«Synthesis, structure, and sensory properties of functional materials based on d- and f-elements compounds»

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The publications for 2017-2021 contain studies focused on the development of methods for the synthesis of new materials based on transition and rare-earth metal compounds that exhibit sensory properties on a wide number of organic and inorganic compounds.

In recent years, the development of science and technology has been actively shifting towards interdisciplinary projects. Thus, one of the promising directions, combining the techniques and approaches of chemistry, materials science, biology, and medicine, is aimed at investigating the fundamental principles of synthesis of multifunctional "smart" materials, which can be used to create cutting-edge microelectronic, sensory, photovoltaic devices, etc.

The team conducted research to develop methods for the synthesis and characterization of metal-organic framework structures (MOFs). MOFs are hybrid metal-organic polymeric materials with easily changeable properties and are currently used in various fields of science and technology, such as in the production of OLED screens for Smartphones and computers, electrochemical and luminescent sensors in analytical chemistry, as catalysts of reactions in the chemical industry. The scientific team successfully synthesized new MOFs based on benzene dicarboxylates of transition and rare-earth metals for luminescent sensors for heavy metal ions. A new technique was developed for the preparation of MOF nanoparticles using ultrasonic methods, which was used to synthesize MOFs of the smallest europium metal-organic framework nanoparticles (8 nm). Also, the mechanism of MOF formation in different solvents was studied by spectrophotometry and light scattering methods.

The team investigated inorganic nanocrystalline materials based on NaYF4 with the addition of various other rare-earth ions that demonstrate luminescent and magnetic properties. The effect of luminescence enhancement of lanthanide ions (Tm3+, Er3+, Eu3+) by co-doping with non-luminescent lutetium and gadolinium ions was discovered. New polymodal agents for cancer tumor bioimaging using luminescence microscopy, X-ray luminescence and magnetic resonance imaging can be developed in the nearest future on the base of the obtained materials. The promising nature of these substances as biomedical agents is due to their unique optical and chemical properties, such as low autofluorescence, high signal-to-noise ratio, high penetration depth into biological samples, reduced toxicity, including phototoxicity, high chemical stability, high values of anti-Stokes shifts, possibility to control luminescence and magnetic properties at the synthesis stage of such compounds, and easy and fast synthetic procedure.

Another scientific direction of the team is the development of enzyme-free electrochemical sensors using direct laser synthesis technologies. Due to the high flexibility of the selective laser sintering process, the possibility of fabrication of patterns of any desired shape and geometry has been demonstrated. We have developed the methods for the fabrication of copper, nickel, and cobalt on the surfaces of various dielectrics (including polymeric wafers) by reductive laser sintering (reductive SLS) and first demonstrated the application of the synthesized structures as working electrodes for enzyme-free detection of biologically significant analytes, including glucose. The team developed methods for laser-induced synthesis of functional materials in various solvents, including deep eutectic solvents (DES). Fundamental principles of laser-induced synthesis in different solutions have been developed, mechanisms of reduction of copper ions under laser irradiation using different precursors have been described, which became possible due to performed investigations of mechanisms of photochemical reactions by femtosecond transient absorption spectroscopy (the complex formation mechanisms and excited-state dynamics of copper(II) complexes were revealed). Applying DES in laser-induced synthesis allowed increasing the synthesis speed by at least two times as compared to the traditional aqueous systems. Thus, the proposed method can successfully compete with traditional laser micropatterning technologies, such as laser sintering and laser-induced forward transfer (LIFT). The team has conducted for the first time laser-induced synthesis in deep eutectic solvents, which can become a starting point for the development of a new direction of laser materials science, as well as for the creation of a new environmentally friendly technology of high-speed laser deposition of various functional materials on dielectric substrates. The proposed approaches are very promising for creating effective and reliable electrochemical enzyme-free microsensors, as well as for creating a scientific basis for the revival of the microelectronics industry.

As a result of the experimental work in 2017-2021 - 15 papers were published in highly ranked peer-reviewed journals indexed in Web Of Science and Scopus (of which 10 in journals of the first quartile Q1 on SJR and/or JCR) with a total impact factor 46.809. One paper was accepted for the cover of the journal as the best publication of the issue. The results of the work were presented at Russian and international conferences (three invited and thirteen oral reports).