

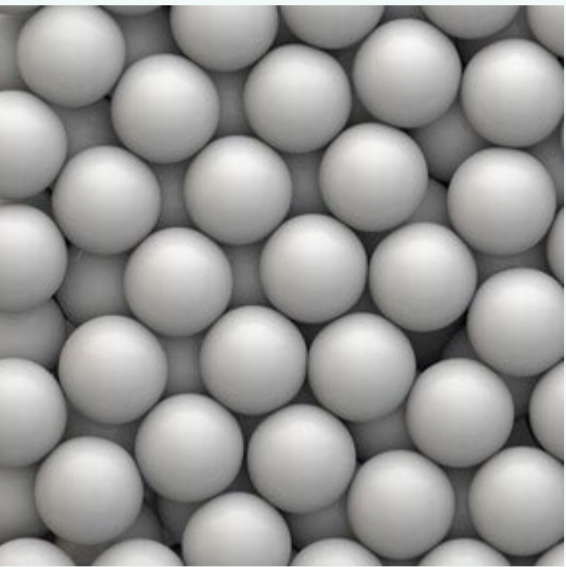
SENSING MICRO-/NANOPARTICLES ON NANO-RING ELECTRODES

Xiaojun Yang, Martin Bennink

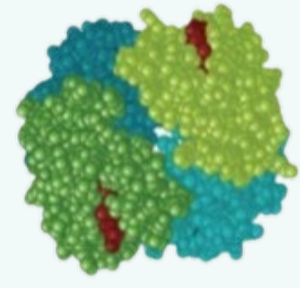
Applied Nanotechnology Research Group, Saxion University of Applied Sciences, Enschede/Deventer, The Netherlands

Introduction

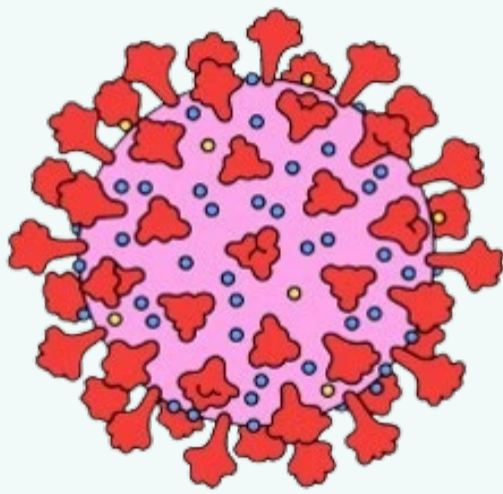
Size measurement plays an essential role for micro-/nanoparticle characterization and quality evaluation. However, conventional characterization techniques are limited by size range, resolution and/or operational complexity. Moreover, it is hard (or even impossible) to measure non-transparent and polydisperse samples, such as food or fluorescent dye particles. Developing a micro-/nanoparticle sizer based on particle-impact electrochemical sensing that is promising to overcome the limits and largely reduce the complexity and corresponding costs. A particle-impact method has been developed to sense non-conductive micro-/nanoparticles, such as latex particles (radii 0.15 and 0.5 μm) [*J. Am. Chem. Soc.* 2004, 126, 27, 8360–8361]. To solve the uneven electrical density on classical disk electrode, nano-ring electrodes are designed and fabricated via photolithography. The particle sizing ability of the nano-ring electrodes are validated by standard polystyrene particles. Furthermore, it enables capturing a single particle and versatile biosensing applications.



