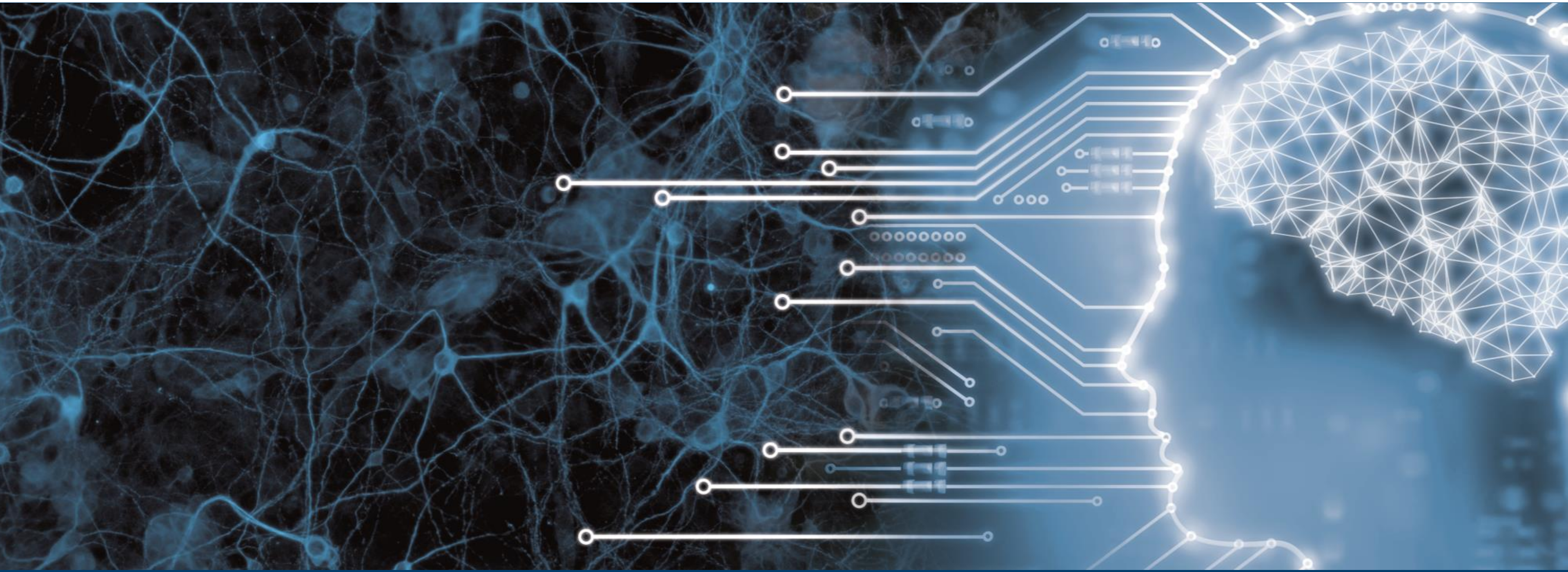
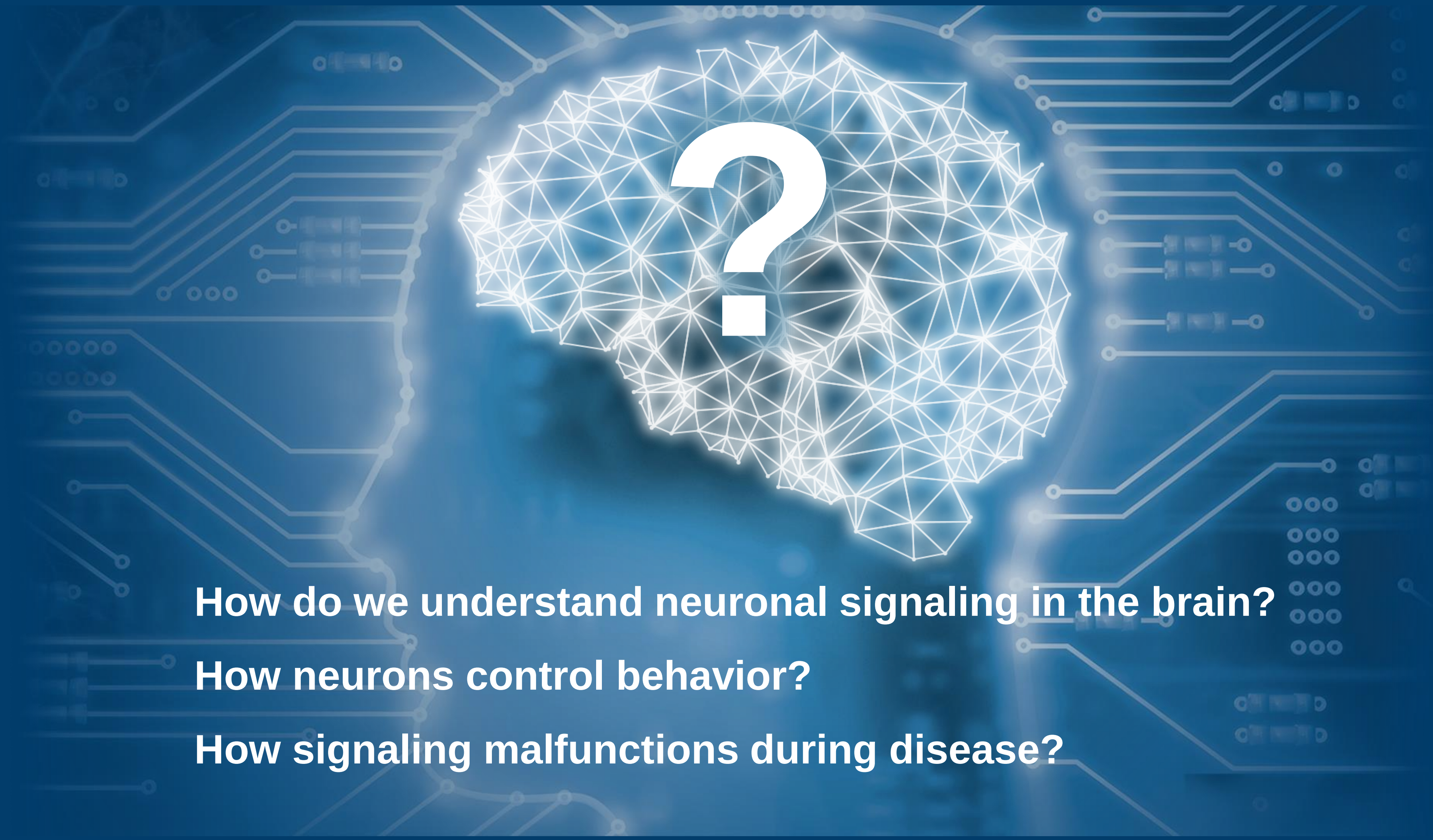


USING INTERDIGITATED ORGANIC ELECTROCHEMICAL TRANSISTORS AS ELECTROPHYSIOLOGICAL AND BIOCHEMICAL SENSORS

Dr. Dirk Mayer



How do we understand neuronal signaling in the brain?

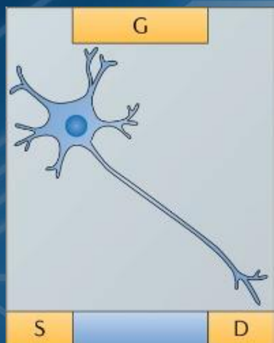
How neurons control behavior?

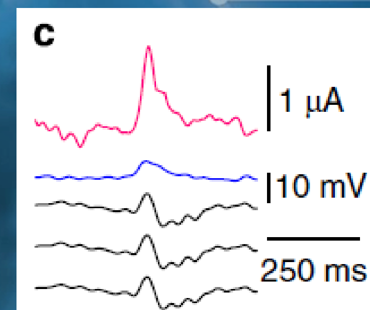
How signaling malfunctions during disease?

