Keeping traditions: from the boom of HTSC to frontiers of functional materials

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Traditions have come to us from the ancient ages, the others are very new but no less valuable. Some of them have been developed during years and years, the others started from triggering events. It was the discovery of high-temperature superconductivity that gave birth to a new and successful tradition of the MSU-HTSC International Workshop. The time for the 7th Workshop has come this year, and we address this issue of the journal to a fruitful and, hopefully, lasting tradition, which is mainly supported by the Inorganic Chemistry Division of the M. V. Lomonosov Moscow State University.

The series of MSU-HTSC International Workshops was started in 1989. Recollecting that time following the discovery of high-temperature superconducting compounds, we should say that it was a period of a real blow-up in solid state science and very enthusiastic research in many physical and chemical laboratories over the world. At that time, attention was focused on HTSC materials. The expectations were, of course, exaggerated being overheated by mass media, which promised immediate and very broad applications of superconductivity. Now, about 17 years after the discovery, we are witness of the successful implementation of many applied projects based on HTSC materials, for instance, microwave filters that improve remarkably the quality of cellular net communications or the powerful and compact electric motors that operate at the boiling point of nitrogen. Another, not less spectacular, realizations are coming, such as superconducting cables for high current applications at 77 K and levitation based transportations. In spite of these important achievements, people, including scientists, in our days have no such a fervour to high-temperature superconductors as late in the 1980s and early in the 1990s. This is reasonable because a fantastic dream is always more attractive than the reality, even if the reality actualizes the dream. The humanity is not able (and is not obliged!) to keep fidelity to the same idea; it demands permanent change of priorities.

Nevertheless, considerable interest of the society to the prospects of superconductivity, even temporal, was very important because for this reason national programmes were established and supported in many leading countries. Russia was not the exception. In former Soviet Union, the science of superconductivity was traditionally of a high level. At first, it concerned theoretical research. It is sufficient to mention the names of V. Ginzbourg and A. Abrikosov – the 2003 Nobel Prize winners, as well as L. Landau, I. Dzyaloshinsky, L. Gorkov and A. Andreev, whose impact to the basic physics of superconductors is universally recognised. Applied research and materials science of traditional (‘low temperature’) superconductors were developed at the I. V. Kurchatov Institute of Atomic Energy and at the Institute of Inorganic Materials (named after Academician

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A. A. Bochvar), where various types of superconducting cables, including Nb_3Sn-based ones, were elaborated, and their production was established. It was a good starting point to formulate the State Programme (of the former Soviet Union) on High-Temperature Superconductivity in 1988.

The ideas and new political priorities of 'perestroyka' influenced the general principles of the programme. It was, possibly, the first scientific national programme having no military orientation. Moreover, from the very outset, the programme was opened for international collaboration. The interdisciplinary programme combined studies in physics, chemistry, and applications of new superconductors. The collaboration between physicists and chemists in this challenging area had became mandatory after very first attempts to understand the 'processing – structure – property' relations for new oxide compounds. The Scientific Council of the National Programme guided by Academician Yu. A. Osipyan (Institute of Solid State Physics, Russian Academy of Sciences) included a section of Chemistry and Materials Technology guided by Academician Yu. D. Tretyakov (M. V. Lomonosov Moscow State University, Department of Chemistry). The Department of Chemistry was the coordination centre and also the main centre of research in the chemistry and materials science of HT superconductors in Russia. The financial support received by scientific institutions involved in the programme made it possible to obtain the most necessary equipment for the synthesis and characterization of superconducting materials.

Among the most important results is, certainly, the discovery of the Hg family of superconductors with record values of critical temperatures, which was made by E. Antipov and S. Putilin jointly with M. Marezio. Note that it was not found by chance but designed on the basis of a structural concept derived from a systematic study of structure modification effects on T_c. Synthetic processes based on the solution homogenization routes were elaborated for most of HTSC compounds. In particular, a freeze drying technique for obtaining Bi2212 powders was elaborated. The powders thus processed are very homogeneous, disperse and easy to form. Due to these qualities, they are currently used in the powder-in-tube technology of superconducting tapes. The organometallic chemical vapour deposition technique was developed for thin films and heterostructures of superconducting compounds of rare-earth and Bi families. The high epitaxial quality of films manifested itself in their critical current values exceeding 10^6 A cm^{-2} (77 K, $H = 0$) and low surface impedance that renders the development of microwave resonators having a quality factor 10–20 times higher than that of a corresponding non-superconducting Cu resonator.

