

The factor determining the development and implementation of new technologies is often the need to use materials with unique properties. It also happens that the creation of a new material reveals a multitude of applications in which it could be used. The development of technology is therefore closely related to the development of materials engineering, which we are currently witnessing. Materials that have received a lot of attention in recent years and have high hopes for application include aerogels.

The very name "aerogel" brings to mind associations with gel but also with air. While gel means a system of solid particles forming a "skeleton" in the structure of which there is a liquid, aerogel is a very similar system, but in its case the liquid has been replaced by gas - usually by air. Thus, one can imagine aerogel as a "jelly" from which the liquid has been carefully removed without damaging and collapsing the solid porous skeleton. The possibility of producing such materials was demonstrated in the pioneering work of Kistler in 1931. Also this researcher showed that aerogels can be produced from a very wide spectrum of substrates, here called precursors: metal oxides, cellulose and other macromolecular compounds. Nowadays aerogels can be based even on the notorious graphene. However, a special role is played by aerogels produced on the basis of organically modified silica (ORMOSIL) compounds. The large variety of available precursors and the further possibility of modifying the surface of aerogels allows full control of their properties.

Silica aerogels are distinguished by many unusual properties: in addition to porosity of up to 99.8%, it is low density, high specific surface area and sorption capacity, but also low thermal conductivity, and other. Such unique characteristics of silica aerogels make them materials with great application potential for areas such as thermal and acoustic insulation, biomedicine, oil industry, space missions and many others.

The mechanical properties of silica aerogels are not so impressive and often they do not allow for their wider application in real applications. Here we find materials that are very brittle, but also very resilient. However, the mechanical nature of aerogels can be controlled. It depends primarily on the synthesis conditions that affect the course of elementary processes during the formation of the aerogel: hydrolysis of the precursor, condensation of its molecules, joining of primary particles into secondary particles, and then into the final structure of the material.

At the basis of the relationship between the mechanical properties of the aerogel and the conditions of their synthesis are the mechanisms of the above-mentioned transformations at all levels of the size scale - from the dynamics of interactions of single molecules, through submicron particles, to macroscopic elements of the structure of the aerogel skeleton, which are their aggregates. In our project, a theoretical description of the synthesis of aerogels and the properties of their structure will be formulated based on extensive experimental research. A multilevel - from particle to macrostructure - approach to modeling and laboratory research will provide a comprehensive description of the nature of these fascinating materials. This description will make it possible to select the synthesis conditions in order to obtain a product with the desired properties, and then - to optimize the manufacturing processes, i.e. to select the conditions under which the aerogel is produced for a specific application.