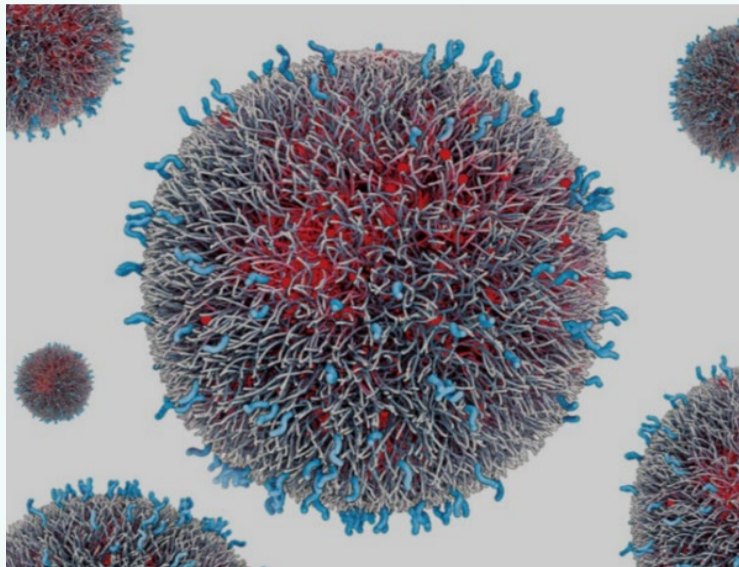
Polymer particles



Macromolecules



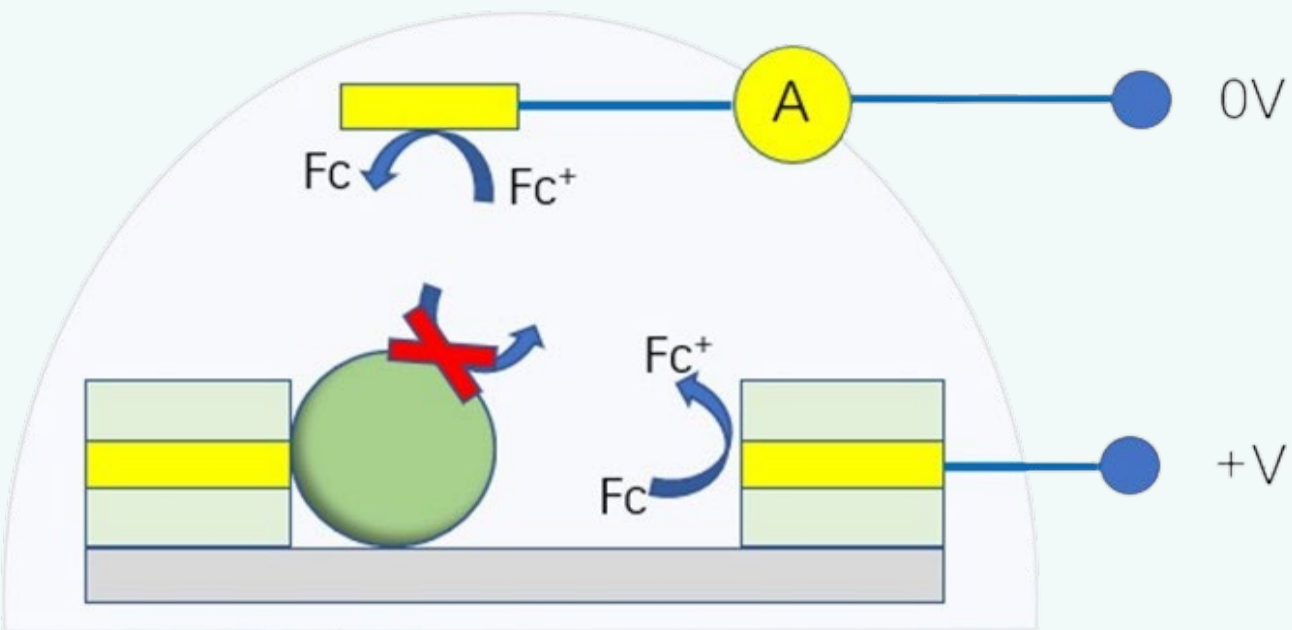
Viruses



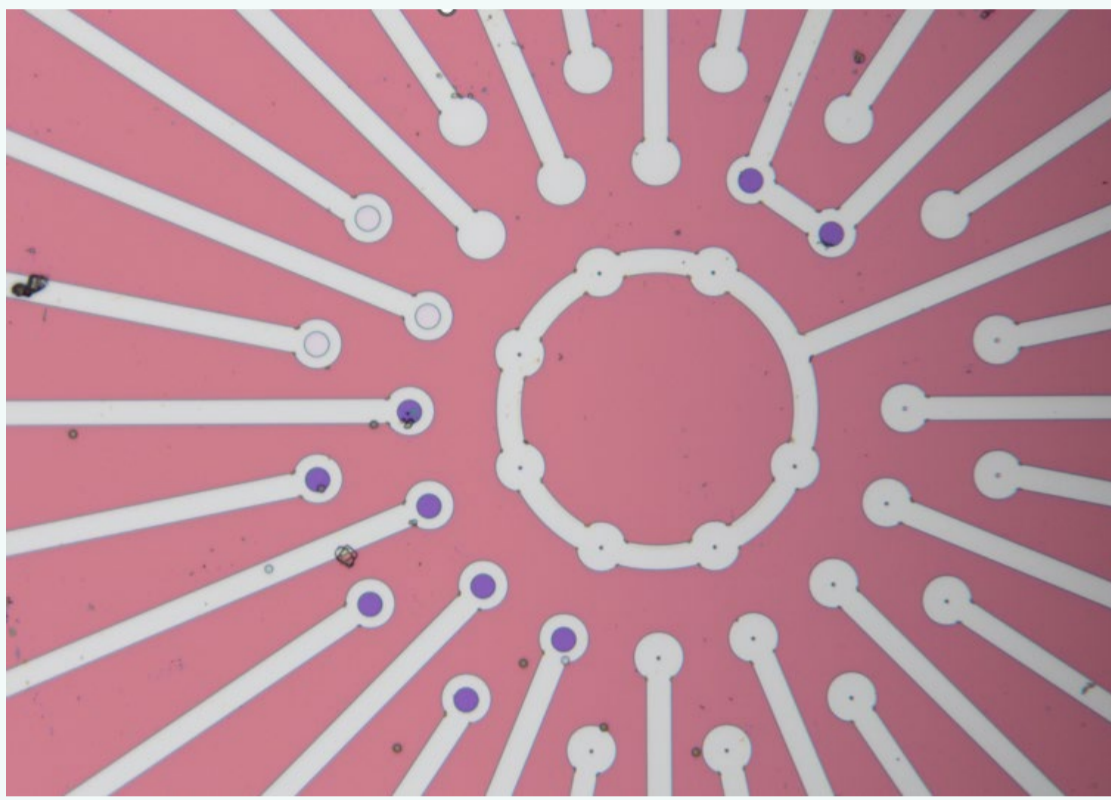
Nanomedicines