Y. Liang, et al. *Advanced Healthcare Materials* **2021**, 2100061.

Organic electrochemical transistors

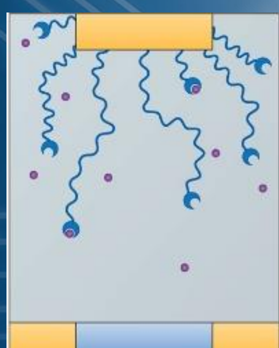
Electorphysiological sensors

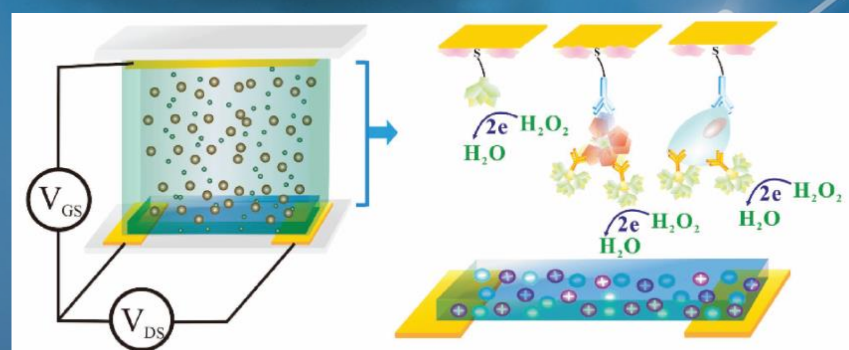




D. Khodagholy, Nature Commun, 2013

Biochemical sensors





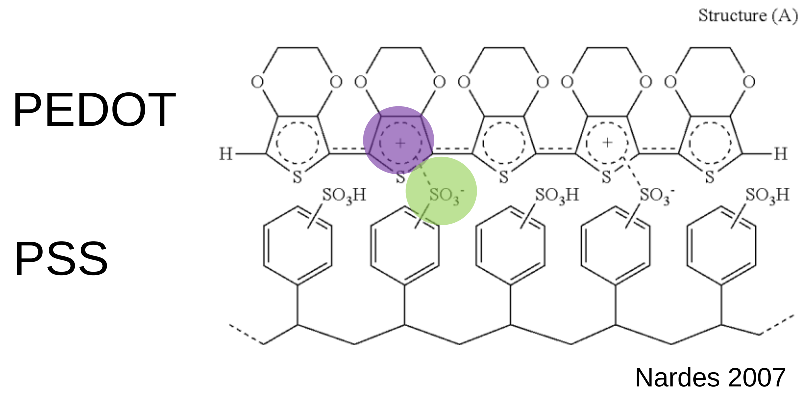
Fu et al Adv. Mater. **2017**, 1703787

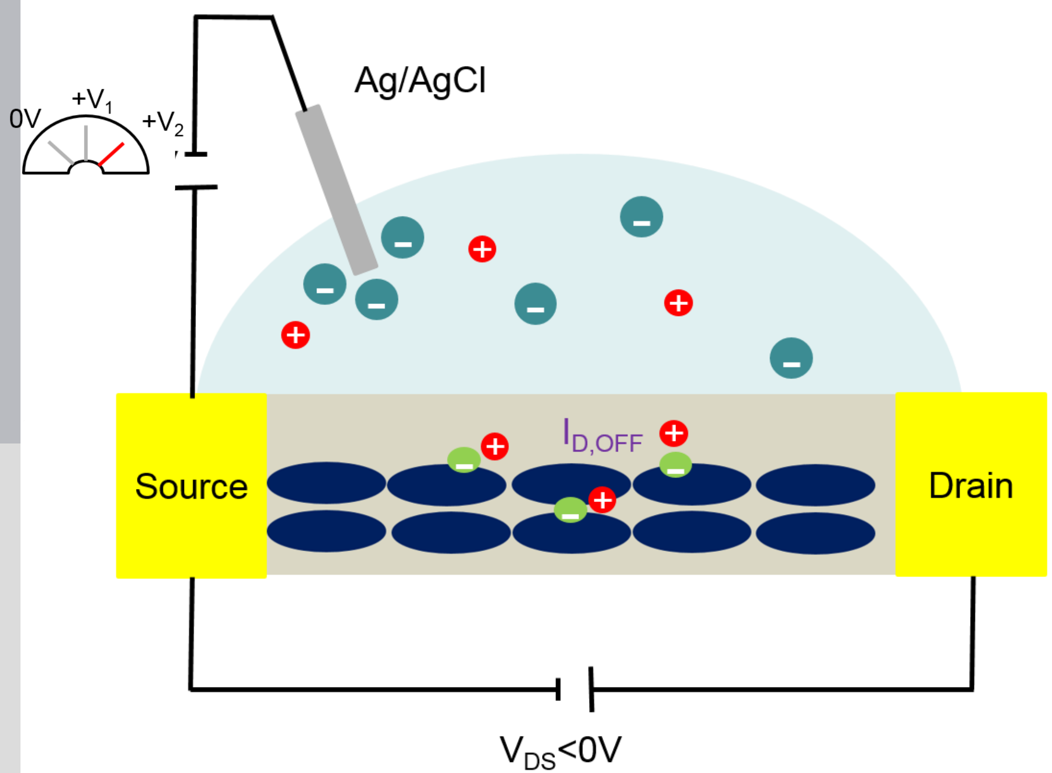
Rivnay, J. *et al.* (2018) Nature Reviews I Materials

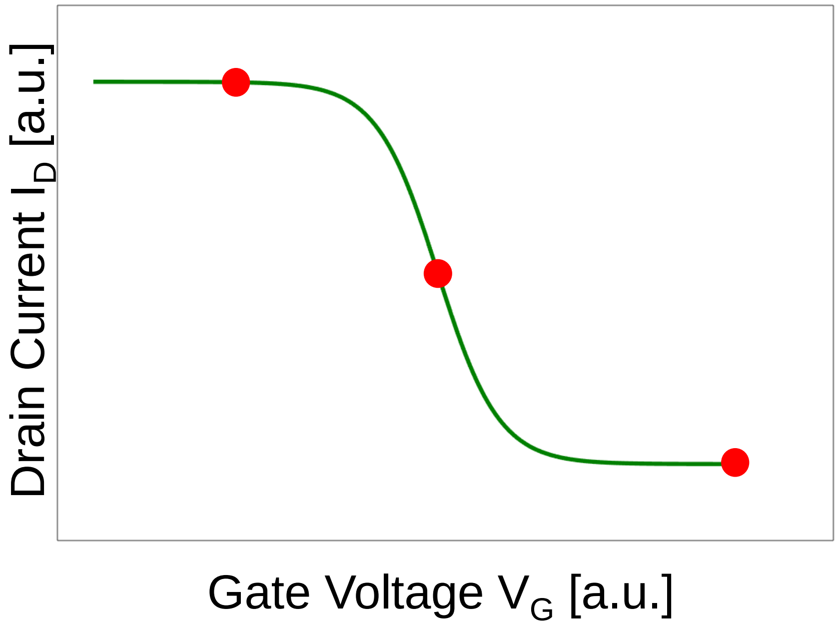
Liang et al. Adv. Healthcare Materials (2021) 2100061