The short but impressive history of HT superconductors indicates that only chemical knowledge is insufficient for successful research work in the field of functional materials. Materials scientists should understand equally well both the physics and the chemistry of phenomena occurring in the course of processing and exploitation of materials. To educate a new generation of specialists in materials design, an interdisciplinary Department of Materials Science (DMS) was established in 1991 at the Moscow State University (MSU). About 200 Masters of Science and 20 Candidates of Science were graduated from the DMS. The education at DMS is tightly connected with the tradition of the MSU HTSC-Workshops. Many outstanding scientists, participants of the workshops, delivered lectures to students, and students took part in the workshops, usually, at poster sessions. Finally, international contacts started during the workshops have opened an opportunity for many students to have a stage in leading laboratories in the world.

Five workshops in 1989–1998 were focused on the chemistry and technology of HTSC materials. A number of new directions in inorganic chemistry and inorganic materials have been developed in the 1990s, starting from the multifarious investigation of HTSC cuprates. The directions of research represent the diversity of approaches within inorganic chemistry and inorganic materials science. Among them are new and advanced methods for the synthesis (solvothermal, sonochemical, sol–gel high-temperature/high-pressure) and characterization (powder and single-crystal X-ray diffraction, various spectroscopic methods, such as vibrational, impedance, electronic, and optical, and different microscopy methods). Physical measurements complement these methods. The topics of the workshops in 2001 and 2004 were not limited to HTSC materials; they included new generations of functional materials with colossal magnetoresistance, low dimensional magnetic materials, photonic crystals, hybrid inorganic/organic materials, supramolecular and nanostructured materials.

Through years, the workshops grew remarkably in the number of participants: 100 persons (including 15 foreign guests from 9 countries) took part at MSU HTSC-I (1989), while more than 240 participants (including 80 foreign scientists from 17 countries) attended MSU HTSC-VII in 2004. Noteworthy, the organizers of the workshops follow the interdisciplinary tradition and always invite not only specialists in solid state chemistry but also physicists, experimentalists and theoreticians, involved in studies of new inorganic materials, thus trying to have a multi-side view of the problems associated with new materials and to create new fruitful interdisciplinary cooperations.

This issue represents the majority of research into inorganic materials delivered at the Inorganic Chemistry Division of the Department of Chemistry and the Department of Materials Science, M. V. Lomonosov Moscow State University. At first it includes a group of papers on advances in the chemistry of cuprates and manganites, showing new synthetic approaches and property evaluations. These range from the effect of fine doping on the functional properties of test compounds through an order–disorder problem to the heterostructure formation, phase stability, and internal oxidation processes. The latter brings us to the development of new synthetic approaches. In addition to the sonochemical and microwave syntheses, a variety of precursor methods, including freeze-drying and sol–gel techniques, are presented. The chemistry of precursors is a new branch of inorganic chemistry, and it is considered in some articles.

A group of communications is dedicated to supramolecular and nanostructured materials. These materials attract more and more attention due to the expectations that new and advanced materials will emerge from the unique possibilities of a new scale of the matter organization and synergistic cooperation. New routes to new luminescent, magnetic and thermoelectric materials are discussed. They include, for instance, PbS nanoparticle stabilization in double hydroxide matrices, the high-temperature formation of semiconducting clathrates, and nanoparticle separation in mesoporous silica. The intrinsic properties, such as crystalline size effect, of nanocomposites along with the use of modern techniques for studying the distribution of constituents within a nanocomposite are presented.

In this issue, epitaxial stabilization of new perovskite- and garnet-like oxides is considered. Not only basic phenomena of thin films are of interest, their prospective applications as data storage media or organic light-emitting diodes (OLED) are highlighted.

A new area of research is related to the integration of chemistry and life sciences. This issue includes communications on the development of phosphate materials for biomedical applications. The modification of synthetic calcium hydroxylapatite for the improvement of the bioactivity of the material, and the development of new quickly hardening cement composites demonstrate the frontiers of bioinorganic chemistry and the chemistry of biomaterials. The graphoepitaxial crystallization of amino acids on a silicon substrate is also described.

The synthesis and structure of a new vanadate, the preparation of trinuclear metal carboxylates, and the preparation of new oxides with selective and efficient catalytic activity by the decomposition of complex nitrates are also of interest.

The contents of this issue reflect the recent activity in the development of inorganic chemistry as a fundamental basis for the elaboration of new generations of functional materials at the Inorganic Chemistry Division of MSU. At the same time, this issue reflects the programme of the latest International Workshop on High-Temperature Superconductors and Novel Inorganic Materials Engineering (MSU-HTSC-VII) in 2004.

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