Tytuł projektu

Nowe kierunki syntezy wielojądrowych okso-kompleksów tytanu(IV) oraz ich zastosowanie do produkcji fotokatalitycznie aktywnych i bioaktywnych materiałów kompozytowych.

Project title

New directions in multinuclear titanium(IV) oxo-complexes synthesis and their use in the production of photocatalytic active and bioactive composite materials.

Dyscyplina /Area of science

Nauki chemiczne

PROJECT DESCRIPTION

Project goals

- To develop the controlled synthesis of multinuclear titanium(IV) oxo-complexes with a strictly defined $\{Ti_a\text{-}(\mu_i\text{-}O)_b\}$ core structure.
- To perform studies on the titanium(IV) structural oxo-complexes conversion processes.
- To carry out the structural characterization of synthesized compounds and studies on their physicochemical, optical, mechanical properties, as well as on their biological activity.
- To use isolated microcrystals of oxo-complexes in order to obtain polymer/inorganic composites, e.g. thin films and fibrous coatings with defined optical, photocatalytic and biological properties.
- To develop and optimize the thermo-inducted spinning method of micro/nanofibres fabrication.

Outline

The unique physicochemical and biological properties of titanium dioxide favour its wide application in variety fields of our life. Especially, the optical properties and photocatalytic activity of materials based of TiO_2 have been intensively studied in recent time. Titania photoactivity is utilized in water splitting, air and water purification, environmental pollutants reduction, and in antimicrobial applications. Recently, much attention has been devoted to the use of titanium oxo-clusters (TOCs) as compounds exhibiting similar properties to TiO_2. Analysis of literature data indicate on a significant importance of TOCs in the synthesis of inorganic-organic hybrid materials, which are produced through introduction of metal oxo-clusters into the polymer matrix. The possible interactions between inorganic and organic components may result in an improvement of structural properties of the polymer, as well as of its thermal and mechanical ones due to crosslinking and filling. The unique properties of oxo-clusters, e.g. photochromicity, photocatalytic/biological activity can give completely new properties to the composite material in comparison to the base polymer. Therefore, the studies on TOCs synthesis of the titanium-oxide core of the desirable architecture, size, and physicochemical properties are important for the production of novel inorganic-organic composite materials. The

studies on the conversion of Ti(IV) multinuclear oxo-complexes based on $\{Ti_a\text{-}(\mu_i\text{-}O)_b\}$ clusters and their controlled synthesis are important part of the proposed project. Moreover, the purpose of the research project is to determine the photocatalytic properties and bioactivity of the inorganic core (titanium-oxygen core) in the environment of organic fragments. Photocatalytic activity studies will be carried out on the base of the UV-Vis induced degradation of organic dyes, stearic acid and acetone. In order to evaluate of antimicrobial activity, LIVE/DEAD, Alamar Blue staining and CFU method will be used. The produced materials will be exposed to gram (+), gram(-) strains, and Candida.

In this PhD project it is planned to determine the mechanism of the structural conversion processes, which allow for the synthesis of oxo-complexes of the defined $\{Ti_a\text{-}(\mu_i\text{-}O)_b\}$ core structure. The solution of this problem is essential for the synthesis of new organic-inorganic composite materials with specific physicochemical and biological properties. Development of fabrication of materials with new photocatalytic, optical, and antimicrobial properties is another objective of the proposed project. Thus, beside issues related to the synthesis, structural and spectroscopic characterization of synthesized new group of compounds, the studies on their optical and photocatalytic properties, and also evaluation of their antimicrobial activity, will be important. The results obtained within the project will create the basis for the development of new generation materials for photocatalytic and biomedical applications.

This PhD project will be conducted in close cooperation with the research groups from the Department of Immunology and Infectious Biology of the Faculty of Biology and Environmental Protection of the University of Łódź and Department of Microbiology, Faculty of Biology and Environmental Protection, Nicolaus Copernicus University in Toruń, in the field of microbiological research and study of the relationships between the structure and morphology of the produced materials, and their biocidal activity. Studies on the structure of the produced nanomaterials will be conducted in close cooperation with the Department of Crystal Physics, Institute of Physics of the University of Silesia in the field of research using X-ray photoelectron spectroscopy (XPS). Estimation of mechanical properties of coatings and fibers will be carried out in the cooperation with Department of Materials Engineering and Bonding, Faculty of Mechanical Engineering, Gdańsk University of Technology.

Work plan

1. Synthesis and structural characterization of multinuclear titanium(IV) oxo-complexes, produced as a result of the titanium(IV) alkoxides reaction with organic acids.
2. The spectroscopic studies on the structural conversions appeared within carboxylato-substituted oxo-clusters $[Ti_aO_b(OR)_c(OOCR')_{4a-2b-c}]$.
3. The studies on the fabrication of polymer-inorganic composites using titanium (IV) oxo-complexes containing $\{Ti_a\text{-}(\mu_i\text{-}O)_b\}$ cores as the fillers.
4. The studies on the wettability, optical, and photocatalytic properties of the organic-inorganic composites.
5. The evaluation of antimicrobial properties of fabricated materials, basing on the studies on their ability to reduce the formation of aggregates/biofilms of reference microbial strains, with the specific physiological characteristics, which are relevant to clinical microbiology.

Literature

[1] U. Schubert, *J. Mater. Chem.* **2005**, *15*, 3701-3715.
[2] P. Piszczek, A. Radtke, T. Muzioł, M. Richert, J. Chojnacki, *Dalton Trans.,* **2012**, *41*, 8261-8269.
[3] A. Radtke, P. Piszczek, T. Muzioł, A. Wojtczak, *Inorg. Chem.*, **2014**, *53*, 10803-10810.
[4] T.J. Boyle, T.M. Alam, C.J. Tafoya, B.L. Scott, *Inorg. Chem.*, **1998**, *37*, 5588-5594.
[5] A.I. Kitajgorodskij, Molecular Crystals and Molecules, New-York, Academic Press, 1973.
[6] P. Piszczek, M. Richert, A. Radtke, T. Muzioł, A. Wojtczak, *Polyhedron*, **2009**, *28*, 3872-3880.
[7] L.G. Hubert-Pfalzgraf, S. Daniele, R. Papiernik, M.-C. Massiani, B. Septe, J. Vaissermann, J.-C. Daran*, J. Mater. Chem.*, **1997**, *7*, 753-762.
[8] A. Radtke, P. Piszczek, A. Topolski, Ż. Lewandowska, E. Talik, I. Hald Andersen, L. Pleth Nielsen,
M. Heikkilä, M. Leskelä, *Applied Surface Science*, **2016**, *368*, 165-172.

Required initial knowledge and skills of the PhD candidate

- ➔ The ability to analytical thinking
- ➔ Willingness to learn and experiments
- ➔ Possession of fundamental knowledge on coordination chemistry and crystallization processes
- ➔ Be interested in interdisciplinary science fields from the borderline nanotechnologies, polymer chemistry, and biology
- ➔ The ability to cooperate in a team, also in international one

Zgłaszający projekt/ Author of the project

dr hab. Piotr Piszczek, prof. UMK stopień/tytuł, imię, nazwisko	piszczek@umk.pl e-mail
	Wydział Chemii UMK jednostka organizacyjna

Proponowani promotorzy i mentorzy/prospective supervisors

1) promotor główny/ main supervisior

dr hab. **Piotr Piszczek**, prof. UMK	e-mail : piszczek@umk.pl
	Wydział Chemii UMK jednostka organizacyjna

2) promotor pomocniczy / co-supervisor
Dr **Aleksandra Radtke**