Working Principle OECTS

Off-State

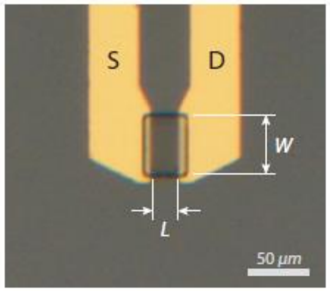




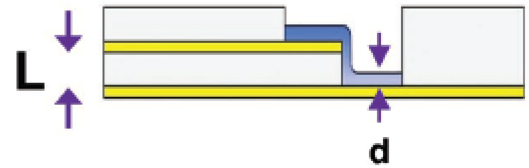


Y. Liang, et al. *Advanced Healthcare Materials* **2021**: 2100061.

Planar OECTs

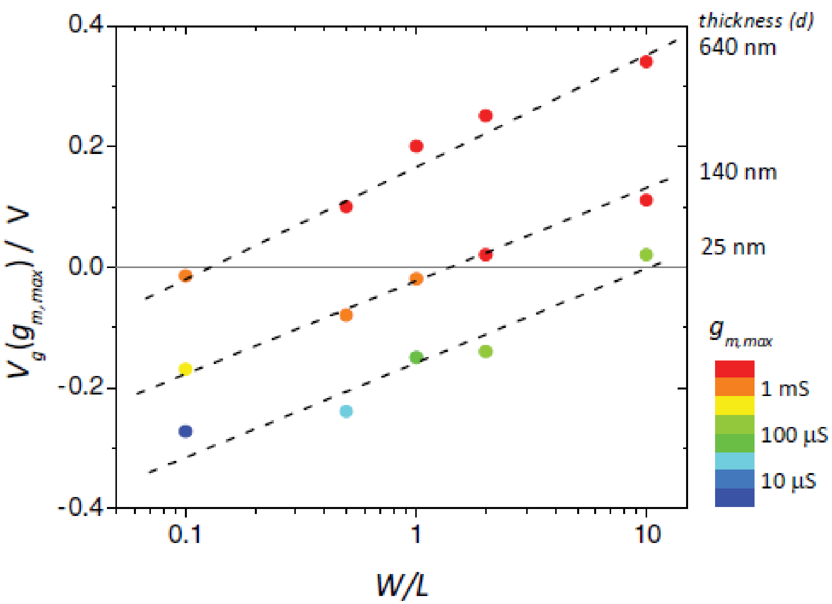


Vertical OECTs

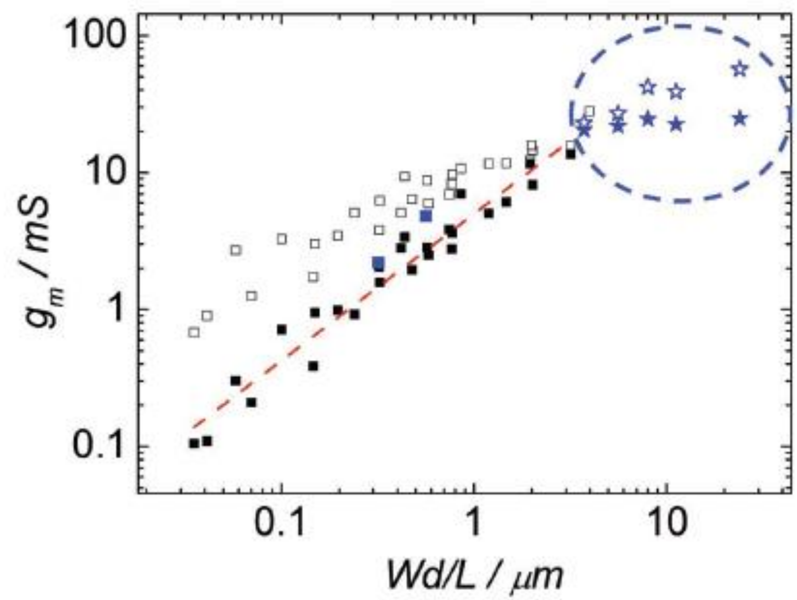


Transconductance

$$g_m = (W \cdot d/L) \cdot \mu \cdot C^* \cdot (V_T - V_G)$$



Rivnay et al Adv.Mater. **2013**, 25, 7010–7014

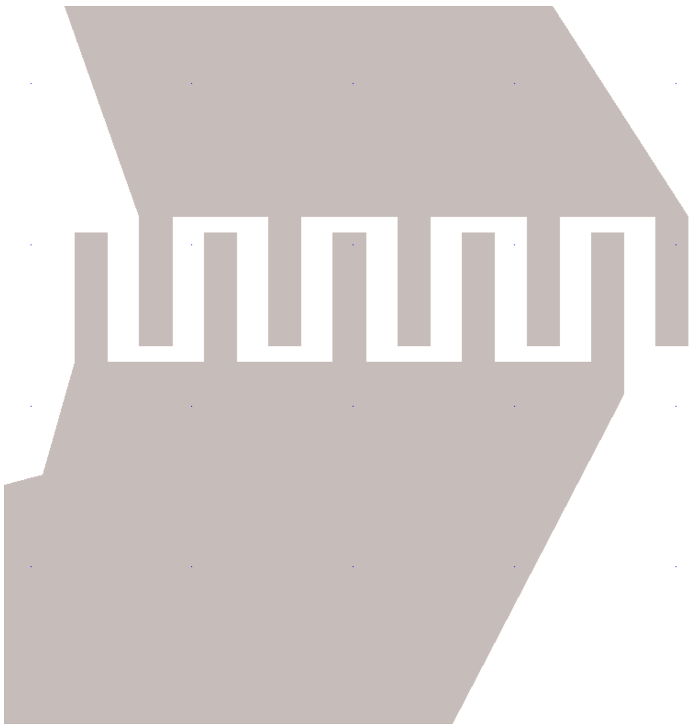


Donahue et al *Adv. Mater.* **2018**, *30*, 1705031

Low transistor density

Electrode Design

Interdigitated Electrodes



Advantage:
Large Channel Width
Short Channel Length

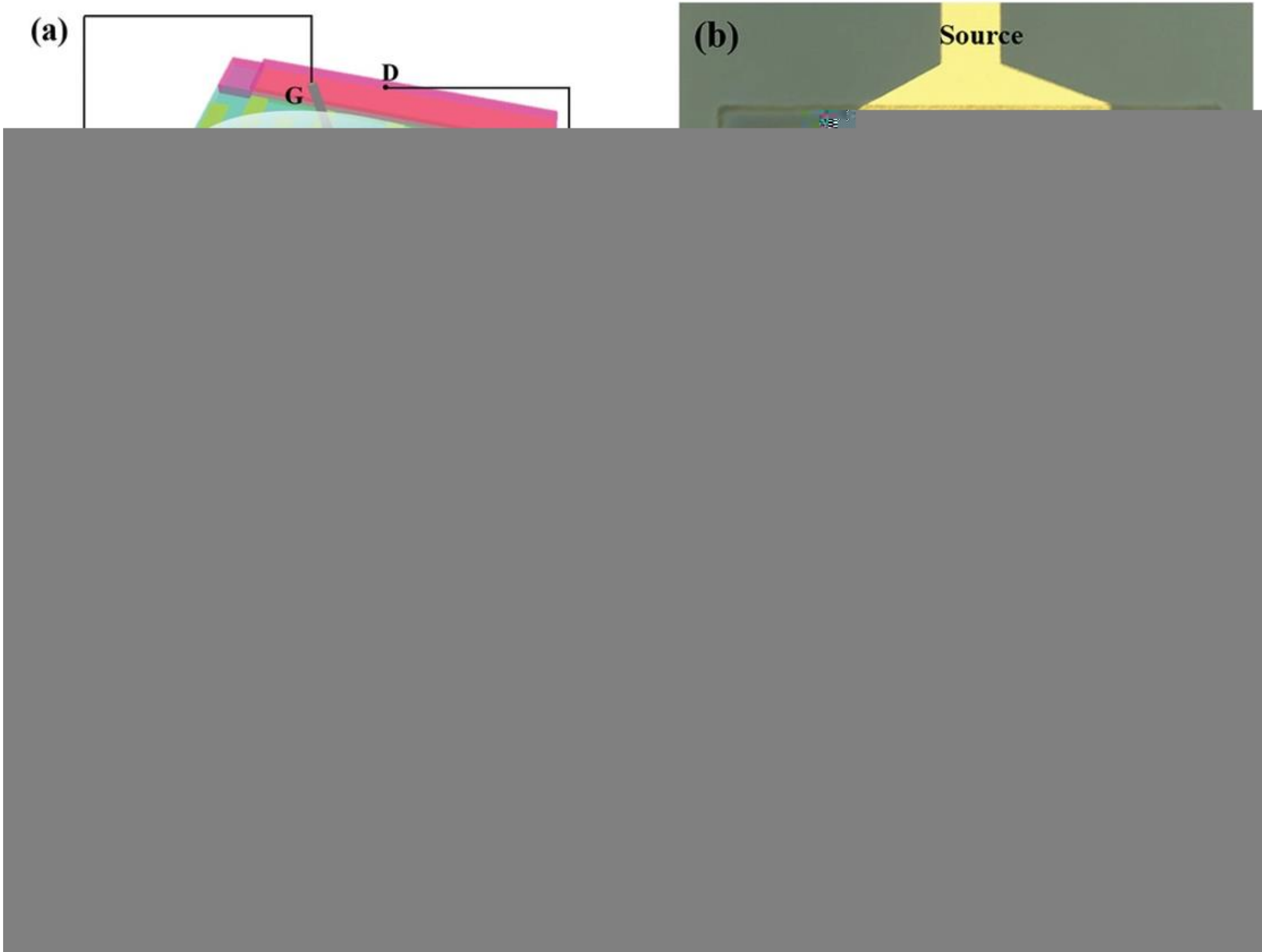
High Current + Low Voltage, High Sensitivity

Dimensions of Single Cells

Potenially improved performance

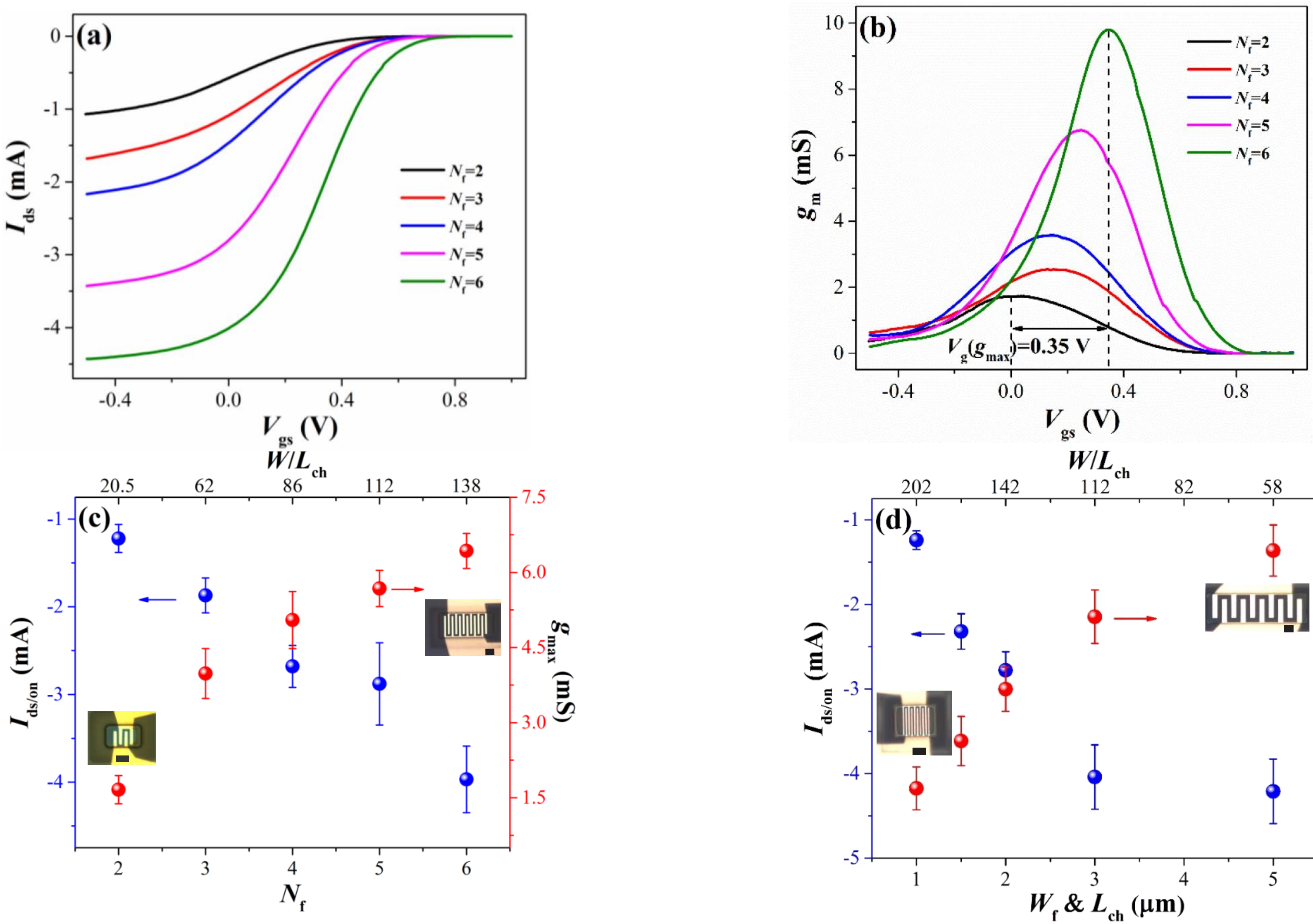
Feature Size ≈ 2µm
Number of Unit Cells 2-6

