3D Printed Soft Organic Electrochemical Transistors

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Introduction and Motivation

- Soft electronics provide an ideal platform for interfacing with the curvilinear and dynamic surfaces of the body
- Organic electrochemical transistors have high ionic sensitivity for capturing electrophysiological signals

Today's Challenges

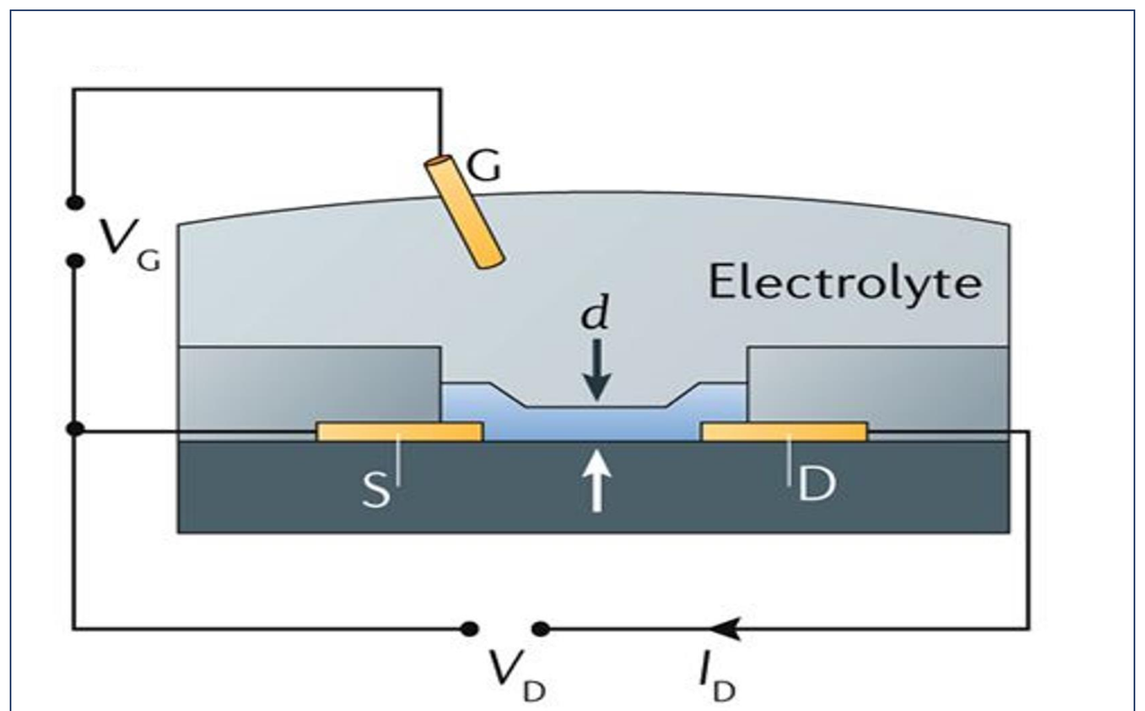
- Conventional silicon based electronics are rigid and brittle
- Development of electronic materials with flexible and stretchable mechanical properties
- Scalable manufacturing of soft electronics

