The chemical and related industries, such as oil processing and the pharmaceutical industry, provide many products that we use widely in everyday life and are necessary to maintain a modern lifestyle. These industries depend heavily on catalytic processes in which the catalyst facilitates the conversion of raw materials into desired products by accelerating the reaction rate or suppressing unwanted by-products. Catalytic processes are also the foundation of green chemistry.

One of the most unusual catalysts are aluminosilicates, called zeolites, having uniform micropores, less than 1 nm, which were discovered in nature as crystalline minerals and subsequently developed as synthetic materials. Initially, they revealed selective ion exchange and gas sorption properties, but later they were found to have outstanding properties as heterogeneous catalysts in the processing (cracking) of crude oil and in the selective conversion of petrochemical products. They are non-toxic and environmentally friendly, stable at high temperatures, showing higher activity than most materials used in catalysis. Zeolites have skeletal structures composed of SiO4 and AlO4 tetrahedra, forming networks differing in size, shape and connections of pores, which determines their reactivity towards various organic compounds. This decisive influence of the structure on the reactivity of zeolites in catalysis and adsorption is the basis for the constant search for new structures synthesized in order to improve or develop new applications and technological processes, recently especially for environmental protection.

A groundbreaking event was the discovery that zeolites, known only in the form of 3-dimensional networks (3D), can form layers less than a few nanometers thick, similar to so-called 2-dimensional (2D) materials. In addition to great fundamental importance, 2D zeolites opened up unprecedented perspectives for creating new structures due to the possibility of expanding and partially filling interlayer layers and manipulating layers, often called "Lego block chemistry", similar to other well-known layered materials. The latter include graphite, graphene, clay minerals (so-called clays), transition metal oxides and hydroxides, disulphides and many others. Zeolite layers provide new features not present in existing 2D materials: strong active centers and pores inside or across the layer, which allow the transport of particles in three dimensions. 2D zeolites are of great significance for synthesis because they can be used to prepare new materials and structures. The most universal approach is provided by their exfoliation, i.e. separation into single layers in a suitable solvent, creating a suspension in the form of single, independent monolayers that can be treated as giant, flat particles in solution. Most known layered materials showed spontaneous exfoliation, while layered zeolites resisted this process for a long time without any apparent reason. Only recently the applicant and colleagues have discovered high-efficiency exfoliation of one of the major industrial zeolites, MWW, by a mild chemical treatment with organic hydroxide. These exfoliated MWW monolayers in water enable the synthesis of zeolite-based materials both by new methods and in new forms that were previously impossible. This is the result of allowed complete mixing in a homogeneous phase, difficult or impossible to achieve by methods appropriate for solids.

The first goal of the project is to generalize the developed method of mild chemical exfoliation to other 2D zeolites. In preliminary studies such exfoliation was carried out for two additional zeolites: MFI and FER. MFI is a particularly important material because it has layers with perpendicular channels and is the second most important industrial zeolite used in various applications. The second goal is to study the basic properties of the obtained suspensions, such as stability, aggregation of layers and the dependence of charge on pH. The third goal, the most important, is to demonstrate practical benefits of using the obtained monolayer suspensions for the synthesis of composite materials and hierarchical structures, which can be improvements over existing ones, as well as completely new ones that cannot be obtained using previously available substances. The planned syntheses will include nanostructures with nanoparticles that separate layers and have different catalytic activity, such as cerium oxide (redox reactions), titanium oxide (photocatalysis), iron oxides (redox reactions and magnetic properties), as well as drugs for controlled delivery. The benefits of creating materials with active centers with different properties located very close to each other, in combination with the presence of large pores, can be new reaction paths and catalytic processes that can be adapted to the needs of various transformations. Solutions containing layers of different zeolites can be mixed to obtain dual activity or to achieve a synergistic effect. The innovation will be the formation of zeolite hybrids with other 2D structures. Both types of material were previously impossible.

Exfoliated layers can also be deposited on substrates or made into thin films. The expected benefits are not only quantitatively improved catalytic processes, but also qualitatively new processes due to the ability to create new combinations of different functions in one catalyst particle.