iOECTs performance



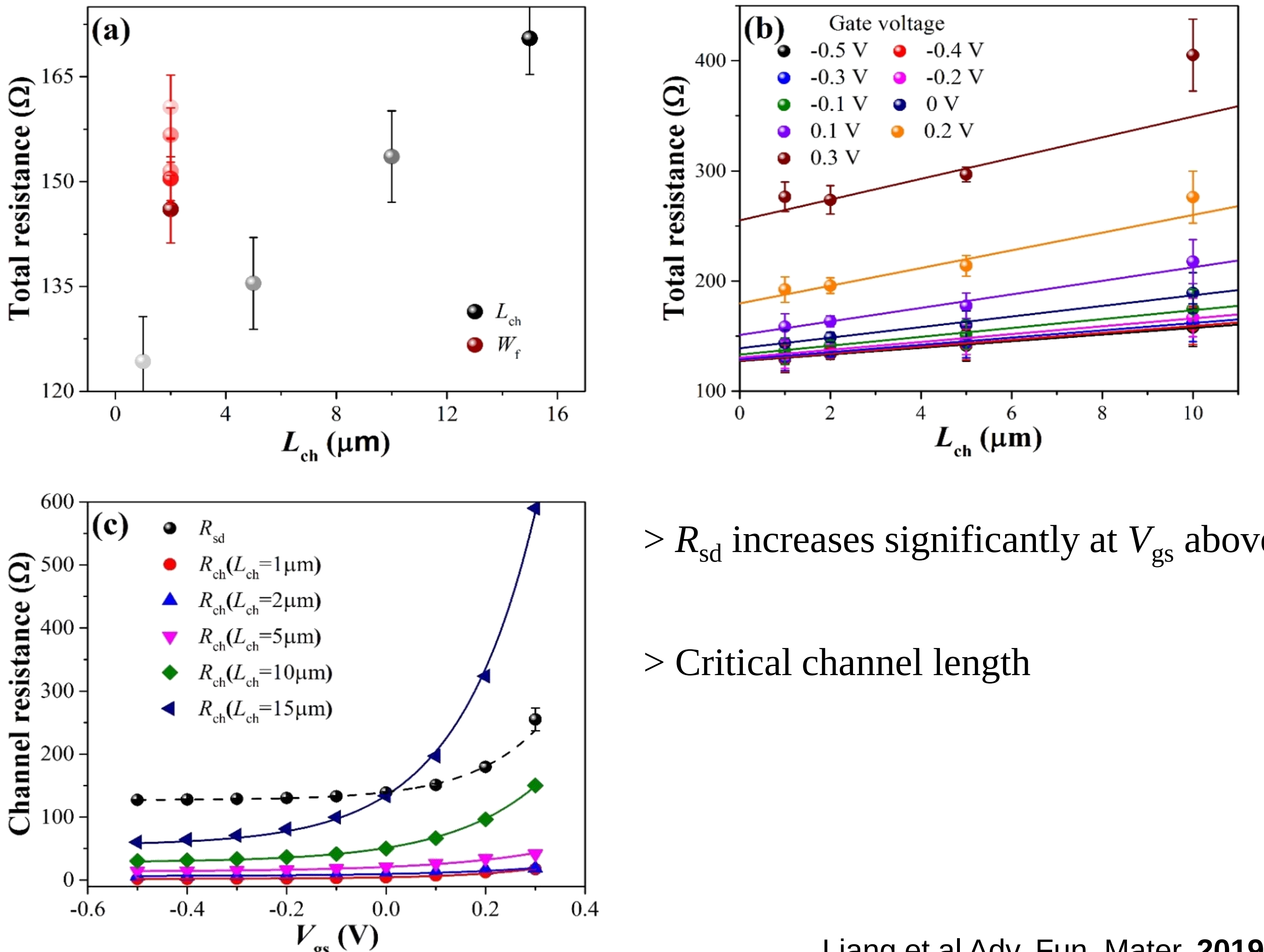
Liang et al Adv. Fun. Mater. **2019** 1902085