Catalytic particles

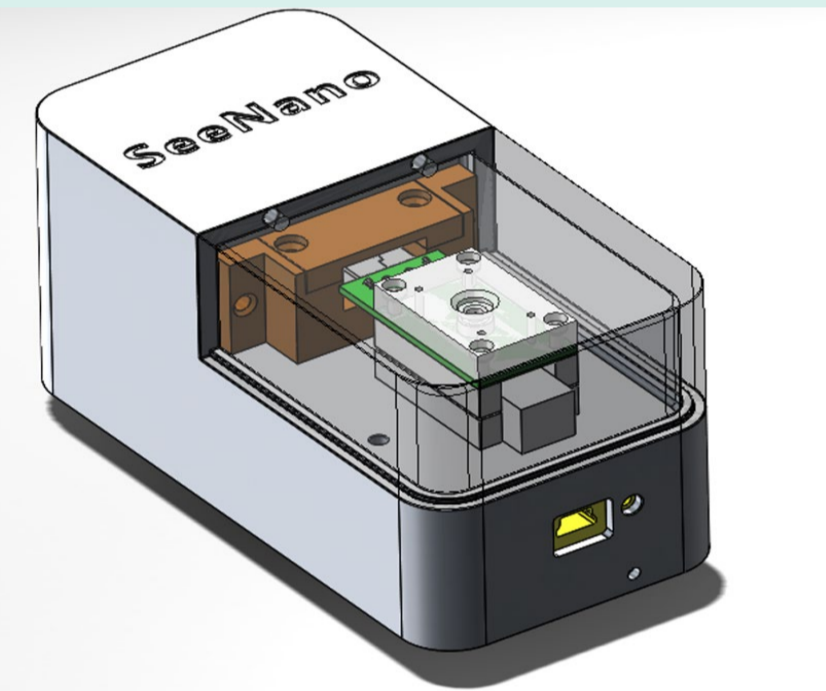


Principle of particle impact electrochemistry



Microscope image of nano-ring electrodes, diameters of 2.5 μm and 10 μm , thickness of 50 nm.

