Inkjet-printed devices and circuits for ultra-low frequency applications

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Outline

- Why we need devices operating in the mHz frequency range?
- Examples of near-future and high-impact applications that will require sustainable electronics;
- Device requirements from a device physics point of view;
- The importance of printed electronics for low-frequency applications;
- Summary.

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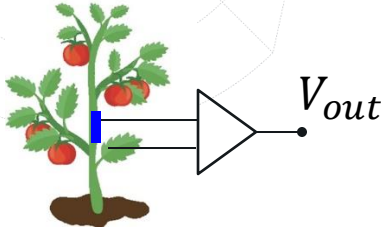
Why low frequency signals are so interesting?

- **Detection of microorganisms**

(Bacteria, algae, fungus use use low frequency signals to synchronize and coordinate activities.(Smart devices to detect bacteria in food, infections in wounds, etc.);

- **Plants bioelectronics**

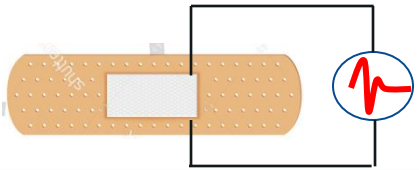
Plants have a nervous "like" system that operates at low frequencies. (sensors for monitoring the environment; effects of pollutants, pesticides; monitoring climate changes; plant-insect interactions, agriculture);



- **Novel biomedical devices**

Skin cells, lung cells, and cancer cells use low-frequency signals to coordinate tasks, namely tissue regeneration, organ formation, and cancer invasion.

(Smart wound dressings, therapeutic devices for cancer)



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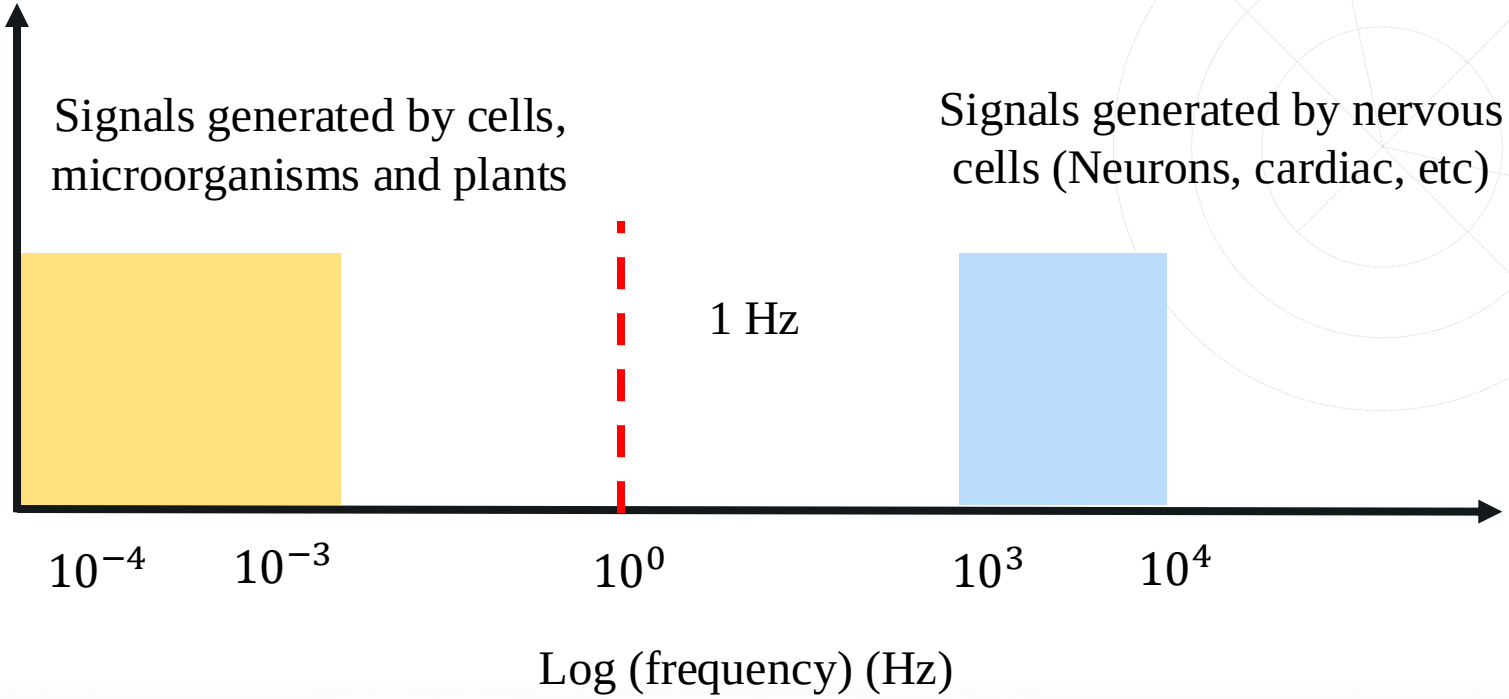
How low is ultra low frequency?



