Encapsulation of model bacterial sensors for optical and electrochemical detection of environmental pollutants

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BioSensei

Environmental pollution poses a major threat to health and biodiversity. In line with the ZERO-POLLUTION programme of the European Union, the BioSensei project addresses this challenge by developing a real-time, multiplexed, end-to-end, on-site optical and electrochemical monitoring system. Using cellular responses, this hybrid biosensor targets both biotic and abiotic pollutants in water (i.e., nitrates and phosphates, endocrine disruptive chemicals, PFAS and toxins).

To this purpose, immobilisation of genetically engineered bacterial cells on the transducer surface is required. Moreover, this project is embedded within a Safe-and-Sustainable-by-Design (SSbD) framework, which includes rigorous risk assessments, thus requiring a null release of modified bacteria from the sensor into the environment.

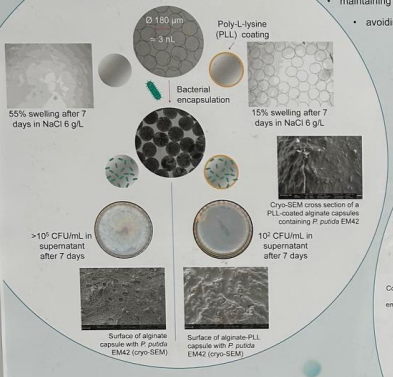
Additional constraints held on this task include:

- ensuring rapid diffusion of analytes from the environment to the bacteria and from the bacteria to the optical and electrochemical transducers
- maintaining a metabolic activity
- avoiding optical or electrochemical interference

Design and characterization

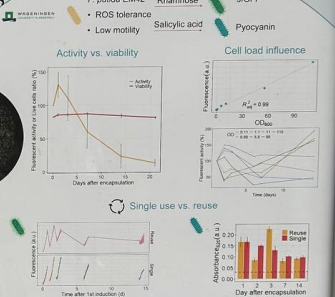
2%$_w$ Na-alginate solution

- Microfluidic jetting in $CaCl_2$
- High yield production
- Monodisperse microbeads
- ✓ Biocompatible
- ✓ Transparent

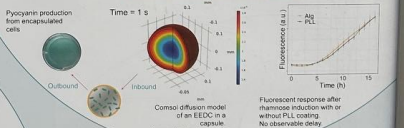


Viability and stability performances

Model sensors



Diffusion through microcapsules



Integration on transducer

System architecture

imec

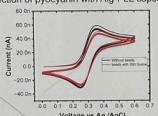
Tyndall National Institute

Optical sensor and chamber

- No interference from capsules in chamber on optical outputs
- Use of a K-based minimal nutritive media
  - Reduces swelling
  - Avoids autofluorescence

Electrochemical sensor

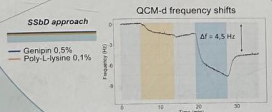
Detection of pyocyanin with Alg-PLL capsules



→ Similar signal output with and without Alg-PLL capsules

Surface immobilisation

SSbD approach



→ Upcoming immobilisation tests

The developed model showed:

- Good microscale encapsulation of bacteria
- Robust LbL protocol decreasing cell release and swelling, complying with biosafety targets
- High viability and potential circular use of such whole-cell biosensors, enhanced by the encapsulation technique
- No major hinderance of analytes diffusion by the polymer system

Further work will :

- Immobilise capsules on SSbD deposition
- Continue integration in sensing device
- Implement relevant synthetic biological input in bacteria (e.g. PFAS, N, P, endocrine disruptors)
- Combine genetic tweeking, allowing multiplexing
- Perform case studies in The Netherlands and Ireland

Acknowledgm
µLife - C
Irig
PFNC
IMEC
Europe
commis

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