Digit number/ width/ channel length



$N_f \uparrow$ $W_f \uparrow$ $L_{ch} \downarrow$ $g_m \uparrow$

Source-drain series vs. channel resistance

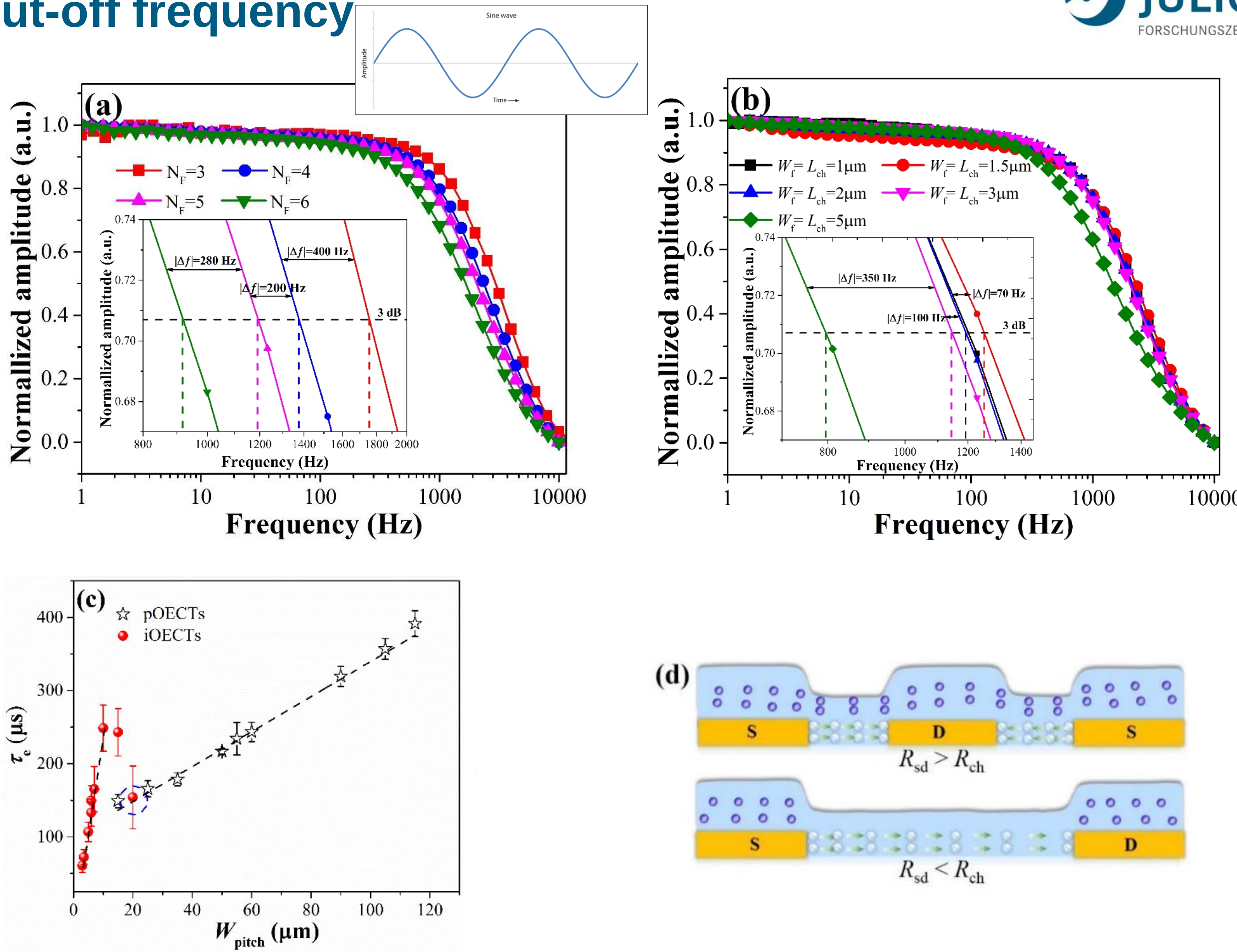


> R_{sd} increases significantly at V_{gs} above 0V

> Critical channel length

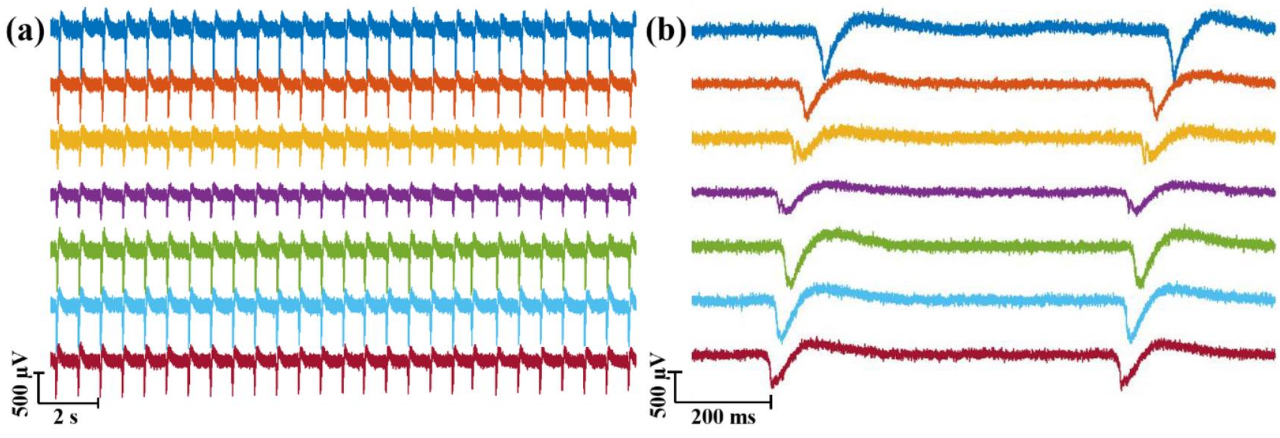
Liang et al Adv. Fun. Mater. **2019** 1902085