Proposed Solution

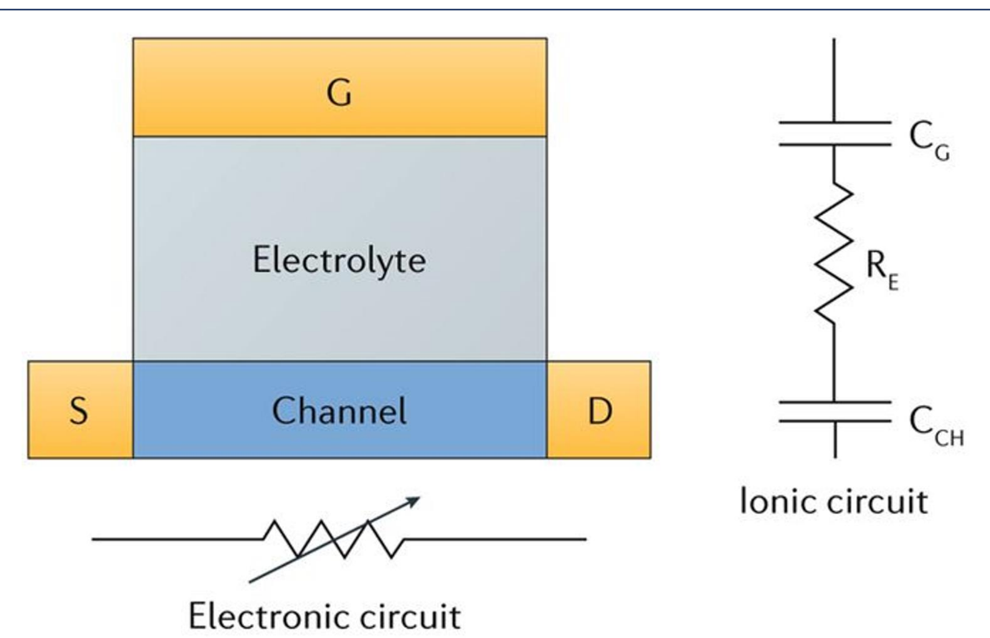
- Utilize 3D printing, where every step in the fabrication process can be controlled, to develop organic electrochemical transistors (OECTs) for biomedical sensing and health diagnosis.

Current Technology: Transistors

- Transistors are the building blocks for electronics
- In particular, organic electrochemical transistors (OECT) are a unique transistor that can be employed to sense electrophysiological signals
- The basic structure of an OECT consists of source (S) and drain (D) electrodes and gate electrode (G).
- Transistor can be modeled using both an electronic and ionic circuit [1]

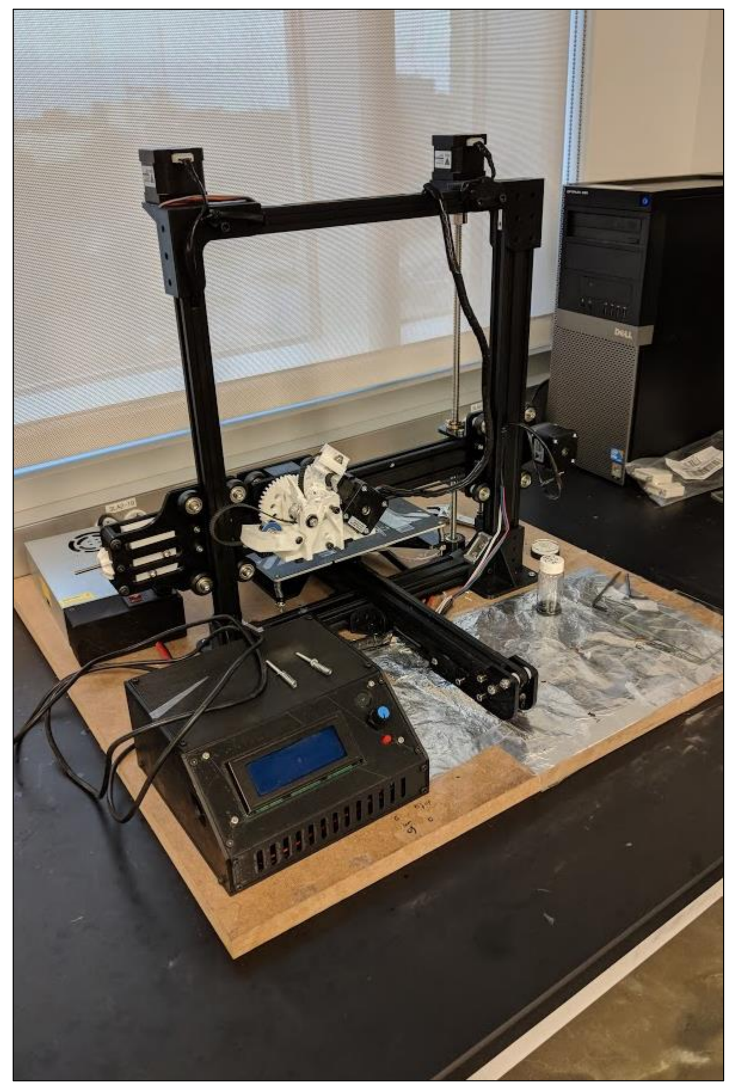


V_G is the gate voltage, V_D is the drain voltage, I_D is the drain current, and d is the channel thickness.



