MICRO-/NANOPARTICLE SIZER

A portable compact device for routine micro/nanoparticle measurement

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Applied NANO TECHNOLOGY

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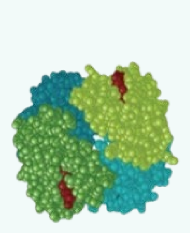
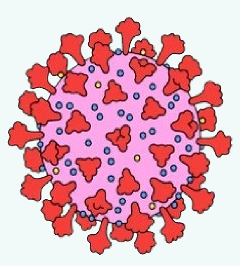
Introduction

Size measurement plays an essential role for micro-/nanoparticle characterization and property evaluation. Due to high costs, complex operation or resolution limit, conventional characterization techniques cannot satisfy the growing demand of routine size measurements in various industry sectors and research departments, e.g., pharmaceuticals, nanomaterials and food industry. Precisely measuring the size distribution of micro-nanoparticles is still a challenge for researchers and lab analysts. The widely used optical techniques are limited by size range, resolution and/or operational complexity. Moreover, it is hard (or even impossible) to measure non-transparent and polydisperse samples, such as food or fluorescent dye particles [1].

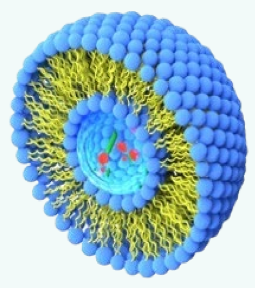
Together with commercial partners, we will develop a portable compact device to measure particle size based on particle-impact electrochemical sensing technology that is promising to overcome the limits and largely reduce the complexity and corresponding costs.



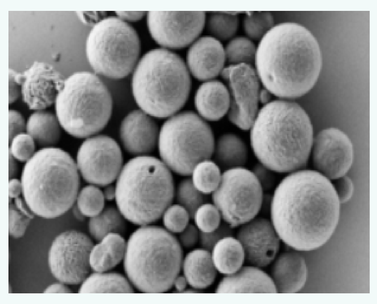
Macromolecule



Virus



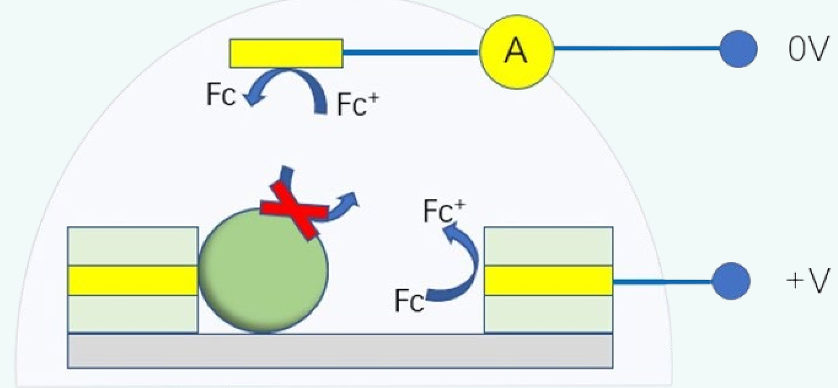
Liposome



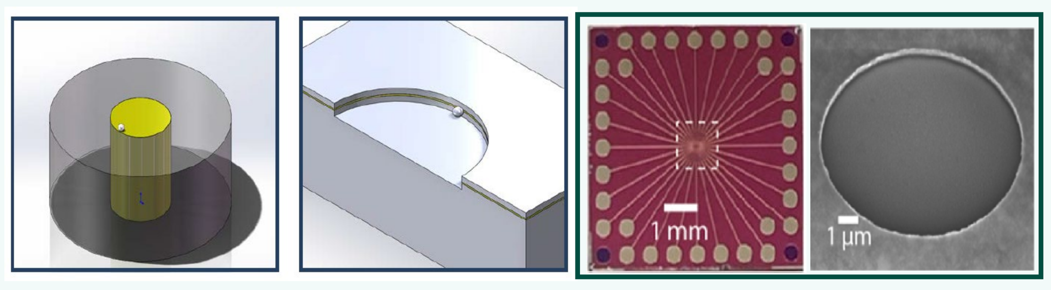
Polymer particles

Background

In the last decade, a particle-impact method has been developed to sense non-conductive single entities, such as latex particles (radii 0.15 and 0.5 μm) [2]. In a ferrocene mediated electrochemical sensing system, a stable current is generated between the working and the counter electrode under an appropriate electrical potential. When a non-conductive particle impacts on the working electrode, a reduction in the current signal is observed because part of the electrode surface is covered, and the diffusion-limited current is thus blocked. In principle, it has potential to measure particles varying from 5 nm to tens of micrometer with a series of different diameters UMEs [3].