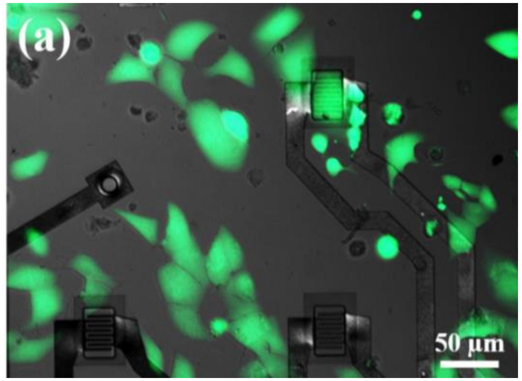
Cut-off frequency



Liang et al Adv. Fun. Mater. **2019** 1902085

Action potentials recordings of HL-1 cells

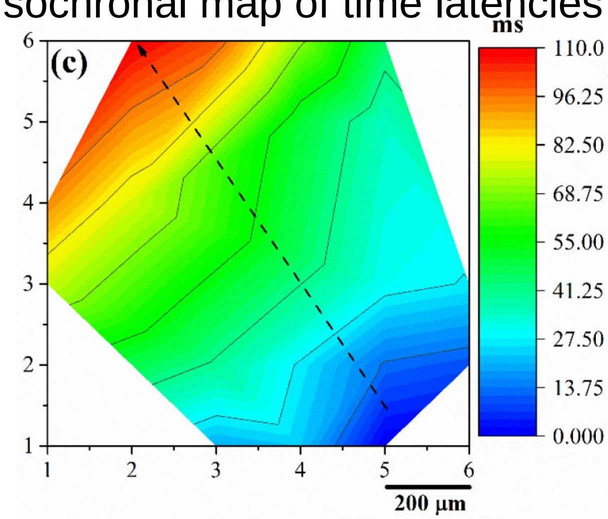




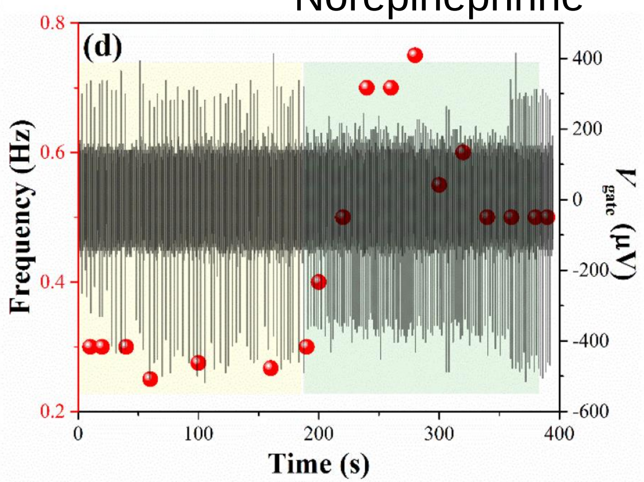
N_f=5, W_f=3 µm, L_{ch}=3 µm

Signal to noise ratio: 7~18

Isochronal map of time latencies



Norepinephrine



Smallest transistor area: 30 µm*22 µm

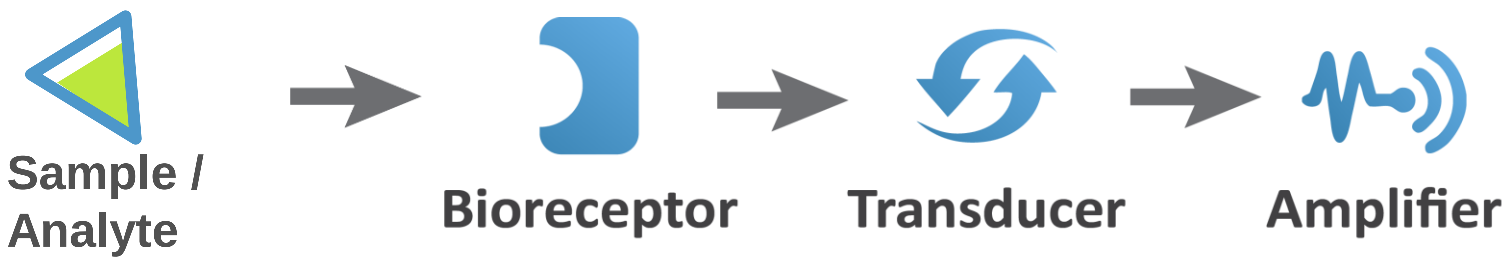
N_f=4, W_f=2 µm, L_{ch}=2 µm

Liang et al Adv. Healthcare. Mater. **2018** 1800304

Liang et al Adv. Fun. Mater. **2019** 1902085

Definition

OECT as Biosensor

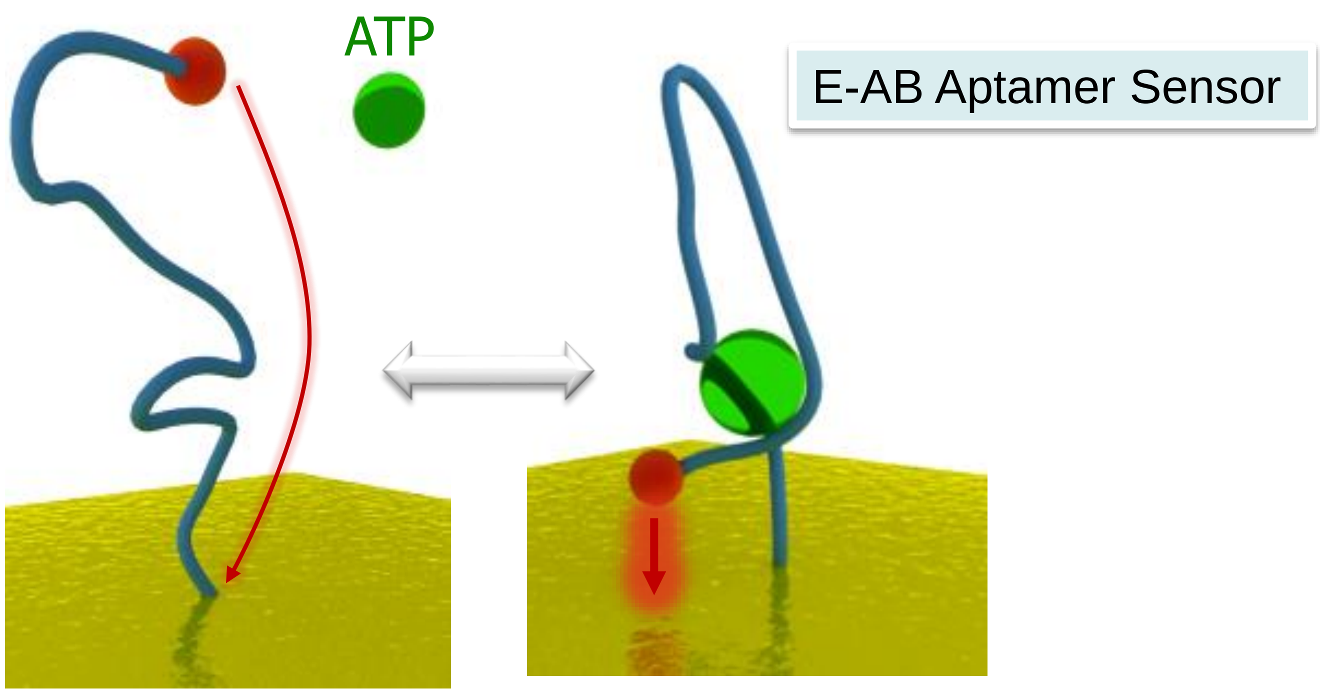


Recognition of targets by Aptamers

Electrochemical biosensors

- Thermostable
- Easy modification
- Inexpensive

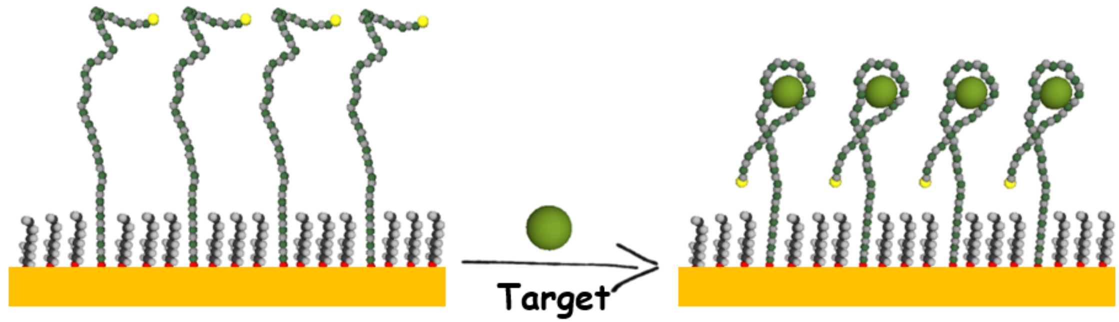
Drawbacks: The obtained electrochemical signals are usually limited by the surface probe density and high background signal



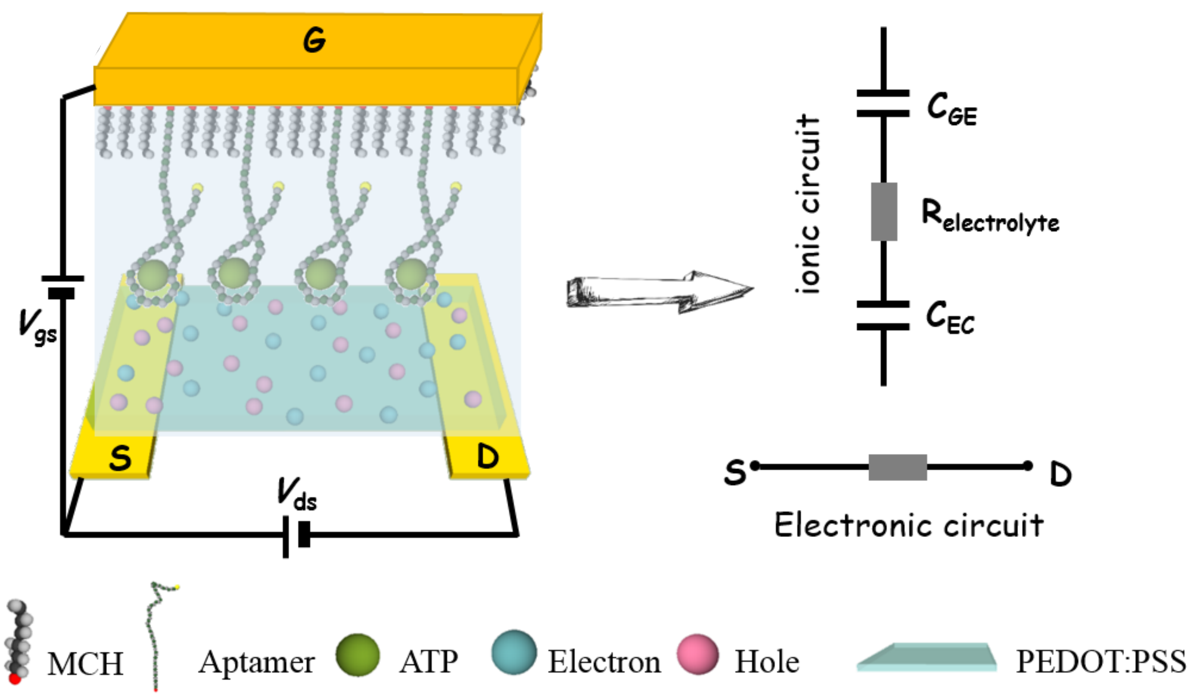
Amperometric vs. Potentiometric Transducer

Amperometric Transducer

Liang et al Bios. Bioelect. **2019** 144, 111668



Potentiometric Transducer



Amperometric Transducer

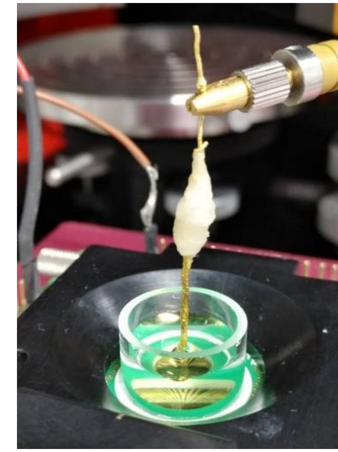
Macroelectrode

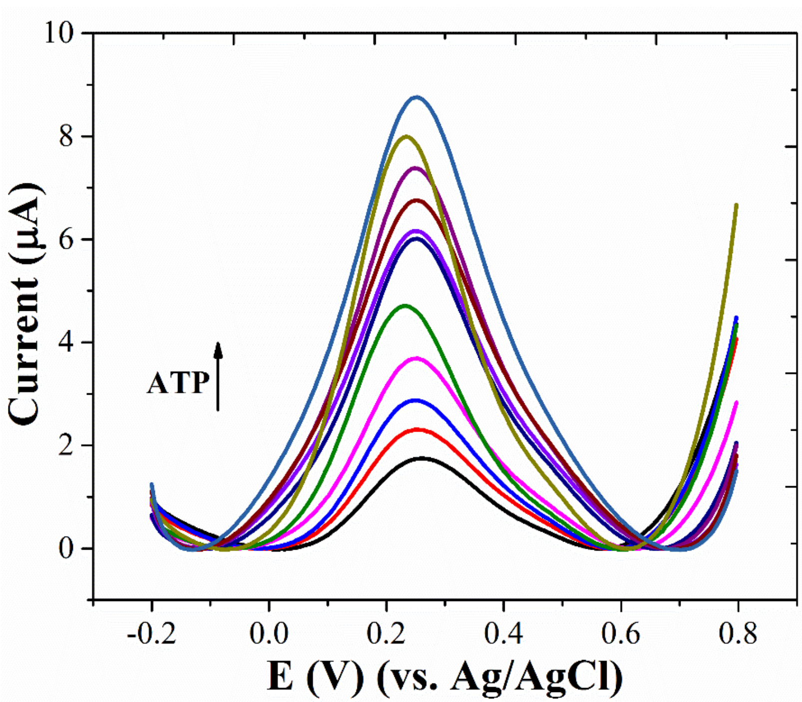
Annealed with a hydrogen flame, then coolded down to room temperature

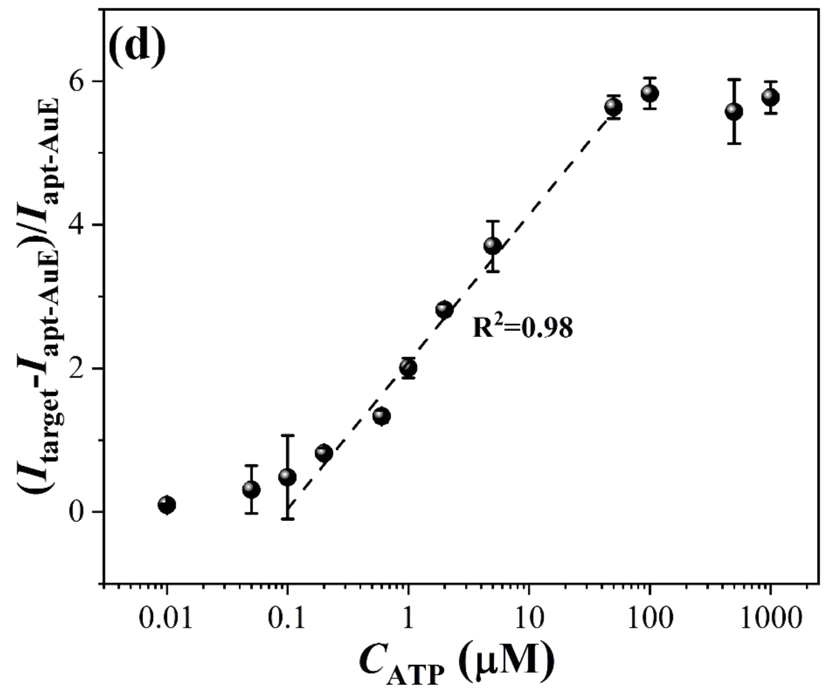
50 mM H_2SO_4 to determin the surface area