Schematic diagram of an OECT.

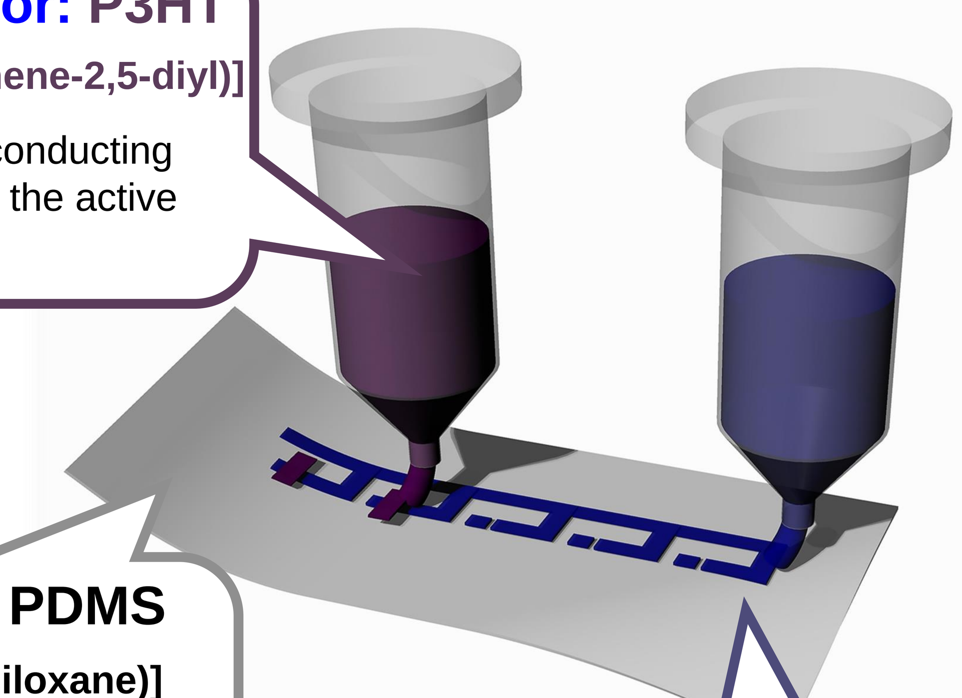
Approach – 3D Printing



- Custom made 3D printer setup with pneumatic extruder, control box, and power supply.

Semiconductor: P3HT
[Poly(3-hexylthiophene-2,5-diyl)]
An organic semiconducting polymer, used as the active layer for OECTs

Substrate: PDMS
[Poly(dimethylsiloxane)]
A soft, stretchable silicon based organic polymer used as the substrate for OECTs

