Novel design for the thermal based biosensor using the transient plane source(TPS) technique

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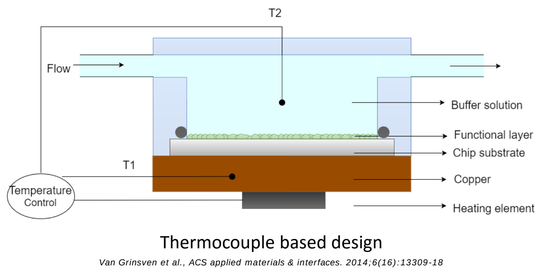
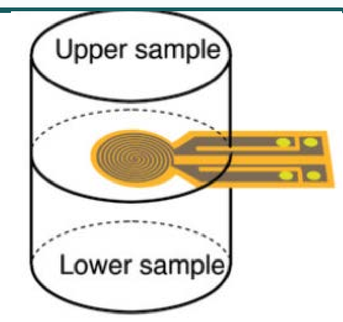
Introduction

In an urge to fulfill the increasing demand for reliable economical biosensor readout techniques, researchers at IMO-IMOMEC developed the **Heat-Transfer Method**. With this method it is possible to **perform bioanalytical tasks by closely monitoring heat transfer trough a detection layer**. The original sensor design uses thermocouples and a separate resistive heater. In order to miniaturize and optimize the HTM setup, a **new sensor design** based on **the transient plane source(TPS)** technique was proposed. The transient plane source technique has been accepted as an ISO standard (ISO/DIS 220072.2). The TPS technique allows **in plane sensing and heating**. The heat transfer method is a label free method and the samples do not require pretreatment or extra reagents.



Thermocouple based design

Van Grinsven et al., ACS applied materials & interfaces. 2014;6(16):13309-18

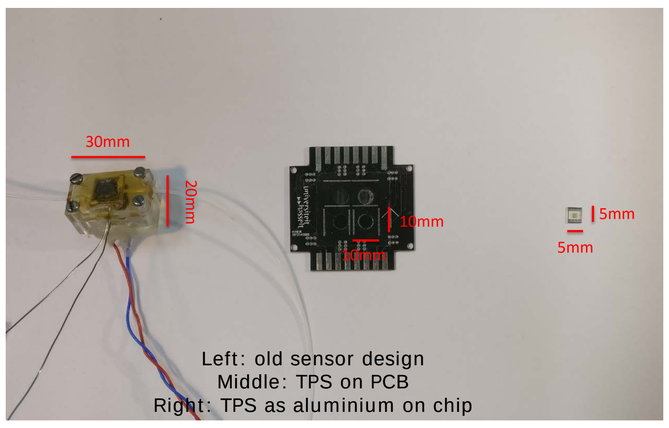


Transient plane source technique

Diagram from Lin et al. (2014)

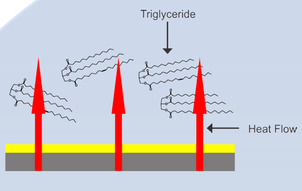
Materials & Methods

Developed TPS designs

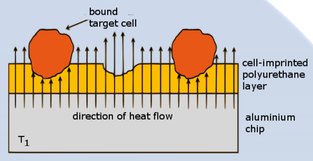


Left: old sensor design
Middle: TPS on PCB
Right: TPS as aluminium on chip

Surface area of the sensor has decreased by 24 times relative to the old sensor design. The transient plane source has been developed on a printed circuit board (PCB), but also by patterning aluminium on a glass substrate. The receptor is applied on to the transient plane source. The receptor's R_{th} will change on the presence of the analyte.