Incubation in DNA oligomer pretreated with TCEP for 16h

Blocked by MCH for 1h



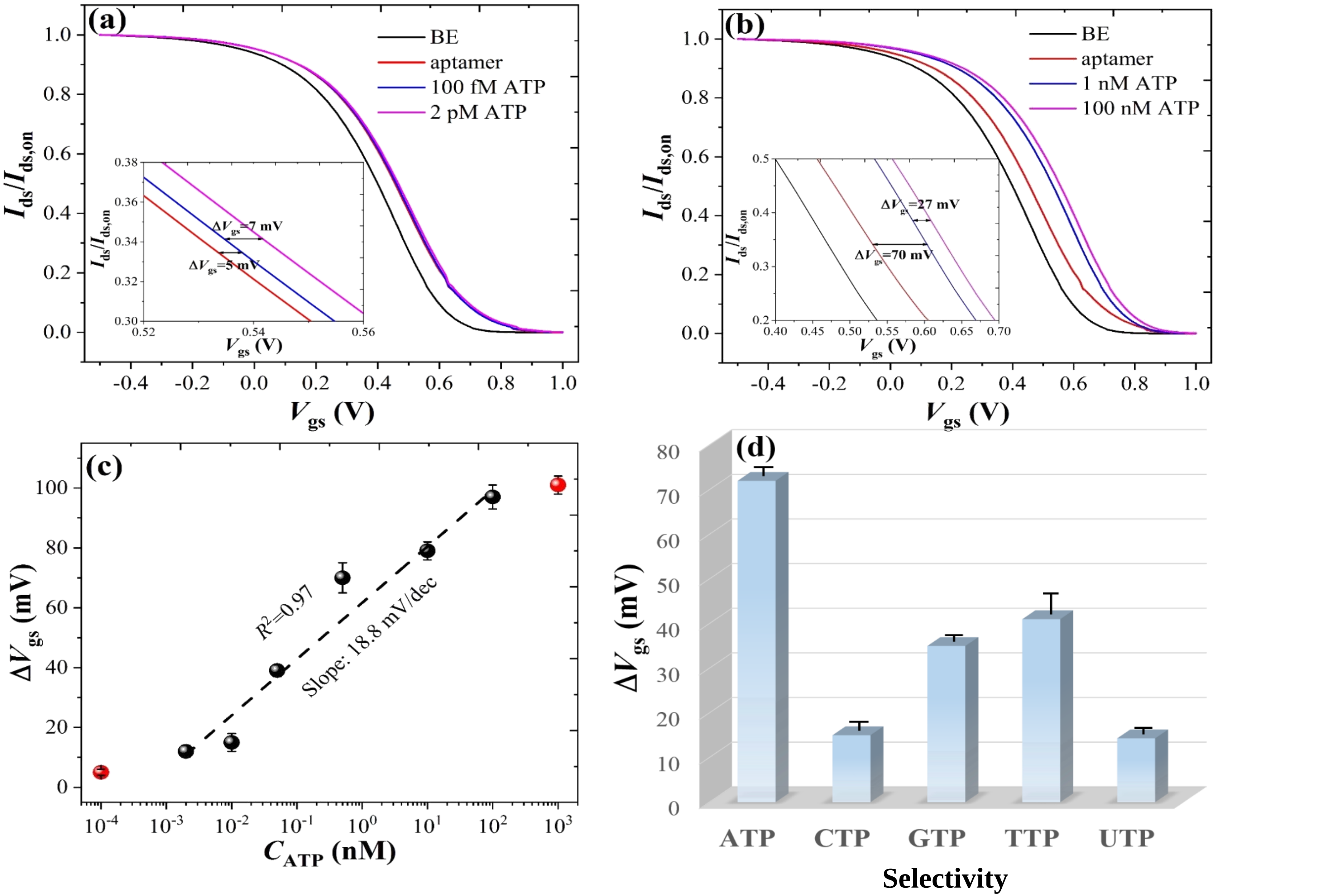




Limit of detection: 100 nM

Liang et al Bios. Bioelect. **2019** 144, 111668

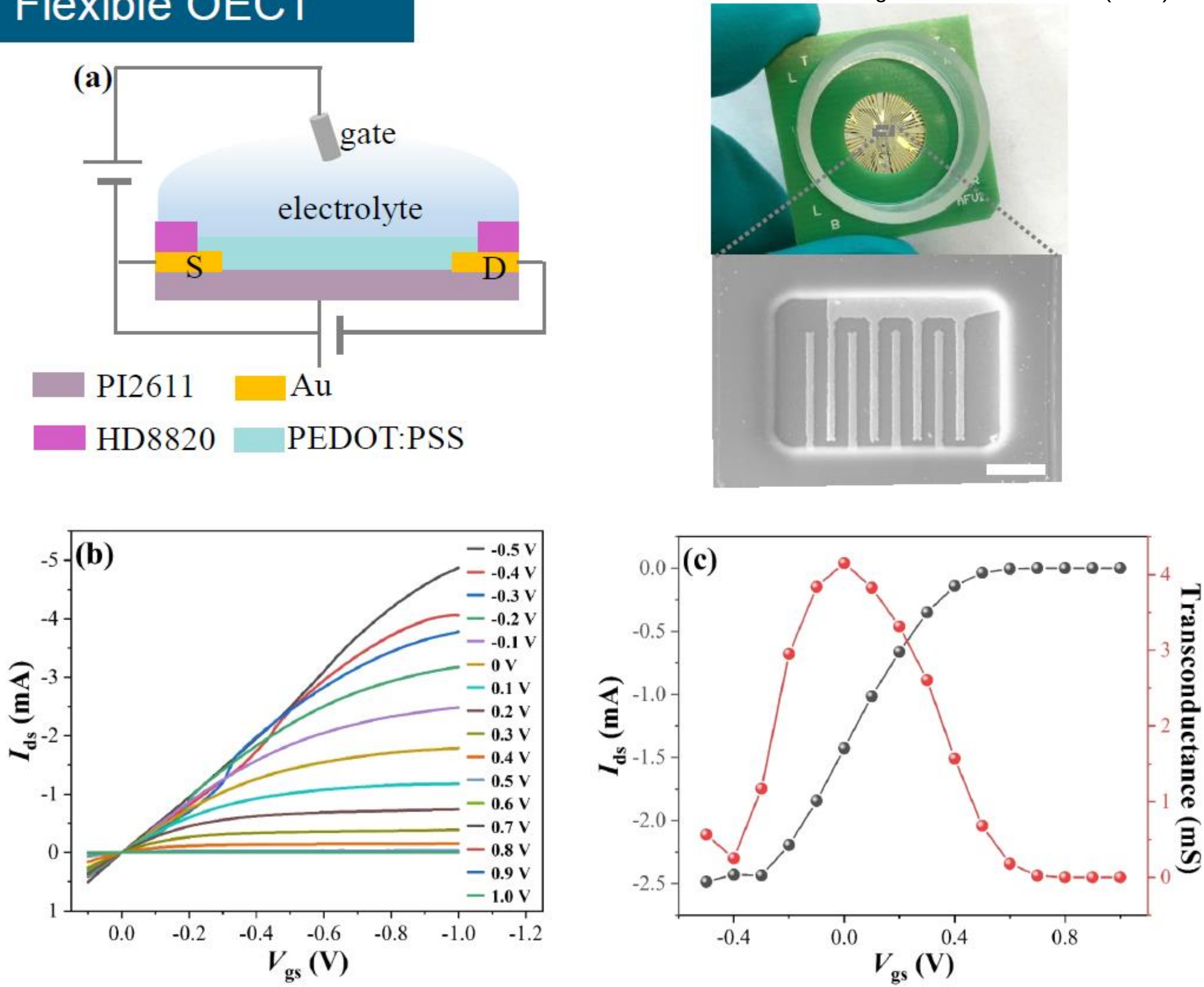
Potentiometric Transducer



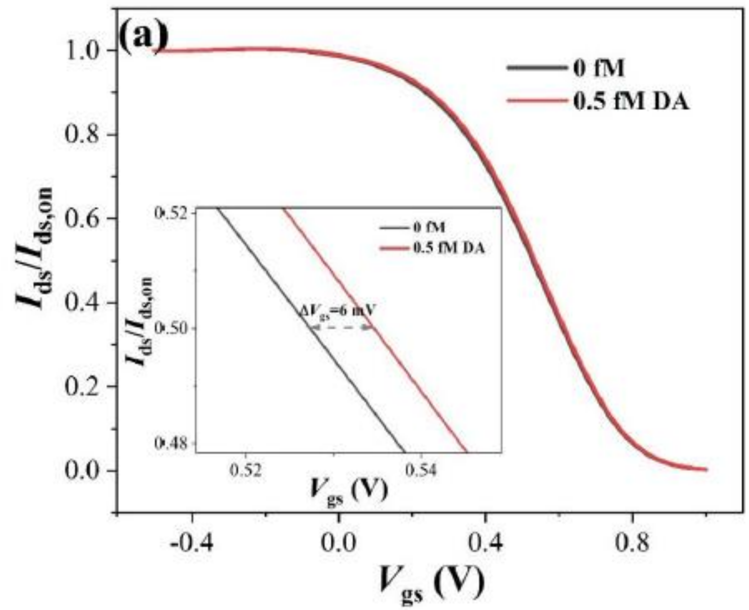
Liang et al Bios. Bioelect. **2019** 144, 111668

