IN SEARCH OF NEW ALTERNATIVE ENERGY SOURCES

As part of the University's initiatives of 'Jan Dlugosz University for the Earth', within the scientific research carried out by the academics of the Faculty of Science & Technology of JDU, Dean of the Faculty of Science & Technology professor Małgorzata Janusik-Makowska (Chair of Theoretical Physics) is currently working on the project: '*Photoactive hybrid structures for photovoltaic applications*'.

Project description:

In view of the continuous development of world civilisation, humanity needs more and more energy that can be derived from fossil or renewable sources. The fossil energy sources such as coal and gas are depleting. On the other hand, the growing exploitation of the Earth's natural resources causes serious ecological problems and extorts the restriction in the use of classic energy sources. Renewable sources are an alternative. In the previous century, only renewable energy sources such as wind and water were used. Today, an additional source of energy is nuclear power, which is causing a lot of controversy in society. An alternative source of energy is the Sun, but in order to use it, it is necessary to develop a way and appropriate materials of converting solar energy into electricity. Today, the most widespread solar energy technology are silicon photovoltaic cells. The highest efficiency of such photocells has been achieved for monocrystalline solar-panels, but the costs of their production are very high, and the investment payback period is very long. Today, it is a source of energy 2-3 times more expensive than fossil fuels, so it is reasonable to conduct research on other materials in a technology capable of converting solar radiation into electricity that can be used for the photoelectrochemical cell design.

The project focuses on experimental and theoretical studies of physical properties of TiO_2-based hybrid materials and organic dye-sensitised zirconium oxide hybrid materials (ZrO_2) that could potentially be used to develop photoelectrochemical cells of the type. In the past, TiO_2 of anatase structure was extensively studied for photovoltaic applications. Its wide bandgap makes it use a small part of solar radiation, thus it is not an excellent material for converting solar energy to electricity. ZrO_2, on the other hand, has better parameters of converting solar energy into electricity, but too wide bandgap of this material gives the possibility of using only UV light, which accounts for only a dozen percent of the electromagnetic radiation of the Sun.

Zirconium oxide is a semiconductor with wide bandgap of 5.4 eV, but at the same time has a high electromagnetic radiation absorption rate and low surface recombination. These properties make ZrO_2 a material with high conversion of electromagnetic radiation into electrical current, which is a positive feature of the material used in photostimulated phenomena. Research is currently underway to reduce the ZrO_2

bandgap to use more solar spectrum ranges for photoinduction. The objective of the project is to study the physical-chemical properties of this material for the construction of photoelectrochemical cells and to compare the properties of zirconium oxide with the properties of titanium dioxide as a material used in photovoltaics. The low photoconversion of cargo carriers in TiO2 compared to ZrO_2 gives hope for the use of zirconium oxide in photovoltaic phenomena, but this requires a thorough examination and understanding of the mechanism of ongoing processes.

The project aims at understanding the mechanism of photoconversion and transferring charge carriers from an organic sensibiliser to semiconductor material to improve the efficiency of DSSC (Dye-Sensitised Solar Cells). In recent years, many scientific teams involved in studying the properties of titanium dioxide have been trying to increase its visible light activity by introducing various types of additives into the structure of TiO_2. In the proposed project, the reduction of the bandgap is planned by the synthesis of non-stoichiometric TiO_x and ZrO_x nanocrystals with different oxygen content and the addition of ions such as nitrogen, copper, nickel to these materials. On the other hand, it is planned to synthesize nanocrystals of different sizes, which together with the change in stoichiometry and admixture will allow to choose structures with the bandgap most suitable for the absorption of sunlight. The selected structures will give rise to the synthesis of mesoporous thin films sensitised with organic dye. The project will contribute to the development of photovoltaics and will give the possibility of the design of modern photoactive materials.