Development of synergy-based antimicrobial nanocomposites for biomedical applications

Summary

The PhD project aims to design and synthesize innovative nanocomposite materials tailored for antimicrobial applications in biomedical fields, including wound dressings, implants, and surface coatings. This research will focus specifically on creating novel nanomaterials by combining metal-based antimicrobial nanoparticles (e.g. Ag, CuO, ZnO) with biologically active organic compounds (e.g., chitosan) to achieve synergistic antimicrobial effects. The most promising combinations will undergo comprehensive assessment for human and environmental safety. The central research question guiding this doctoral thesis is: how do specific combinations of metal-based nanoparticles and organic compounds influence their antimicrobial effectiveness and safety?

Research field:	Chemistry and biotechnology
Supervisors:	Mariliis Sihtmäe Dr. Kaja Kasemets
Availability:	This position is available.
Offered by:	School of Science National Institute Of Chemical Physics And Biophysics
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

The research

The emergence and rapid spread of antibiotic and drug-resistant bacterial and fungal infections represent a significant challenge to public health, contributing to mortality rates comparable to those of cancer. Efforts to address this issue require a multi-faceted approach, including research into new antimicrobial agents. This *PhD* project addresses this issue by designing and synthesizing novel synergy-based antimicrobial nanocomposites (NCs) for biomedical applications, including wound dressings, medical implants, and surface coatings in healthcare settings. Synergy, in this context, implies that the combined antimicrobial activity of these materials exceeds the sum of their individual effects (i.e., 1 + 1 > 2).

The research will focus on synthesizing multifunctional nanocomposites by integrating antimicrobial metal-based nanoparticles (e.g., Ag, CuO, ZnO, and their doped versions) with biologically active organic compounds, such as chitosan. These combinations are expected to enhance antimicrobial performance through complementary mechanisms of action. Both individual components and their combinations will be studied to identify the most effective formulations. The most promising antimicrobial combinations will undergo comprehensive assessment for both human (*in vitro*) and environmental safety.

The goals of the PhD project are to:

- Synthesize and characterize a library of nanocomposites by combining antimicrobial nanoparticles (NPs) (e.g., CuO, ZnO, Zn-doped CuO NPs) with chitosan of varying molecular weights.
- Propose antimicrobial-by-design and safe-by-design strategies to develop synergy-based antimicrobial nanocomposites for biomedical applications (e.g. wound dressings, surface coatings).

Responsibilities and (foreseen) tasks

- Synthesis of CuO, ZnO and Zn-CuO NPs functionalized with different chitosan formulations
- Physicochemical characterization of NPs using DLS, XRD, EDX, SEM, TEM and FTIR
- Evaluation of NCs' antimicrobial efficiency to bacteria (e.g., *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*) and fungi (*Candida* spp)
- Assessment of NCs cytotoxicity *in vitro*
- Assessment of NCs environmental safety
- Data analysis

- Manuscript writing

Applicants should fulfil the following requirements:

- A master's degree in biology, chemistry or a related discipline
- Clear interest in the topic of position
- Ability to plan and conduct laboratory experiments
- Strong and demonstrable writing and analytical skills
- Solid teamwork and independent work skills
- Excellent knowledge of English (both verbal and written)

(The following experience is beneficial:)

- Synthesis and characterization of nanoparticles
- Working with microbes
- Working with mammalian cells *in vitro*
- Working knowledge of statistics

The candidate should submit a motivation letter justifying their interest in this position and explaining their suitability (in terms of skills, experience, and background) for the PhD project.

We offer:

- 4-year PhD position in one of the leading (nano)toxicology research laboratories in Tallinn, Estonia.
- Opportunities for conference visits, research stays, and networking with leading experts to develop antimicrobial nanomaterials for biomedical applications.

About the department

The Laboratory of Environmental Toxicology, headed by Dr Anne Kahru, contributes to the following strategic programs of the National Institute of Chemical Physics and Biophysics (NICPB): environmental toxicology, chemistry and macromolecular interactions, *in vitro* toxicology, and the 3Rs. Strong emphasis is placed on environmental toxicology, nanotoxicology, and the design of antimicrobial nanomaterials. The research activities range from studying fundamental aspects of biology to applications. The lab's high scientific research level has led to several previous and currently funded EU and other International cooperation projects. The Laboratories have up-to-date facilities in chemistry, microbiology, cell culture, and ecotoxicology.

(Additional information)

For further information, please contact Dr Kaja Kasemets, kaja.kasemets@kbfi.ee and Dr Mariliis Sihtmäe, mariliis.sihtmae@kbfi.ee or visit https://kbfi.ee/environmental-toxicology/?lang=en

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