Based in Ghent University at the Department of Chemistry, the NanoSensing Group explores the exciting field of nanothermometry for theranostics under the guidance of Prof. Anna M. Kaczmarek. A pioneering, cutting-edge research in lanthanide and dye based nanothermometry and hybrid nanomaterials.

After obtaining a Master's degree in chemistry in Poland (Adam Mickiewicz University in Poznan), Prof. Dr. Anna Kaczmarek did her doctoral thesis on luminescent applications of nano- and micromaterials at Ghent University. After completing her doctorate, she carried out post-doctoral work at Ghent University, the University of Cordoba in Spain and Utrecht University in the Netherlands.

2020 marks a decisive turning point for Prof. Dr. Anna Kaczmarek. That year, she was appointed Associate Professor at Ghent University and shortly afterwards she was awarded an ERC Starting Grant for her project "NanOthermomteRs for THeranostics" (NORTH, 2021-2026). This project focuses on combining temperature diagnostics and therapy to treat cancer in hybrid inorganic-organosilica nanomaterials. Theranostics is an emerging field of medicine that uses nanoparticles to simultaneously diagnose and treat diseases. The goal of the EU-funded NORTH project is to combine thermometry in the physiological range with either drug delivery or photodynamic therapy (PDT) all in a single hybrid nanoparticle constructed from Periodic Mesoporous Organosilica (PMO) with lanthanide inorganic nanoparticles grown inside the pores and/or voids of the (hollow) PMO particles.

Prof. dr. Anna M. Kaczmarek, head of the NanoSensing Group

The NanoSensing Group team

Temperature sensing and drug delivery in a single particle

In the field of theranostics, the use of nanomaterials, which allow combining multiple functions in just a single particle, would be able to change the entire healthcare scene and the way certain diseases are treated. Thus, the project proposes a rational design where hollow, porous, biocompatible, multifunctional materials will combine temperature sensing and drug delivery or photodynamic therapy in a single particle. The ERC Starting Grant has enabled Prof. Dr. Anna Kaczmarek to set up her own research group: the NanoSensing Group.

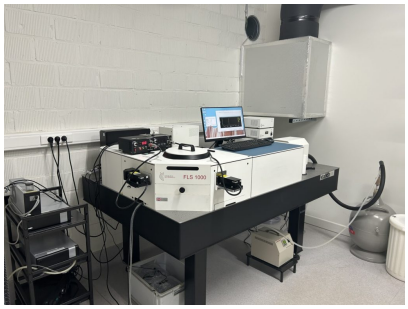
Innovative luminescent thermometers without heavy metals

Another important ongoing project in the NanoSensing Group is the ERC Proof of Concept (PoC): “LUMInescence ThermOmeters fOr cLinicS” (LUMITOOLS). The aim of this project is to design innovative luminescent thermometers without heavy metals. Current techniques for in vivo temperature mapping are inadequate. Luminescent nanothermometers show potential for clinical use, but their development is hindered by concerns about nano-safety, toxicity, and biocompatibility. Many proposed fluorescent nanothermometers contain heavy metals, which pose additional challenges. The LUMITOOLS project aims to address these issues by developing nanothermometers using luminescent, degradable nanomaterials that do not contain heavy metals. The goal is to create stable, high-performing nanothermometers that biodegrade completely after use. This advancement could significantly enhance future in vivo thermometry research and may lead to the development of nanothermometers with substantial potential for clinical applications. This new line of research, the only one of its kind, could be implemented in hospitals over the next few years.

Improving the efficacy of cancer immunotherapy

A third major project in the team is mobilising the energies of Prof. Dr. Anna

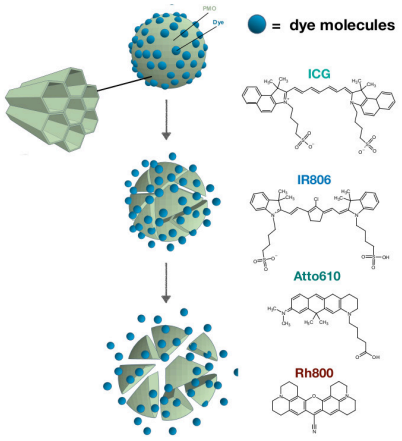
Kaczmarek's research: 'Triple Punch against melanoma'. This is a GOA project funded by the Ghent University. Together with collaborators Prof. Andre Skirtach (Biotechnology Department UGent) and Prof. Dmitri Krysko (UZ Gent), this project heeds the rapid growth of cancer immunotherapy, which offers a new perspective for designing effective treatments. However, often responses are low since tumours exhibit different resistance mechanisms. This project combines photodynamic therapy with photothermal ablation based on nanocapsules and nanothermometers, aiming to trigger immunogenic cell death and induce efficient anti-tumour immunity. It will improve the efficacy of cancer immunotherapy. This project has facilitated a new research line of nanoheaters in the NanoSensing Group.