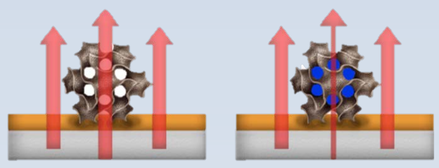
Fat concentration of fluids



Surface imprinted polymers (SIPs) for cell detection

Kasper et al., ACS applied materials & interfaces. 2013; DOI: 10.1021/am401605d

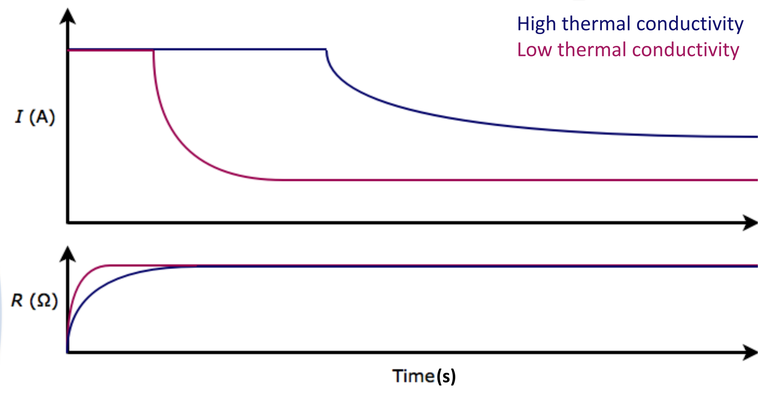
Receptor



Molecularly imprinted polymers(MIPs) for small molecule detection

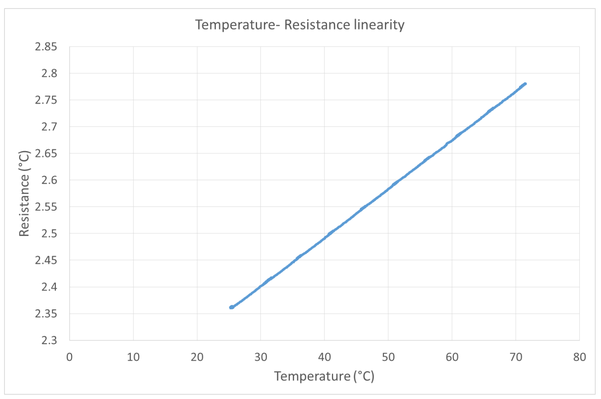
Van Grinsven et al., ACS applied materials & interfaces. 2014;6(16):13309-18

Control algorithm & readout method for the TPS design



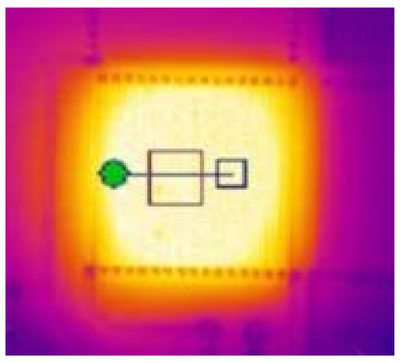
The control algorithm keeps the sensor at a fixed elevated temperature. It does this by maintaining a constant resistance. Indeed, the electrical resistance is linearly correlated to the temperature. To heat up the TPS a certain amount of current is needed. That amount is a measure for the heat transfer resistivity of the receptor.

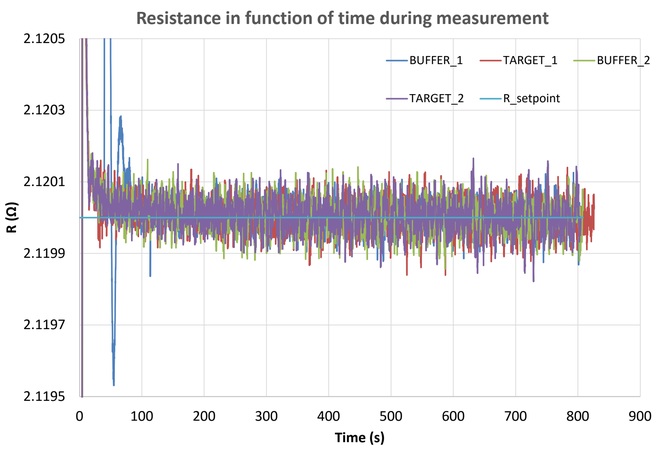
Characterization



The transient plane sources are calibrated within a climate chamber. The temperature coefficient of resistance (TCR) is derived from the slope. A higher TCR results in a higher sensitivity of the sensor.

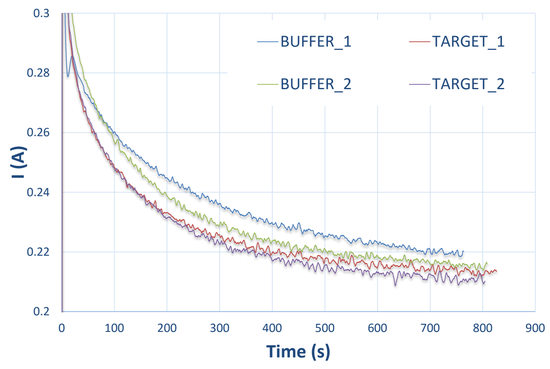
The heat distribution of the TPS can be seen in the IR image. The center of the transient plane source shows an equal heat distribution.

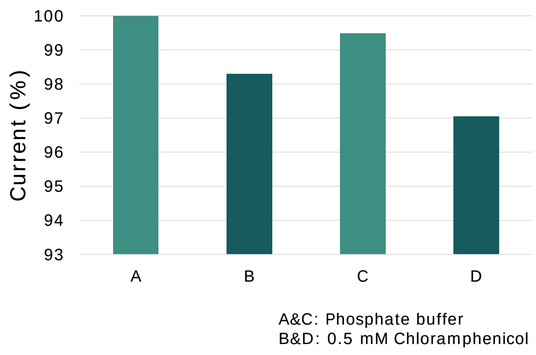




During a measurement the resistance has a maximum deviation of ±0.0001Ω on the 2.120Ω setpoint. This relates to a maximum error of 0.01°C

Results





A&C: Phosphate buffer
B&D: 0.5 mM Chloramphenicol

Chloramphenicol molecules were detected with MIP detection layer. The measurement is performed in 4 steps. During step B buffer solution is reapplied, the current however does not return to the same level. This proves that molecules have indeed been detected.

Conclusion & Future potential

By functionalizing the transient plane source with different receptors different bioanalytical tasks can be performed. From this point of view the transient plane source can be utilized as a platform. The TPS design has been fully characterized in order to prove the reliability of the biosensor.

Future potential:

- Diamond transient plane sources
- Multichannel functionality
- Nano MIPs, grafting MIPs directly onto transient plane source

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