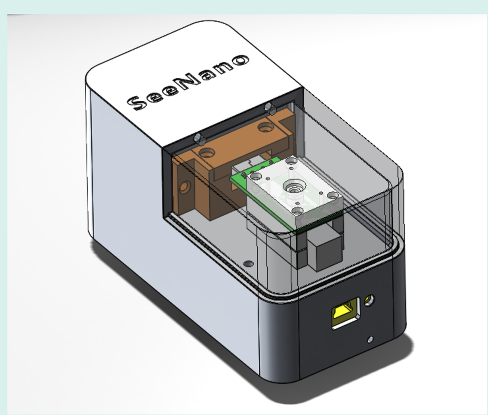
Researchers from University of Twente invented ring UME chips (with ring diameters of 2.5 μm and 10 μm, electrode thickness of 50 nm) to solve the issue of having different current sizes depending on the landing location, which is the characteristic of conventional disk-shaped UME. The ring UME shows excellent particle sizing ability by acquiring a narrow size distribution for given standard polystyrene particles [4].

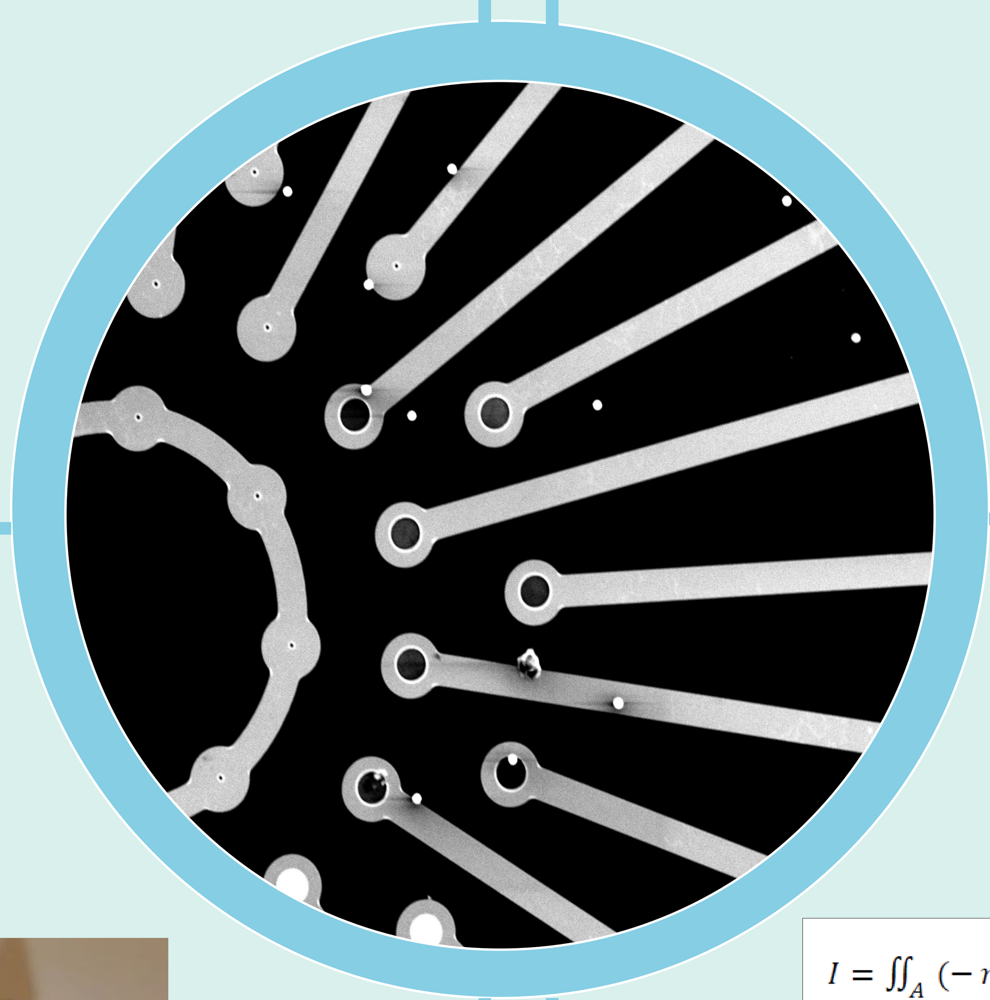


Results & Discussion

Motivated by the particle measurement requirements from industry and research community, a micro-/nanoparticle sizer prototype has been developed by integrating the forementioned ring UME chips in a portable device.

