1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

Synthesis of hybrid graphen/biosilica composites using diatom biomass as a precursor.

1.1. Project goals

The aim of the project is to synthesize new hybrid graphene-biosilica composites using diatom biomass as a precursor and applying the thermochemical biomass conversion method, as well as a detailed characterization of the physicochemical properties of the obtained composites.

1.2. Outline

Graphene and silica are two materials that have a wide range of applications due to their unique properties. Based on the numerous advantages of graphene and silica, the synthesis of graphene-silica hybrid composites will allow obtaining new functional materials that integrate the properties of both components. These properties include high mechanical strength, excellent electrical and thermal conductivity, and the ability to absorb UV radiation. Such materials are of great interest in various industrial fields due to the prospect of effective use. Currently, graphene-silica hybrid composites (G/SiO_2) are used in construction, electronics, medicine, battery production, photovoltaic cells, aerospace and automotive industries, and others. However, various conventional methods for the synthesis of silica and graphene or graphene-silica hybrid composites often require the use of hazardous chemicals or significant energy consumption, which creates environmental and economic problems. Therefore, environmentally safe, sustainable methods for the synthesis of graphene-silica composites are highly desirable. Such a "green" synthesis of graphene-silica composites can be carried out using diatom biomass as a natural source (precursor) of both silica and carbon. In this respect, diatoms are a spectacular example of the unique ability of single-cell microorganisms (microgalgae) to synthesize amorphous biosilica (silica exoskeletons) with a hierarchical three-dimensional structure, which is an additional advantage in synthesized graphene-silica composites. These unique abilities of diatoms arouse considerable interest due to the perspective of controlled biosynthesis of composite materials (precursors) consisting of 3D structured openwork biosilica and organic matter that can be transformed into carbon form.

In general, the use of diatom biomass as a precursor for the synthesis of graphene-biosilica composites can fulfill a sustainable and environmentally friendly strategy that is in line with the principles of circular economy and the use of renewable resources. In recent years, the great potential of the synthesis of carbon materials such as graphene or graphene oxides based on the use of various types of biomass has been recognized. However, in the published scientific works, there are no reports on the use of diatom biomass for the synthesis of graphene materials or graphene-biosilica hybrid composites. Therefore, the idea of developing a method for the synthesis of graphene-biosilica hybrid composites may have good prospects for obtaining new functional materials needed in modern technologies.

1.3. Work plan

Work plan (48 months).

1. Cultivation of selected diatom species in photobioreactors to obtain diatom biomass. Studies of physicochemical properties of diatom biomass using a number of instrumental methods (Raman spectroscopy, FTIR, XRD, TGA, NMR, TOC, SEM, TEM, AFM, ASA, ICP/MS, porosimetry, spectrofluorimetry). 1-12 m.
2. Synthesis of hybrid graphene-biosilica composites using a thermochemical method of conversion of diatom biomass without the use of a catalyst in the synthesis process at the stage of biomass graphitization (diatom biosilica acts as a catalyst). 6-18 m.
3. Synthesis of hybrid graphene-biosilica composites using a thermochemical method of conversion of diatom biomass using a catalyst (Fe, Ni, Co, Cu, etc.) in the synthesis process at the stage of biomass graphitization. 18-36 m.
4. Studies of physicochemical properties of obtained hybrid graphene-biosilica composites using a number of instrumental methods (Raman spectroscopy, FTIR, XRD, TGA, NMR, TOC, SEM, TEM, AFM, ASA, ICP/MS, porosimetry, spectrofluorimetry). 6-36 m.
5. Preparation of a review paper, development of obtained research results, characterization of physicochemical properties of obtained composites, preparation of manuscripts and publications, preparation of a doctoral thesis for defense. 1-48 m.

1.4. Literature *(max. 7 listed, as a suggestion for a PhD candidate preliminary study)*

1. Handayani, M.; Nafi'ah, N.; Nugroho, A.; Rasyida, A.; Prasetyo, A.B.; Febriana, E.; Sulistiyono, E.; Firdiyono, F. The Development of Graphene/Silica Hybrid Composites: A Review for Their Applications and Challenges. *Crystals* 2021, *11*, 1337. https://doi.org/10.3390/ cryst1111133.
2. Jing-Ye Tee, Fong-Lee Ng, Fiona Seh-Lin Keng, Choon-Weng Lee,Bingqing Zhang, Shiwei Lin, G. Gnana kumar, and Siew-Moi Phang, Green synthesis of reduced graphene oxide by using tropical microalgae *Chlorella* sp. and its application in biophotovoltaic devices, *Science* 27, 2024, 109564, https://doi.org/10.1016/j.isci.2024.109564.
3. Ma, M.; Li, H.; Xiong, Y.; Dong, F. Rational design, synthesis, and application of silica/graphene-based nanocomposite: A review. *Mater. Des.* 2021, *198*, 109367.
4. Fernando G. Torres, Omar P. Troncoso, Liset Rodriguez, Gabriel E. De-la-Torre, Sustainable synthesis, reduction and applications of graphene obtained from renewable resources, *Sustainable Materials and Technologies* 29 (2021) e00310.
5. Andrew T. Smith, Anna Marie LaChance, Songshan Zeng, Bin Liu , Luyi Sun, Synthesis, properties, and applications of graphene oxide/reduced graphene oxide and their nanocomposites, *Nano Materials Science* 1 (2019) 31–47, https://doi.org/10.1016/j.nanoms.2019.02.004.
6. Jhantu Kumar Saha, Animesh Dutta, A Review of Graphene: Material Synthesis from Biomass Sources, *Waste and Biomass Valorization* (2022) 13:1385–1429, https://doi.org/10.1007/s12649-021-01577-w.
7. Smith A.T., LaChance A.M., Zeng S., Liu B., Sun L., Synthesis, properties, and applications of graphene oxide/reduced graphene oxide and their nanocomposites. *Nano Materials Science.* 2019;1:31-47. DOI: 10.1016/j.nanoms.2019.02.004.

1.5. Required initial knowledge and skills of the PhD candidate

Master's degree in Chemistry. Knowledge of physical, organic and inorganic chemistry is essential, as well as the ability to analyze, interpret and present experimental results.

1.6. Expected development of the PhD candidate’s knowledge and skills