A portable device



Design of the prototype



Device realization

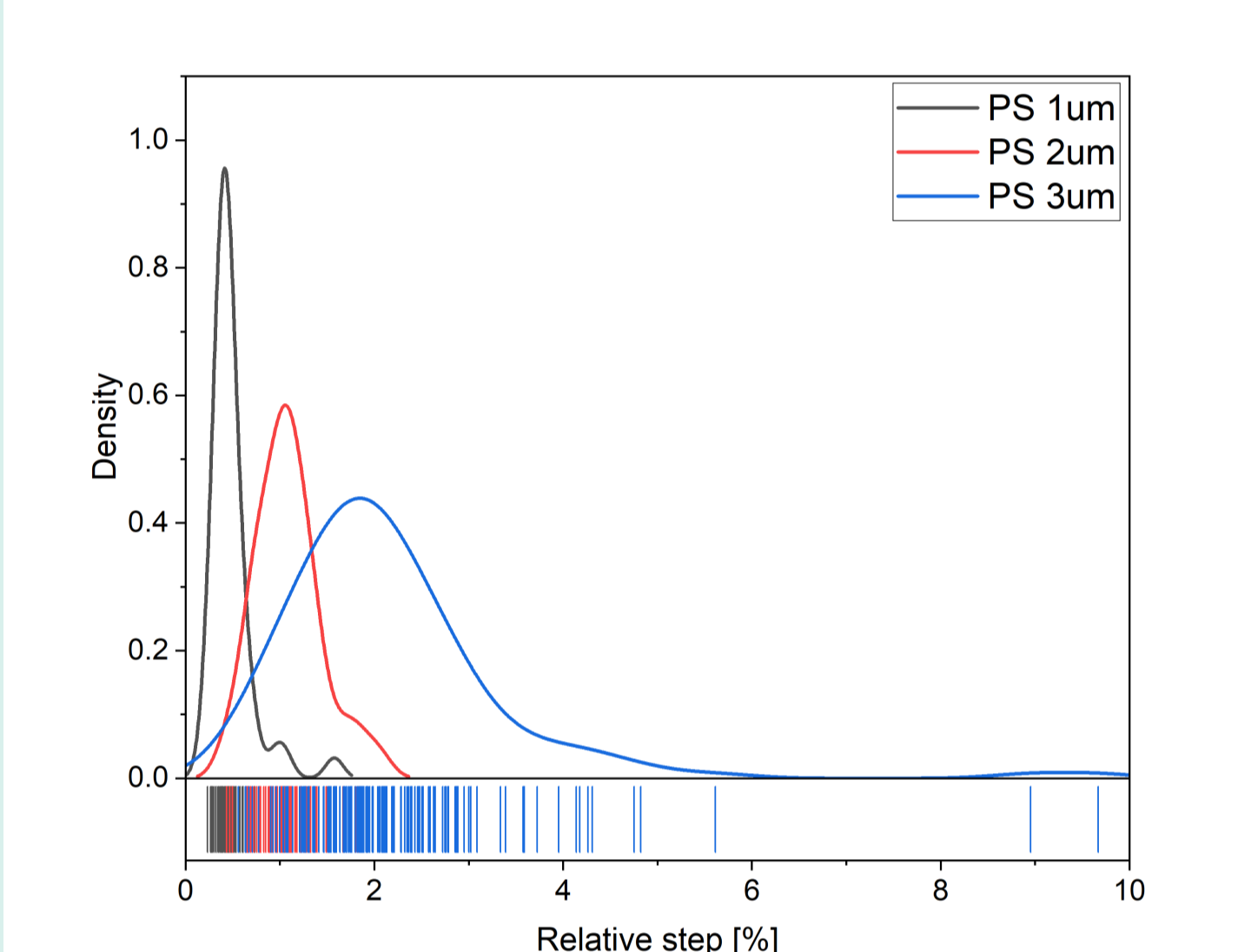


A chip holder with flexible interfaces

Particle sizing

- ❖ Polystyrene particles 1, 2 and 3 μm impacting on a nano-ring electrode 10 μm diameter, respectively.
- ❖ The relative current step size ($\Delta I/I_i$) is proportional to the particle size.
- ❖ The mean step sizes match well with the simulations.
- ❖ The wide distribution is probably due to particle size variance (3-5% by supplier) and the interference between particles.