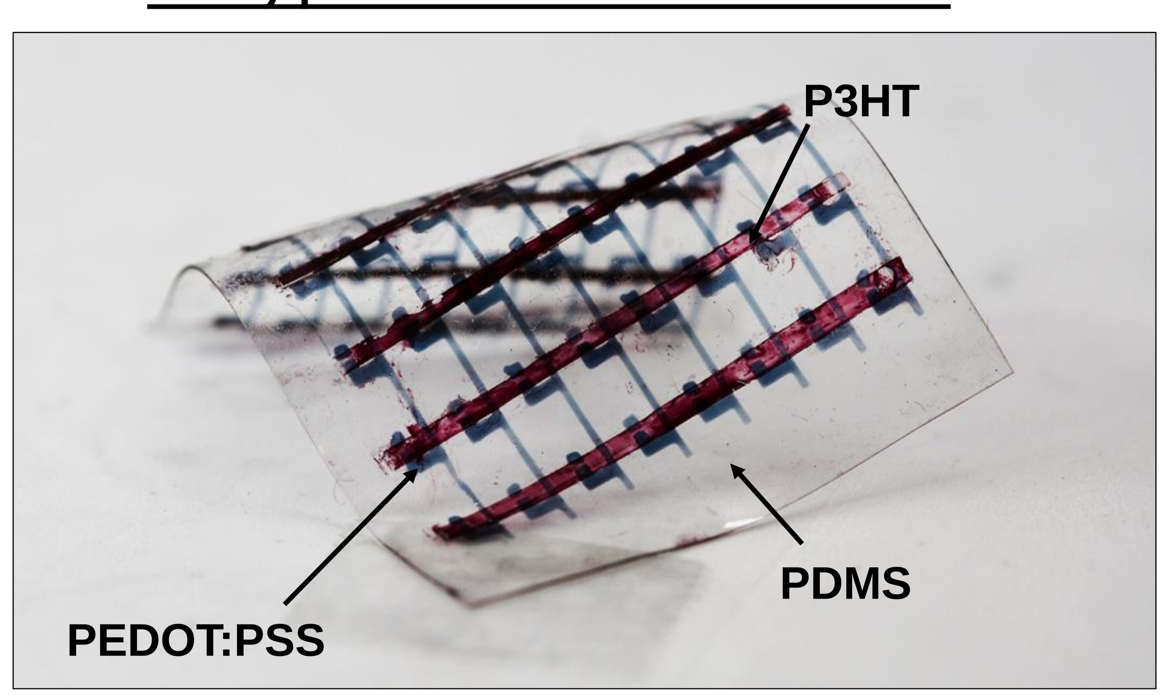


Conductor: PEDOT:PSS
[Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate)]
A soft, stretchable polymer conductor, used as source and drain electrodes for OECTs

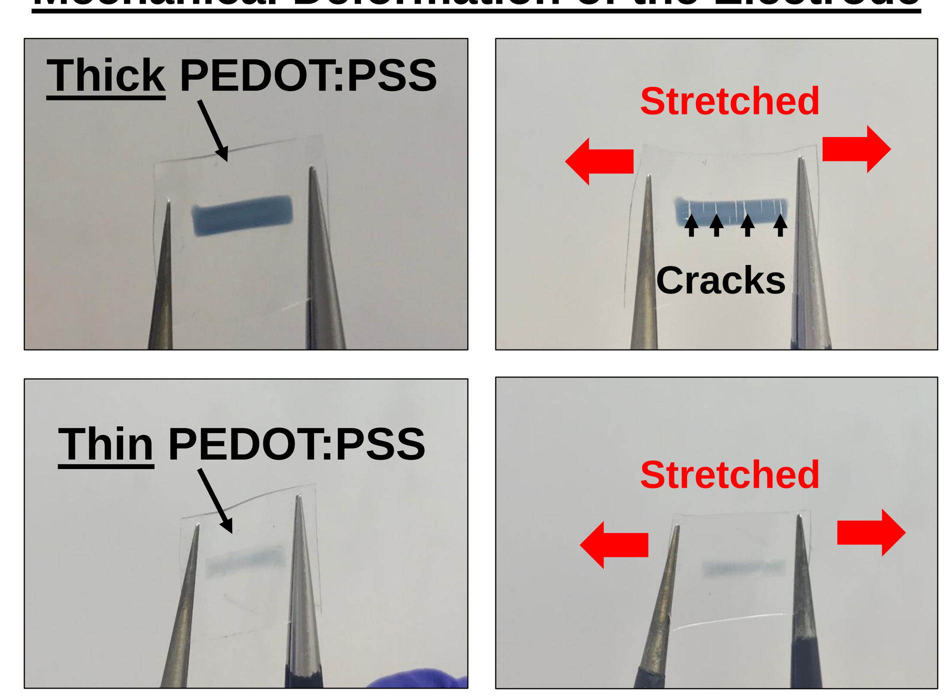
The thickness of PEDOT:PSS electrodes affects its mechanical properties.

