur to the reaction system of acetate route synthesis of CuS nanoparticles proposed by Prof. P. Balaz, elongated needle-like CuS nanocrystals were formed. In the results of simple acetate route synthesis, spherical CuS nanocrystals have been prepared. When as-obtained CuS nanocrystals with different shapes were tested for antibacterial activity against *E. Coli* and *S. Aureus* bacteria, needle-like copper sulfide (nCuS) nanocrystals were less-selective than spherical one. Thus,

developed method can serve as protocol for the shape-controlled synthesis of other chalcogenide compounds.

Zhandos Shalabayev proved to be a thoughtful and responsible researcher. During his doctoral thesis, he could publish two articles in international journals with high impact factor namely Colloid Journal (IF $\approx$ 1) and ACS Sustainable Chemistry and Engineering (IF $\approx$ 7). In addition, during his Ph.D. a conclusion on the issuance of two patents was received from RSE National institute of intellectual property (Republic of Kazakhstan) and Eurasian patent organization (Russian Federation). This proves once again that Zhandos is a hardworking and smart young scientist.

Overall the Ph.D. thesis of Zhandos Smagulovich Shalabayev represents a great deal of work. The results are well presented and their interpretation is at a high scientific level. The research it describes is of the international standard. This thesis is ready to be defended orally and certainly, meets the requirements for the degree of Ph.D. in the specialty 6D072000 – Chemical Technology of Inorganic Substances.

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