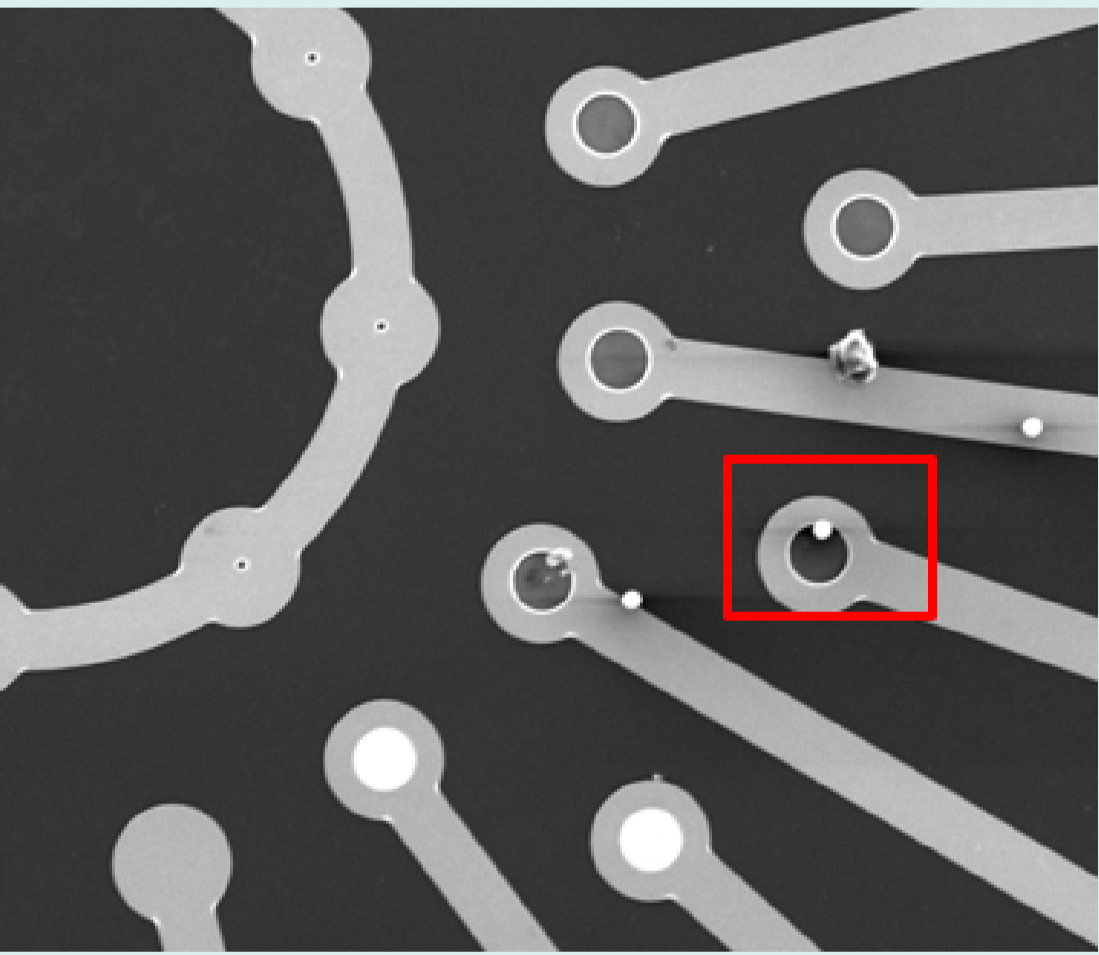
Particle size	Calculated ΔI (%)	Measured ΔI (%)	Measurement S.D. (%)
1 μm	0.6	0.48	0.23
2 μm	1.53	1.1	0.35
3 μm	2.51	2.2	1.26