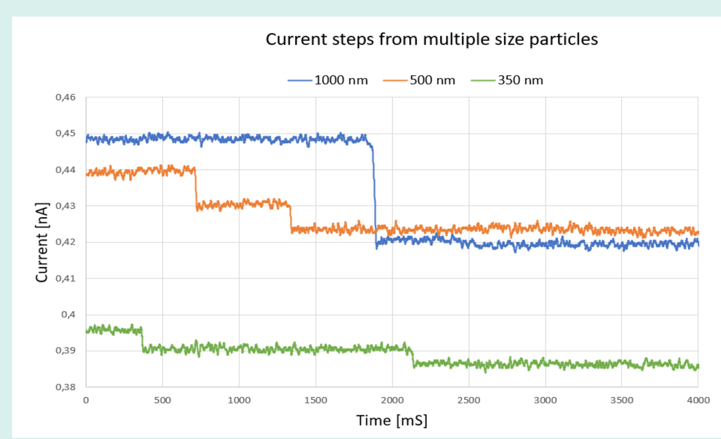
Thanks to the simplicity of the technology, the device has only a few parts, namely, an electrical unit, a ring UME chip and the related flow cell, and a metal enclosure etc.



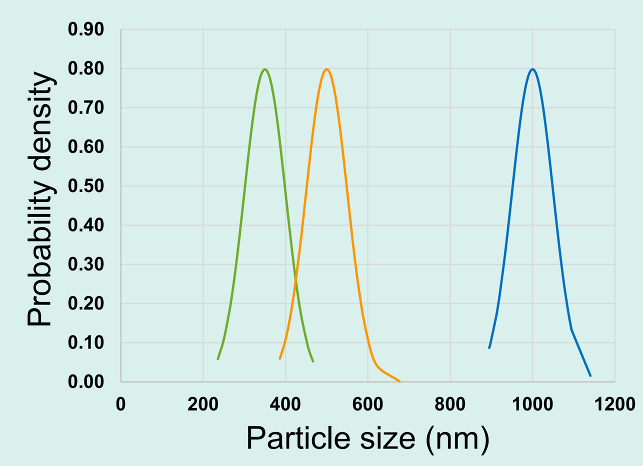


The particle-impact technology allows sizing particles with very low centration in low salt conditions. For each measurement, it only requires a 30-microliter sample contains $2x10^5$ to $2x10^6$ particles. Compared to traditional micro-nanoparticle sizing techniques, it could measure individual particles rather than averaging the sizes of a batch of particles. Therefore, it is able to characterize the heterogeneity of polydisperse particles. Using the currently chip, particles with diameters from 300 nm to 3 μm could be precisely measured. As a next step, the measurement range will be expanded to from 30 nm to 20 μm by introducing more specific ring electrodes.

