CSC-RUB PhD Project Proposal

Title: Near infrared fluorescent nanosensors for in situ detection of bacteria

Sector of research: Physical Chemistry, bioanalytical chemistry

Degree awarded: PhD (Dr. rer. nat.)

Keywords: Nanomaterials, biosensors, near infrared fluorescence, surface chemistry, molecular recognition, solvation, biomedical diagnostics

Supervisor of PhD project: Prof. Dr. Sebastian Kruss, Functional interfaces and biosystems, Department of Chemistry, Ruhr-University Bochum, e-mail: sebastian.kruss@rub.de

Research focus of supervisor: Our goal is to understand and tailor nanomaterials and their interfaces. For this purpose, we develop and use novel (optical) techniques that provide access to high spatial, temporal and chemical resolution and enable us to ask completely novel questions. One major focus is near infrared fluorescent biosensors. They enable us to image chemical communication in networks of cells but are also used for biomedical diagnostics.

Publications (5 selected): H-index: 32

(1) Florian Mann, Phillip Galonska, Niklas Herrmann, Sebastian Kruss: Quantum defects for functionalization of carbon nanotubes, **Nature Protocols 2022**, 17, 727-747, DOI: 10.1038/s41596-021-00663-6.

(2) Robert Nißler, Andrea Müller, Frederike Dohrmann, Larissa Kurth, Han Li, Eric Cosio, Benjamin Flavel, Juan Giraldo, Axel Mithöfer, Sebastian Kruss: Detection of plant polyphenols with near infrared fluorescent sensors, **Angewandte Chemie 2021,** DOI:10.1002/anie.202108373.

(3) Robert Nißler, Oliver Bader, Maria Dohmen, Sebastian Walter, Christine Noll, Gabriele Selvaggio, Uwe Groß, Sebastian Kruss: Remote near infrared identification of pathogens with multiplexed nanosensors. **Nature Communications 2020**, DOI: 10.1038/s41467-020-19718-5.

(4) Gabriele Selvaggio, Alexey Chizhik, Robert Nißler, Daniel Meyer, Loan Vuong, Helen Preiß, Niklas Herrmann, Florian Mann, Zhiyi Lv, Tabea Oswald, Alexander Spreinat, Luise Erpenbeck, Sebastian Kruss: Exfoliated near infrared fluorescent calcium copper silicate nanosheets for biophotonics. **Nature Communications 2020**, DOI: 10.1038/s41467-020-15299-5.

(5) Juan Pablo Giraldo, Honghong Wu, Greg Nekirk, Sebastian Kruss: Nanotechnology approaches to engineer smart plant biosensors, **Nature Nanotechnology 2019**, DOI:10.1038/s41565-019-0470-6.

Second Supervisor of PhD project: The second supervisor will be chosen together with the PhD student based on the best fitting expertise from faculty members of the chemistry department (e.g. Prof. Poul. Petersen, Prof. Thomas Günther-Pomorski, Prof. Christian Herrmann, Prof. Martina Havenith).

Summary of research plan:

Background: Bacterial infections are one of the major causes of death around the world and an increasing problem due to antibiotic resistance. The best strategy against bacterial infections would be to prevent or monitor infections. An ideal diagnostic tool could provide

fast and reliable information about a bacterial contamination without sample taking, isolation, purification or culturing. So far, such a technology does not exist.

Study objective: In this project we develop fluorescent nanosensors that identify bacteria and meet these criteria. We use near infrared (nIR) fluorescent single-walled carbon nanotubes (SWCNTs) as building blocks. SWCNTs fluoresce in the advantageous nIR region (850 -1700 nm) and are chemically tailored to bind motifs that are released by bacteria or present on their surface. The central idea is to use multiple sensors to fingerprint bacteria.

Expected Results:

1. High-throughput synthesis of novel recognition units/sensors: One of the great challenges in chemistry is to find or create new recognition motifs such as antibodies. The advent of a new kind of covalent chemistry on SWCNTs (sp^3 quantum defects without destruction of nIR fluorescence) could pave the way to even more powerful sensors. We want to better understand the possibilities and limitations of this novel chemistry. The main goal is to tailor but also permute the organic recognition phase on SWCNTs faster and with higher precision.

2. Sensors for drug resistance: The sensors will be tailored to detect different signaling molecules, metabolites and enzymes. Antibiotic resistance is another feature of bacteria of high relevance. Therefore, we aim to design sensors that report antibiotic resistance.

Methods: The PhD student will learn novel bioconjugation techniques and working with pathogens in our fully equipped labs. Additionally, we will use existing and custom-built NIR spectrometers and microscopes to investigate the nanosensors in detail.

Candidate Requirements: Good English language skills. MSc in (bio)chemistry, biophysics, physics or materials science and an interest in interdisciplinary and quantitative topics.

An A-grade (“very good”) qualifying degree at either the level of Master or Diploma to enter the iGSS’s Track I or an A-Grade (3 yr. or, preferably, 4 yr.) Bachelor to enter the Track II.

Motivation for CSC application (max 250 words): I can offer the candidates an interdisciplinary environment in a world-wide leading group in fluorescent nanosensor research. The students have access to advanced optical setups and techniques and can become members of structured PhD programmes in which I am a member (IGSN, iGSS). I have an additional affiliation to the Fraunhofer IMS, where interested students have the possibility to gain insights into more applied research and commercialization.

Additional benefits as an iGSS member:

- You will be embedded in a high-profile research environment.
- You are integrated in the International Faculty Solvation Science and will gain international work experience during a 2 – 3 months internship abroad.
- You will benefit from personal development possibilities, the entrepreneurial attitude within RESOLV and a broad spectrum of lectures as well as transferable skills courses.
- You will develop your science communication skills by presenting your research to the public and you are provided with funding for visiting international conferences.