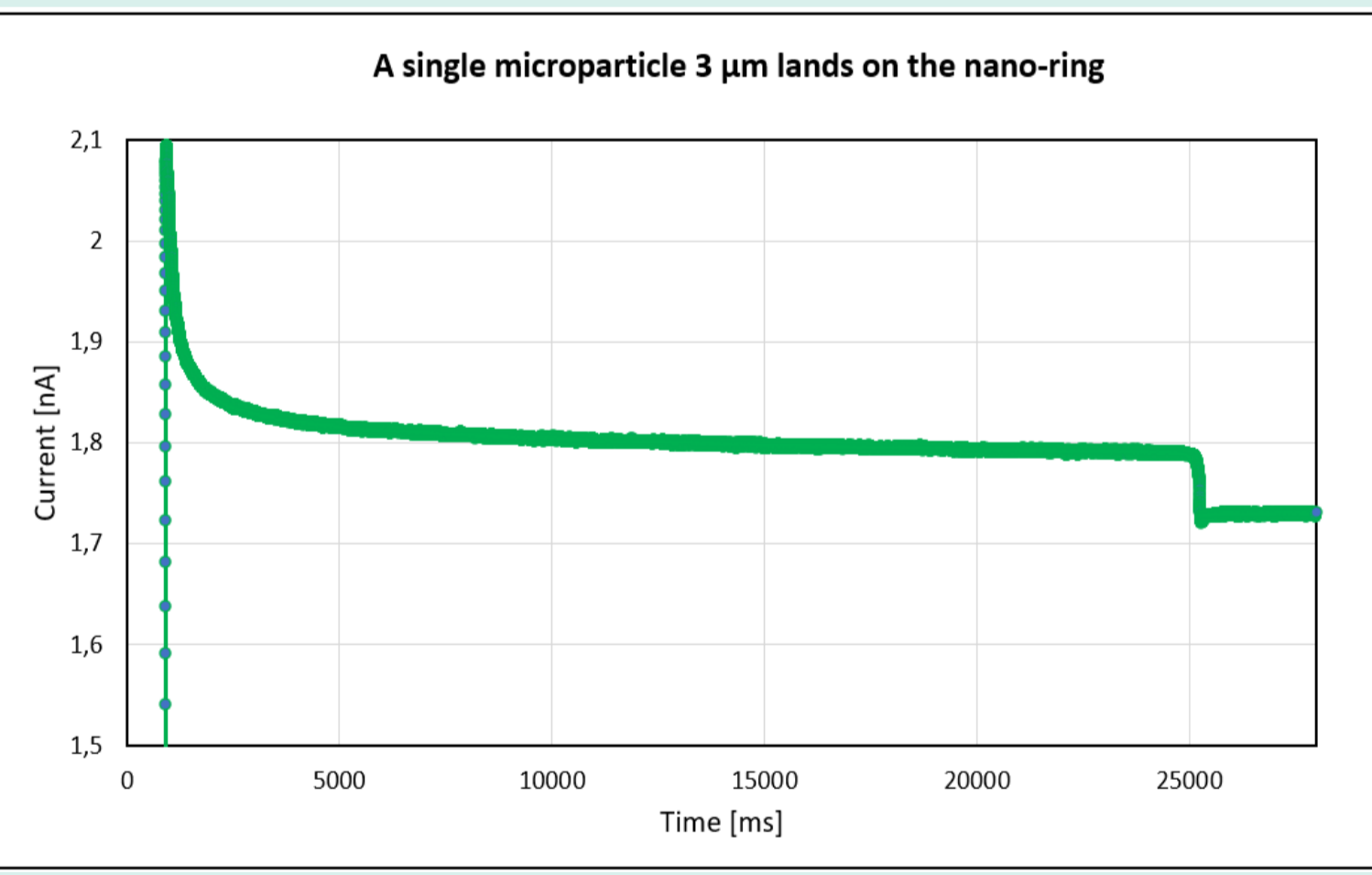
Statistic results of the relative current steps

Capturing a single particle

- ❖ Diluting the particle concentration to sub-femtomolar range (0.2 Femtomolar 3 μm polystyrene particles used).
- ❖ A single particle landing event can be recognized from a step signal. The capture was confirmed by later SEM characterization.
- ❖ A low-cost reliable particle capturing/positioning method.