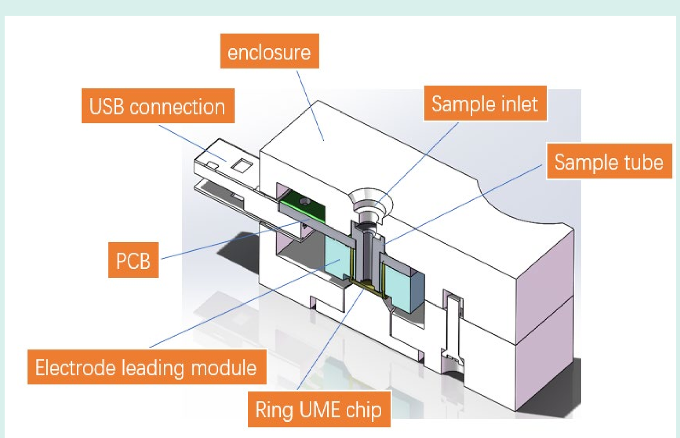
Signal examples for the measurement

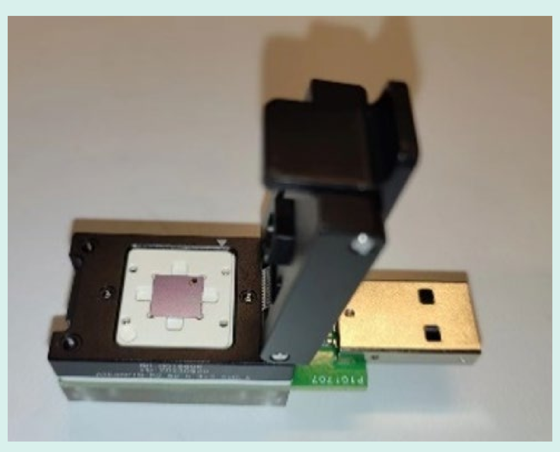


An expected size distribution



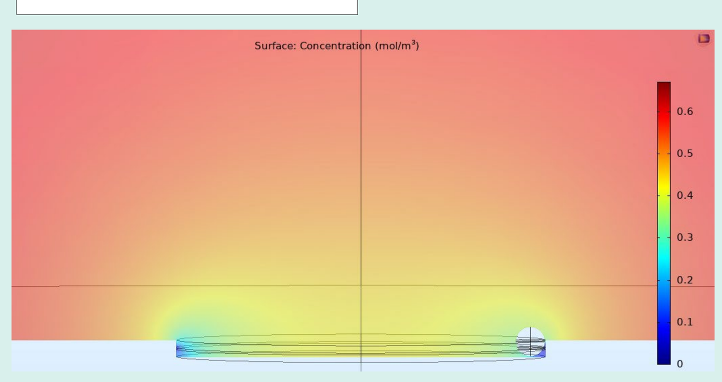
The success of the chip holder is largely attributed to practical research. Although the principle is simple, driving a novel sensor chip outside of the laboratory is not easy. In particular, stability and portability are hard barriers to overcome.





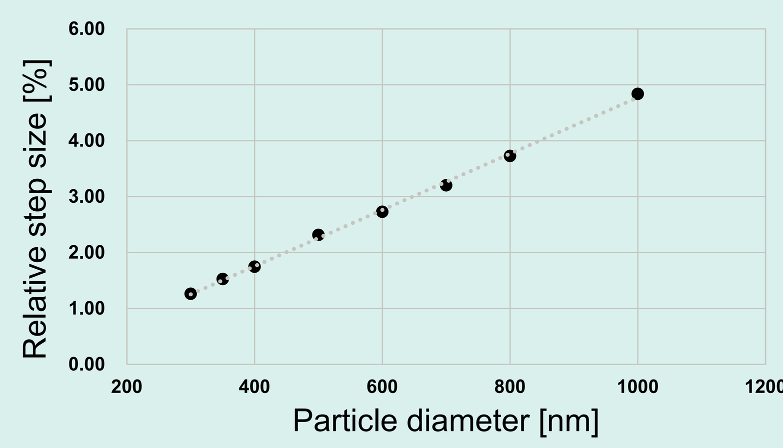
Based on electrochemical theories, models to predict the current step sizes has been established on multi-physics simulation platform COMSOL. The electrochemical current formula and the redox mediator concentration distribution are shown below. Then the step sizes can be derived from the simulation. Taking the example of particles 300 nm to 1 μm impacting on a 2.5 μm diameter ring UME, the calculated relative step sizes are linearly proportional to particle sizes.

$$I = \iint_A (-n\,FD\,\nabla c_{\perp})$$



Redox concentration distribution in the particle-UME work domain

Relative step size vs. Particle size on a 2.5 um Ring-UME



Conclusion & Outlook

We achieved a prototype for a portable micro-nanoparticle sizer by applying particle-impact electrochemical sensing. Besides appreciating the beauty of the fundamental science, we hope to bring it into reality as fast as we can. Contrasting to existing micro-nanoparticle sizing techniques, it stands out by its accuracy, simplicity, portability and cost-effectiveness etc. Directly working with academic and local commercial partners allows us to timely tailor technology development to real needs in time.

With this application-oriented research, we are on the way to overcome a few bottleneck problems. Among them, building up calibration curves and extending the measurement range will contain the first prior positions. At the same time, optimizing the measurement process and thus increasing the user friendliness is also in our considerations.

After this project, we expect to move a concrete step to validate the current prototype in an environmental situation, which could accurately measure industrial micro-nanoparticles rather than standard samples.

Acknowledgements

Team
Saxion students: Quincy Meins, Joel Tromp, Patrick Tuinema, Sjoerd Peeters.

Partners
University of Twente: Serge Lemay, Taghi Moazzenzade, Bas ten Brinke; Nanomi B.V.: Rob Duwel; Solstice Pharmaceuticals B.V.: Wim van Hoeve.

Grant
KIEM GoChem 2022-2023

References

Partners

UNIVERSITY OF TWENTE. bio electronics; SeeNano ALL FOR LIFE; nanomi monosphere technology A LUPIN GROUP COMPANY; Solstice pharmaceuticals; SIA Regieorgaan