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FET-based integrated charge sensing in a MEM organ-on-chip platform

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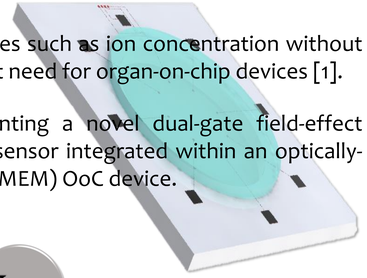
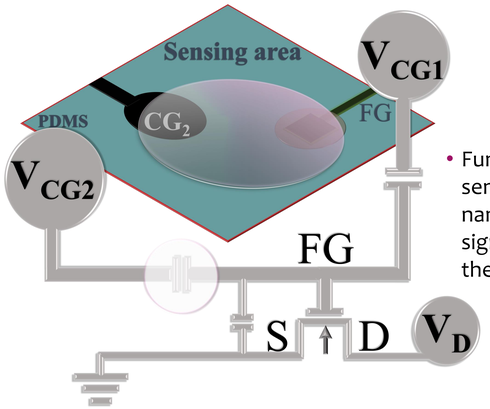
Introduction

- Real-time monitoring of biological cues such as ion concentration without relying on optical systems is an unmet need for organ-on-chip devices [1].
- Here we meet this need by presenting a novel dual-gate field-effect transistor-based (FET-based) charge sensor integrated within an optically-transparent microelectromechanical (MEM) OoC device.

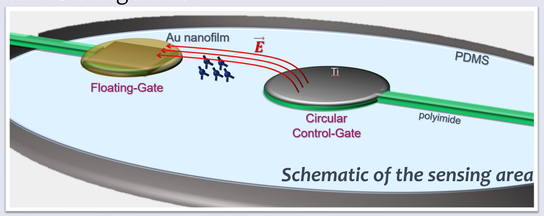




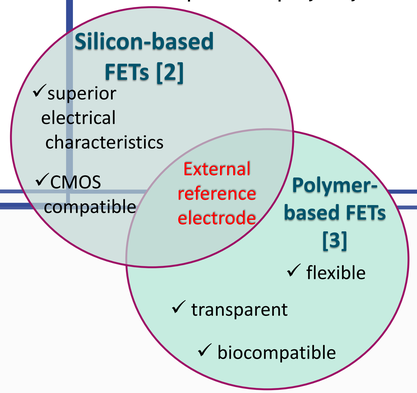
- Functionalization of Ti sensing electrodes by Au nanoparticle films significantly increases the sensor sensitivity.

Silicon-Polymer hybrid Field-Effect Transistor

- Potential difference between floating-gate(FG) and circular control-gate directs the ions towards FG, depending on their mass to charge ratio.
- Charges in close proximity of the FG extension modulates the channel conductance in the FET
- This can be tracked by monitoring changes in the threshold voltage or drain current.

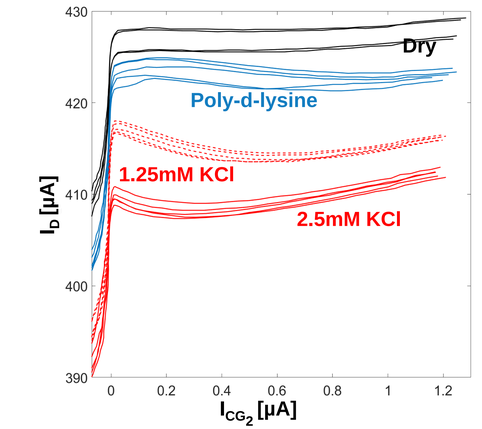


- This device eliminates the usage of external and bulky reference electrode, which is common for FET-based biosensors.
- We validate the biocompatibility of the sensor and its response to poly-D-lysine and KCl.