3D Printed Soft Electronic Devices

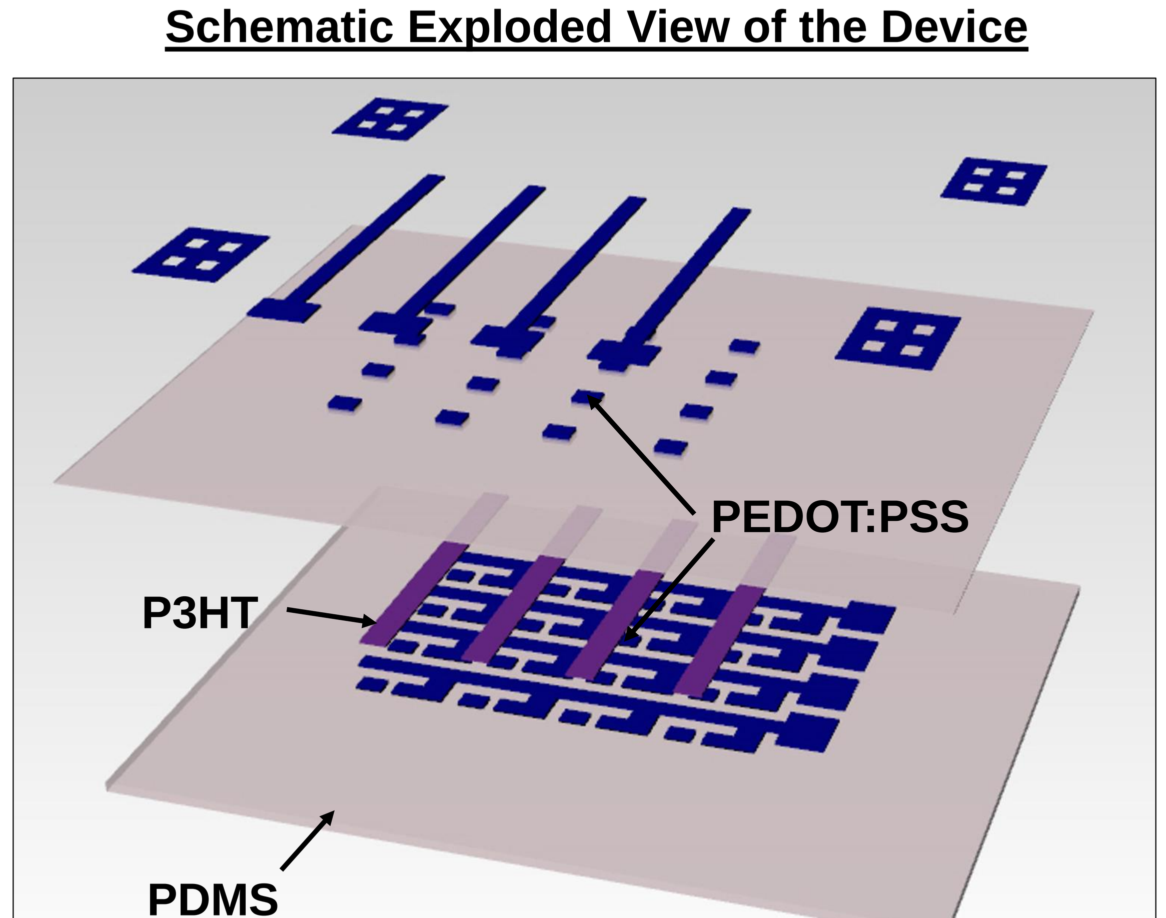
A fully printed Soft Electronic Device



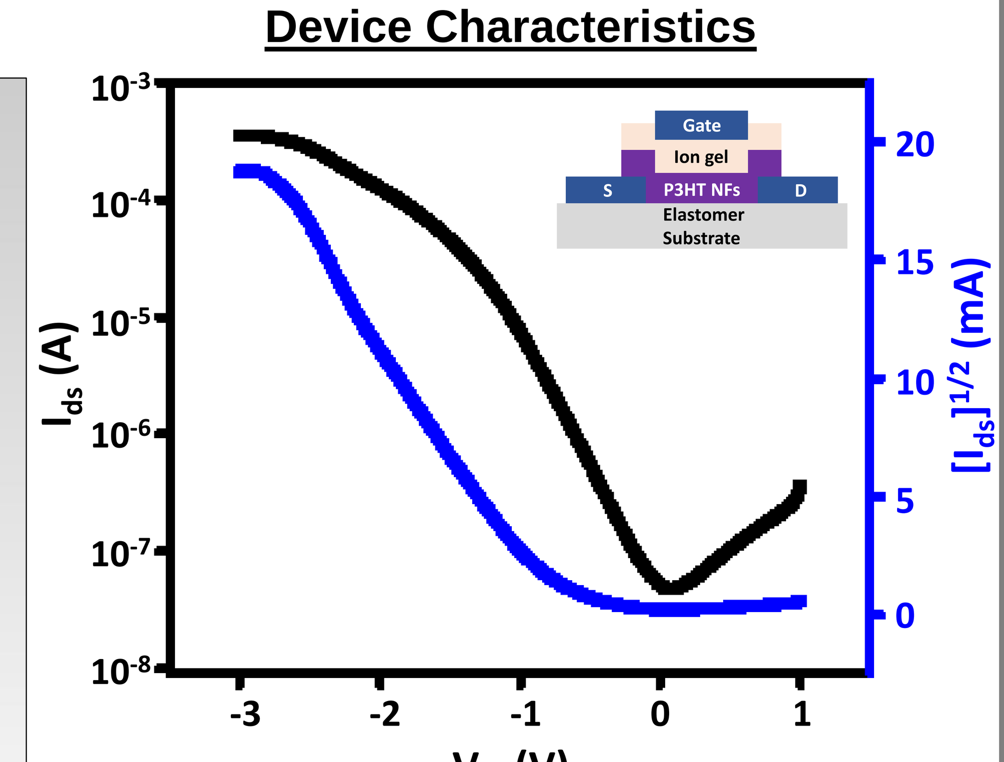
Mechanical Deformation of the Electrode



Schematic Exploded View of the Device

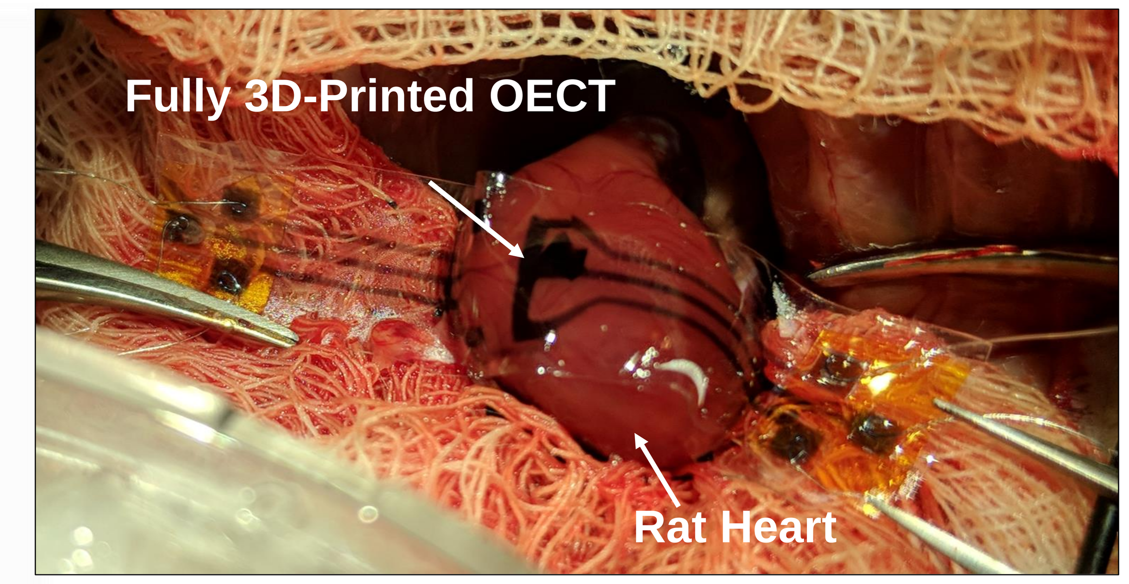


Device Characteristics

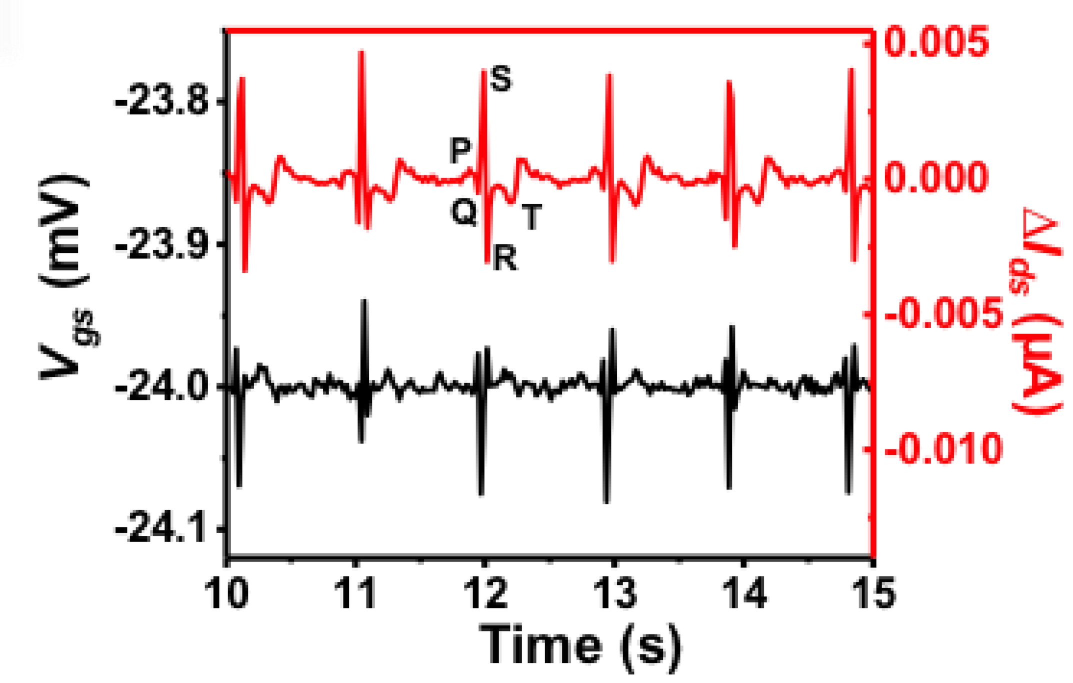


- The fully printed transistor shows high performance *p*-channel characteristics

Biomedical Applications



- Optical image of a fully 3D printed organic electrochemical transistor on a rat heart



- Fully 3D printed transistors can be used to monitor electrical signals from the heart for applications such as detecting and preventing heart arrhythmia.

Conclusions

- The soft organic electrochemical transistor is successfully fabricated with a 3D printing process.
- Printed thin electrode (PEDOT:PSS) has no obvious cracks under mechanical strain.
- The fabricated device shows high performance and typical p-channel transistor characteristics.
- The demonstrated biomedical experiment proves the feasibility of our approach for biomedical applications of soft electronics.

Future work

- Develop new printing process to print on ultra thin surfaces for improved conformability
- Develop high resolution heart sensors and brain sensors to mapping the cortex
- Develop and test new devices for sensing other parameters such as pressure and heat

Acknowledgement

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Reference

[1] J. Rivnay, S. Inal, A. Salleo, R. M. Owens, M. Berggren, and G. G. Malliaras, "Organic electrochemical transistors," Nat. Rev. Mater., vol. 3, p. 17086, 2018.