The NanoSensing Group's equipment

European collaborations

Prof. Dr. Anna Kaczmarek has close research collaborations with Prof. Andre Skirtach (Biotechnology Department UGent), Prof. Dmitri Krysko (UZ Gent) and Prof. Kristof Van Hecke (Department of Chemistry UGent). At European level, she is working with the big names in the thermometry community: Prof. Andries Meijerink (Utrecht University, The Netherlands) and Prof. Markus Suta (Dusseldorf University, Germany). A unique European expertise that these top researchers are determined to preserve on European soil.



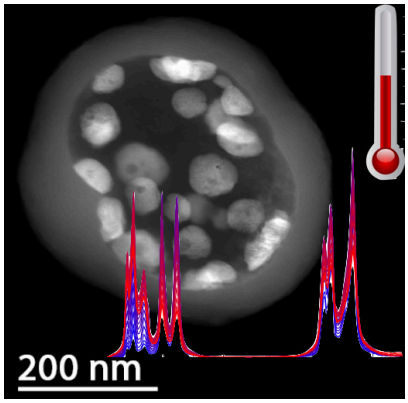
Degradable thermometers scheme

Publications

Although Prof. Dr. Anna Kaczmarek already has around a hundred publications to her name, she is particularly proud of an article published on 14 September 2024 in the journal Advanced Optical Materials under the title “Novel Type of Non-Toxic, Degradable, Luminescent Ratiometric Thermometers Based on Dyes Embedded in Disulfide-Bridged Periodic Mesoporous Organosilica Particles”. Despite the excellent thermometric performance of many developed luminescent nanomaterials, their use has not gone beyond proof-of-concept in vivo experiments to date. An important issue is engineered nanothermometers’ potential toxicity and bioaccumulation in the human body considering the ultimate objective of clinical applications. This work explores the possibility of designing visible, as well as near-infrared, emitting luminescent ratiometric nanothermometers based on appropriate organic dye mixtures embedded in hollow disulfide-bridged periodic mesoporous organosilica (PMO) particles. Such hybrid particles show excellent thermometric performance in the physiological temperature range (20–50 °C), favorable degradability in simulated physiological conditions, as well as no toxicity to healthy normal human dermal fibroblast (NHDF) cells in a wide concentration range. This motif renders a very promising approach to designing novel non-toxic, decomposable, luminescent ratiometric thermometers.

Another publication, dated 15 October 2024, is just as promising: published in ACS Applied Materials & Interfaces (Vol 16/Issue 42), it is entitled “Toward Upconversion (Yb–Er) and near-Infrared (Yb–Ho–Er, Nd–Yb) Thermometry with Sea Urchin Type $GdPO_4$ Nanoarchitectures”. In the face of growing demand for the development of materials that integrate both BW-II and BW-III thermometry systems with drug delivery functionalities, this study focuses on the development of $GdPO_4$ materials, utilizing both hard and sacrificial template routes to synthesize (hollow) $GdPO_4$ porous sea urchin-like

particles. It also illustrates the successful loading of these materials with doxorubicin (DOX·HCl), a model anticancer drug, showing these particles exhibit pH-dependent DOX release. The investigation involves assessing their cytotoxicity on Normal Human Dermal Fibroblasts (NHDFs), to determine their viability for potential use in biological applications. The study also investigates how effectively loading the particles with DOX enables targeted delivery to a cellular model of lymphoma (Jurkat E6-1), resulting in cell death.



Hybrid thermometers

Looking forward

The NanoSensing Group has no shortage of research challenges, each more stimulating than the last. We still need to find the perfect “recipe” for nanomaterials that are effective, non-toxic and rapidly eliminated from the human body. We also still need to reach the clinical phase and convince the medical community of the merits of these nanomaterials. Their hybrid nature, free of heavy metals, should be a powerful argument in this respect!

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