Due to the continuous development of civilization, humanity needs more and more energy, which can be derived from fossil fuels or renewable sources. Resources of fossil fuels like coal and natural gas are getting smaller and are starting to end. On the other hand, the increasing exploitation of natural resources of the Earth causes serious environmental problems and forces the use of classical energy sources to be limited. Alternatives are renewable sources. In the previous century, only renewable energy sources such as wind and water were used. Also the alternative source of energy is the Sun, but to use it is necessary to develop a way to convert solar energy into electricity and to synthesize the appropriate materials for this purpose. Today, the most widespread solar technology are silicon based photovoltaic cells. The highest efficiency of such solar cells was achieved for monocrystalline silicon layers, but their production costs are very high and the payback time is very long. The production and utilization of silicon photovoltaic cells is 2-3 times more expensive than fossil fuels, so it is reasonable to investigate other materials capable to convert solar radiation into electricity, which can be used for the construction of photoelectrochemical cells.

This project is devoted to the experimental and theoretical study of the physical properties of hybrid materials based on mesoporous titanium dioxide (TiO_2) and zirconium dioxide (ZrO_2) sensibilized by organic dyes, which potentially can be used to build dye sensitized solar cells (DSSCs). In the past, TiO_2 has been investigated extensively for photovoltaic applications, but its wide energy gap allows to use only ultra violet (UV) part of the solar radiation and in consequence mentioned material is no excellent for converting solar energy into electricity. The ZrO_2 has better conversion parameters, but its wide energy gap gives possibility to use only UV light, which is only a few percent of the electromagnetic radiation of the Sun. Zirconium dioxide is a semiconductor with wide band gap equal to 5.4 eV but has high absorption coefficient for electromagnetic radiation and low surface recombination of charges. These parameters make the ZrO_2 as material with high conversion of electromagnetic radiation into electric current, which is positive feature of the material used for photostimulated phenomena. At present, research is ongoing to reduce the energy gap of the ZrO_2 in order to have possibility to use larger range of solar spectrum for photovoltaics. The aim of the project is to study the physicochemical properties of mentioned material and to compare the properties of zirconium dioxide with the properties of titanium dioxide as materials potentially used in photostimulated processes. The low photoconversion of charge carriers in the TiO_2 compared with the ZrO_2 give hope for the use of zirconium dioxide in photovoltaic phenomena, but this requires careful examination and understanding of the mechanism of the occurring processes.

The purpose of this project is to understand the mechanism of photoconversion and the transfer of charge carriers from the organic sensitizer to the semiconductor in order to improve the efficiency of the DSSC solar cells. In recent years, many research teams investigating properties of titanium dioxide try to increase its activity in the visible light by introducing a variety of dopants into the TiO_2 structure. In the proposed project, the reduction of energy gap is planned by the synthesis of non stoichiometric TiO_x and ZrO_x nanocrystals with different oxygen content and doping of these materials with ions such as nitrogen, copper, manganese and nickel. On the other hand, it is planned to synthesize nanocrystals of different sizes, which together with the change in stoichiometry and doping will allow to choose the structures with the energy gap most appropriate for the absorption of sunlight. Selected structures will provide the basis for the synthesis of thin mesoporous layers which will be sensibilized by organic dyes. The project will contribute to the development of photovoltaics and will provide the basis for the design of advanced photovoltaic materials.