Preliminary Results

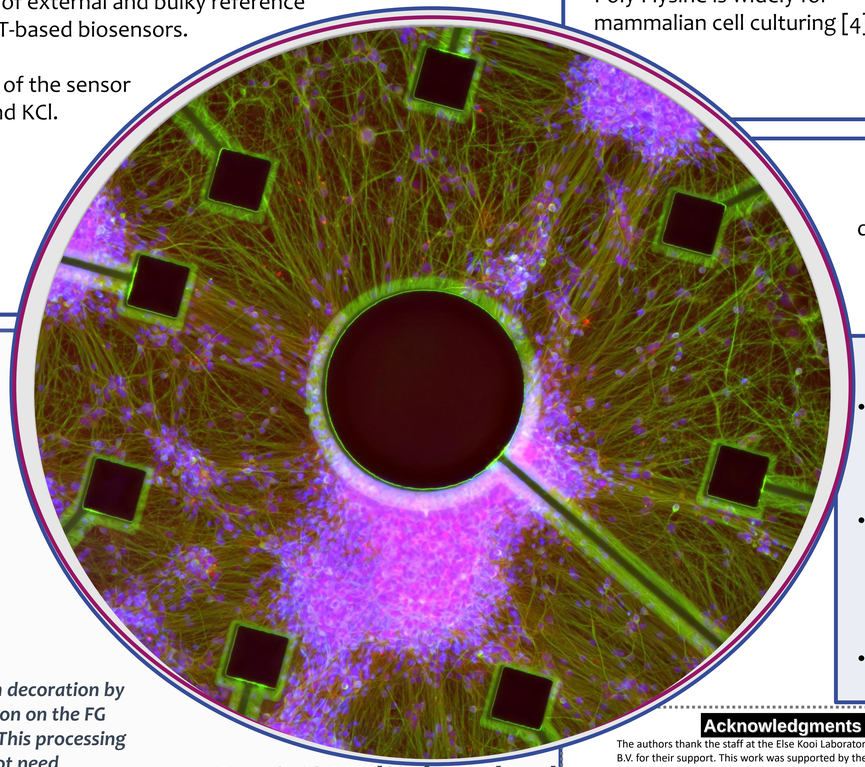
- I_D shifts due to different liquids on Au-decorated sensor. V_{CG_2} (-2V to 2V), V_{CG_1} = 5V
- The absolute change in I_D value is linearly proportional to the charge concentration of the solution.
- Different concentrations of KCl solutions and poly-d-lysine were used for haracterization. Poly-l-lysine is widely for mammalian cell culturing [4].



Biocompatibility Tests

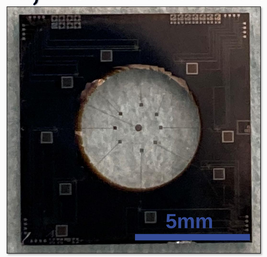
Neural Progenitor Cells (NPCs) were successfully differentiated on the chips into cortical neurons for 7 days.

The chip is suitable for live measurements of hiPSC-derived cortical neurons.

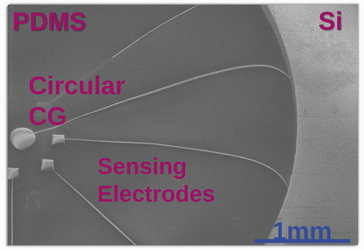


Stained with DAPI [blue], MAP2 [green] synaptophysin [red]

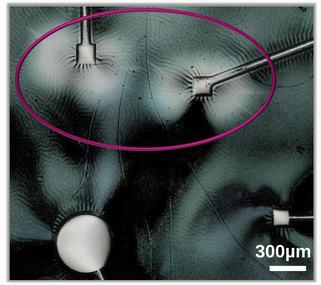
Wafer-Scale Fabrication



After wafer-scale fabrication, the wafers were diced to 1cm x 1cm chips.



SEM image of the chip, from the backside. Suspended PDMS membrane with electrodes can be seen.



Au nanofilm decoration by spark ablation on the FG electrodes. This processing step does not need lithography.

Conclusions & Outlook

- We integrated extremely compact FET-based electrochemical sensors with enhanced sensitivity and selectivity within an advanced MEM OoC device.
- NPCs were successfully differentiated to cortical neurons on chip, and preliminary results suggest that our MEM OoC device can be employed for testing the K+ level of brain cells.
- Future studies will focus on selectivity of the electrodes towards specific ions.

Acknowledgments

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