Russian physicists synthesize materials for recycling radioactive waste

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Experts from the National Research Nuclear University MEPhI have upgraded a method to synthesize complex oxides. This will result in materials with the best properties to create radioactive waste recycling matrices and heat-resistant ceramic coatings. In addition, the new materials can act as heat-resistant coatings in aircraft engines and turbines.

In the past few years, researchers have been studying complex oxides in the Ln_2O_3-MO_2 systems where Ln denotes rare-earth elements, with M standing for an element in the titanium subgroup. Scientists are interested in the phase-transition phenomenon for a conversion from "order" to "chaos." This phenomenon deals with the position of atoms inside crystal lattices.

As a rule, research papers provide data obtained during studies of the structure and properties of crystallized $Ln_2M_2O_7$ compounds, obtained using a high-temperature solid-phase synthesis method. In this case, scientists are interested in the amorphous compound's transition to a crystalline state.

According to the research paper's authors, this method makes it impossible to collect data about the formation of nano-crystal structures and their evolution.

MEPhI researchers used another synthesis method based on firing a priori amorphous precursors of future substances obtained by depositing metal-salt solutions, at different temperatures.

"We observed the process of changing the atomic and electronic structure of the abovementioned complex oxides during the evolution, as well as the evolution of amorphous substances into nano-crystal and crystal structures, for the first time," said Professor Alexei Menushenkov from the Department of Solid-State Physics and Nano-Systems. "We proved that X-ray absorption spectroscopy and combined dispersion spectroscopy are sensitive to electronic and atomic structure changes in complex oxides, depending on the type of rare-earth elements and preparation methods," he added.

The use of unique research and combined methods became an important aspect of this work. Scientists used the X-ray absorption spectroscopy method and X-ray diffraction involving synchrotron radiation, the combined dispersion spectroscopy method and infrared spectroscopy, X-ray scanning electron microscopes with energy-dispersion analysis functions and thermal gravimetric analysis.

A combination of these complicated and expensive methods gave us data on a substance's changing cation and anion structures. Additional methods were used to analyze substance samples.

The researchers used extended X-ray absorption fine structure (EXAFS) and X-ray absorption near edge structure (XANES) methods to study changes in a material's atomic and electronic structure at the BM08 (LISA) station of the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, under the HC-3039 project for the use of beam emitters, with Menushenkov's team winning a tender and obtaining permission to use them.

According to the scientists, the project's results are important for fundamental research and in the context of obtaining optimal properties of complex oxides for various practical applications. The new ceramic materials can be used to make heat-protection coatings, matrixes for recycling radioactive waste and for solid-state fuel elements. It is also possible to use them for making neutron-absorbing materials in nuclear reactors.

More information: V.V. Popov et al. Formation and evolution of crystal and local structures in nanostructured Ln 2 Ti 2 O 7 (Ln = Gd–Dy), *Journal of Alloys and Compounds* (2018). DOI: 10.1016/j.jallcom.2018.02.263

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