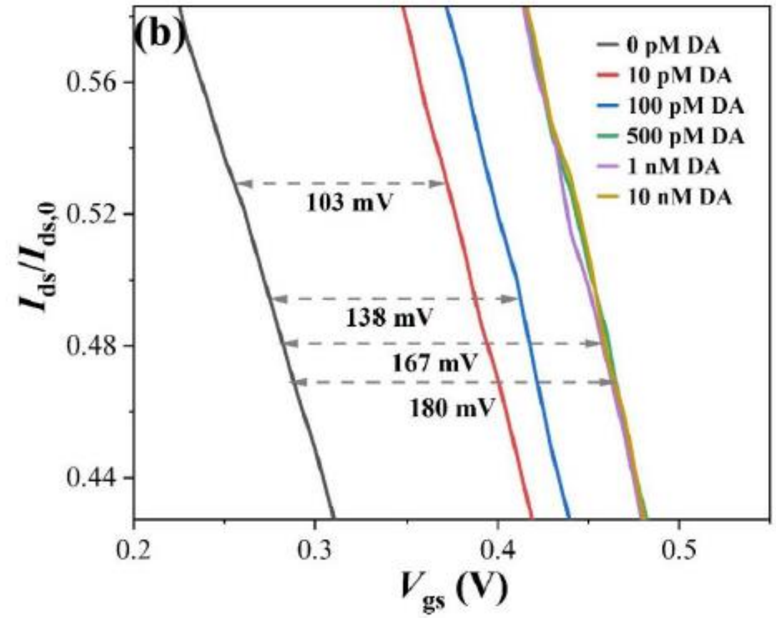
Flexible OECT

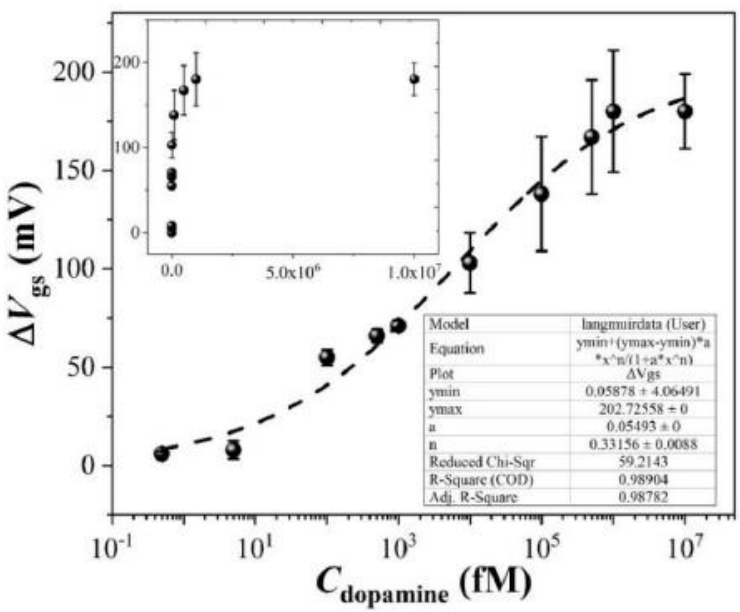
Liang et al. *Materials* 13.11 (2020): 2577.

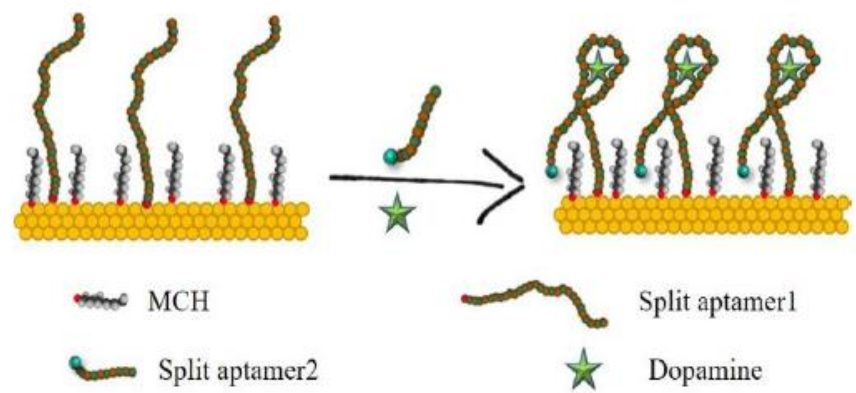


Dopamine detection via OECT





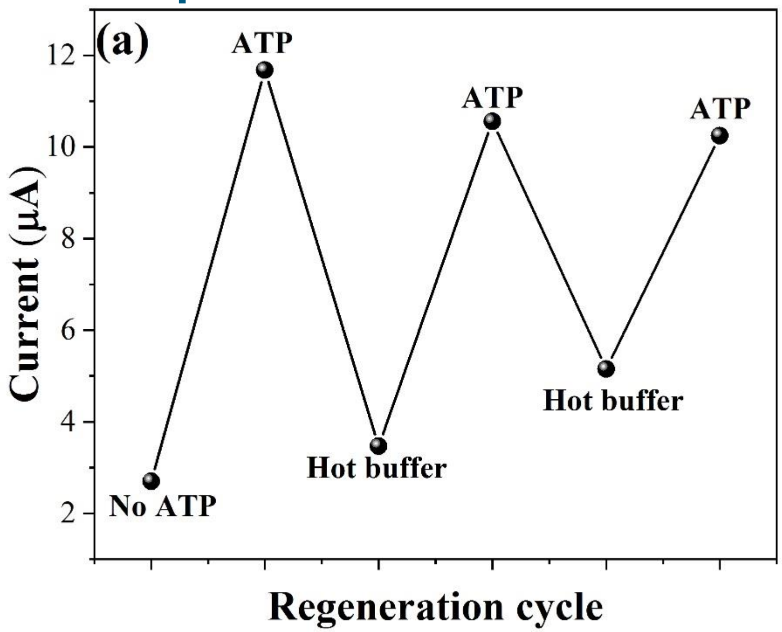




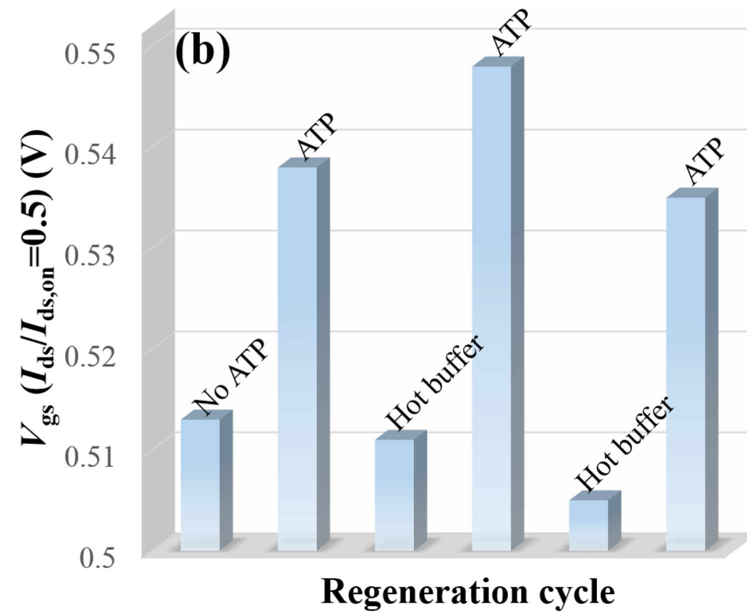
Liang et al. *Materials* 13.11 (2020): 2577.

Sensor reusability

Amperometric Transducer

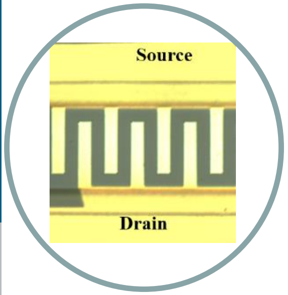


Potentiometric Transducer



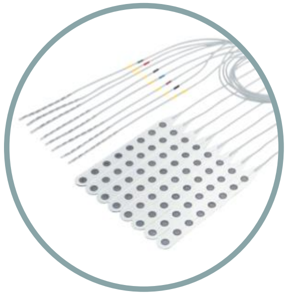
Liang et al Bios. Bioelect. **2019** 144, 111668

Future directions



iOECT performance limited by source-drain series resistance
3D source and drain electrodes, improve charge injection
Improve channel stability

+



High density iOECTs potentially facilitate combination of electrochemistry with electrophysiology on chip but requires integration of gate electrode

Σ

Grand future challenge is to integrate different devices to better understand the coordinated changes of action potentials and different molecules on different time and length scales in the brain