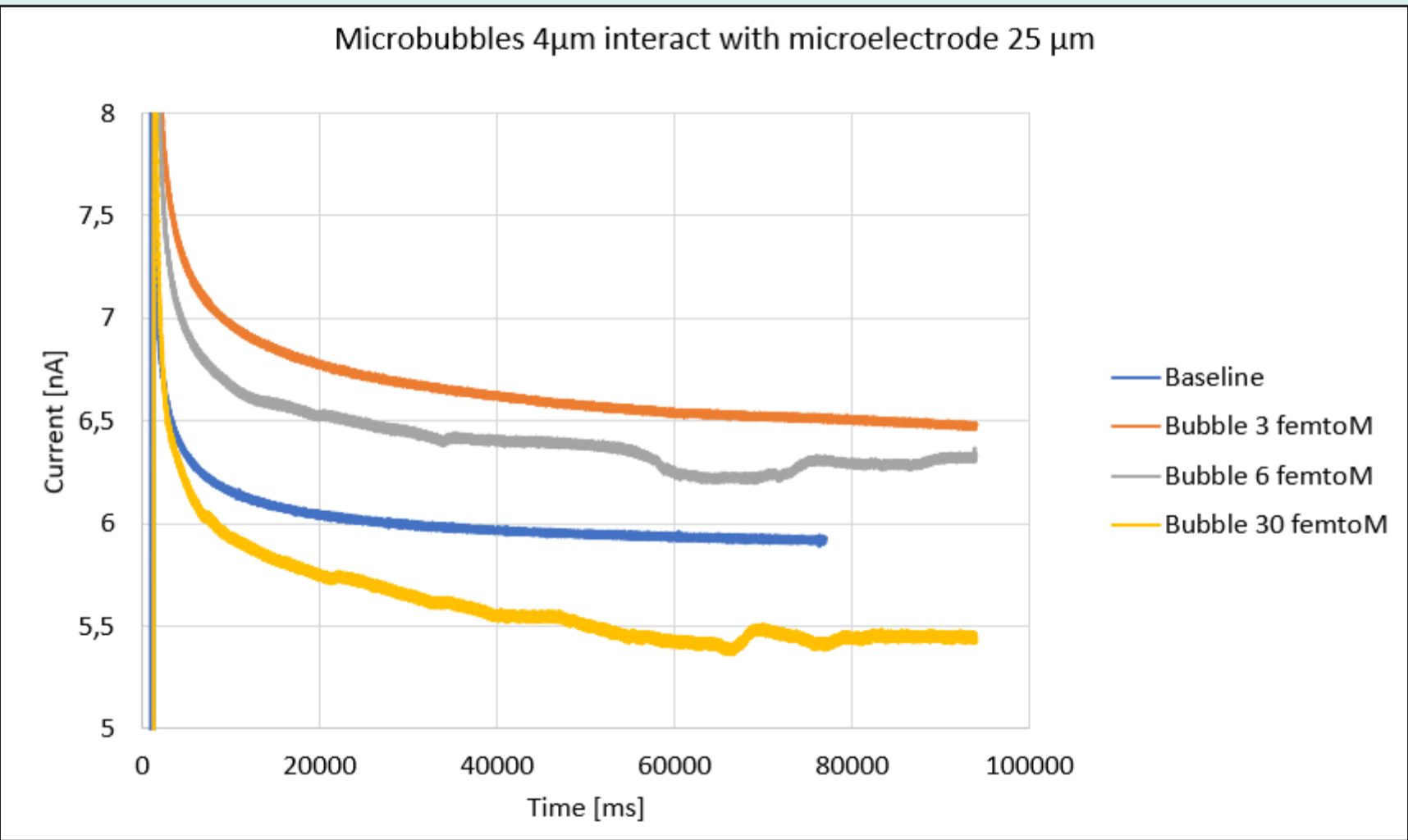


SEM image of a single particle purposely captured



Excessive solution can be removed when a single landing event occurs.

Microbubble-electrode interaction



Current signals record bubble-electrode dynamic interactions

- ❖ Microbubbles with uniform size can significantly enhance ultrasound imaging quality in medical diagnosis. Liposomes at 100 nm level are inherent byproducts in the bubble generation system. Bubble yield can be evaluated by measuring the concentration of these liposomes while that remains a challenge.
- ❖ A first trial to sense the interaction between low concentration microbubbles and a microelectrode is demonstrated. Multi-dimension micro-nano electrodes may solve this problem.

Achievements & Outlook

- ❖ The particle sizing ability is validated by measuring current steps for polystyrene particles 1, 2 and 3 μm .
- ❖ Single particle capturing/positioning method.
- ❖ Size-based biosensing method.

Further work

- ❖ The size-based biosensing are towards cost-effective point-of-care diagnostic applications.
- ❖ The single particle capturing will be useful for microplastics analysis, single cell research etc.
- ❖ The limitations of chip regeneration, inefficient data acquisition can be overcome by utilizing nano-electrode array, functional polymer film and other creative solutions.

Acknowledgements

Team

Saxion students: Quincy Meins, Joel Tromp, Patrick Tuinema, Sjoerd Peeters, Joël Tuinman, Stag Laninga.

Partners

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

Grant

KIEM GoChem 2023