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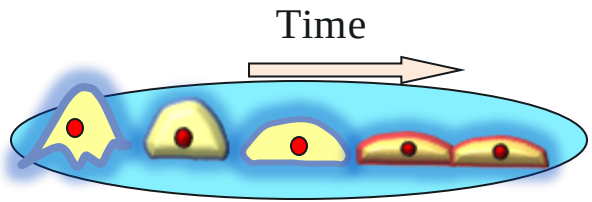
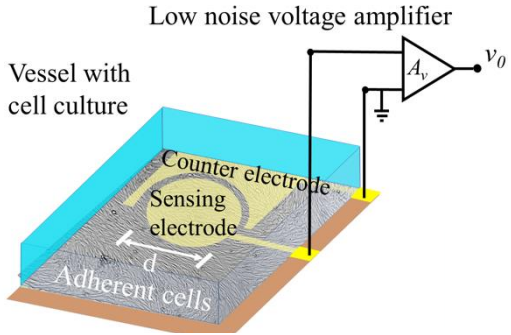
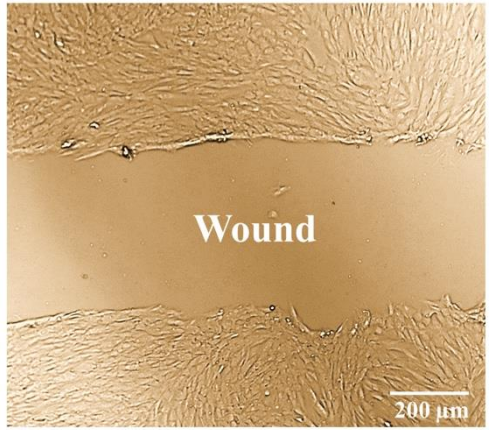
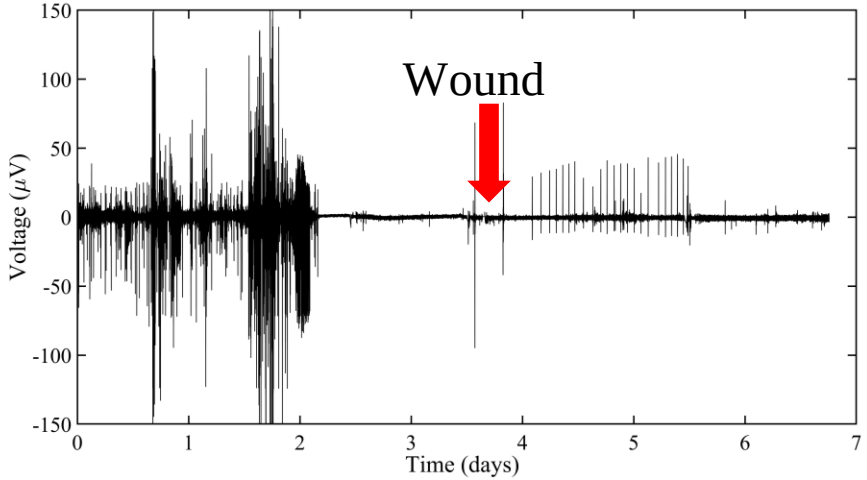
An example: Signal frequencies in the skin !









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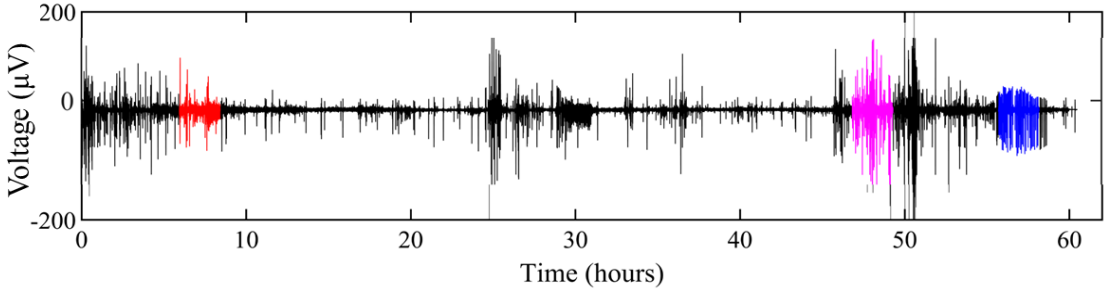
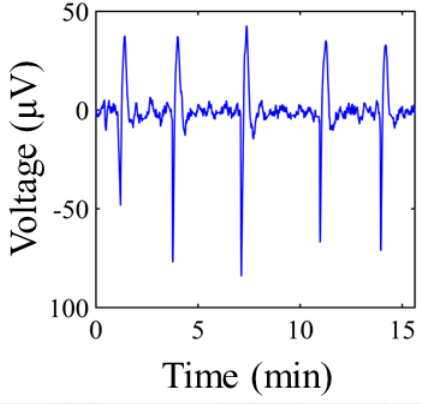
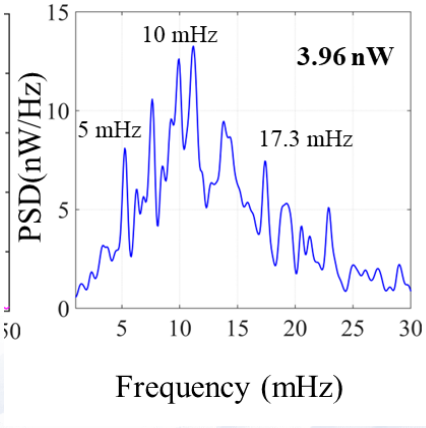
An example: Signal frequencies in the skin !

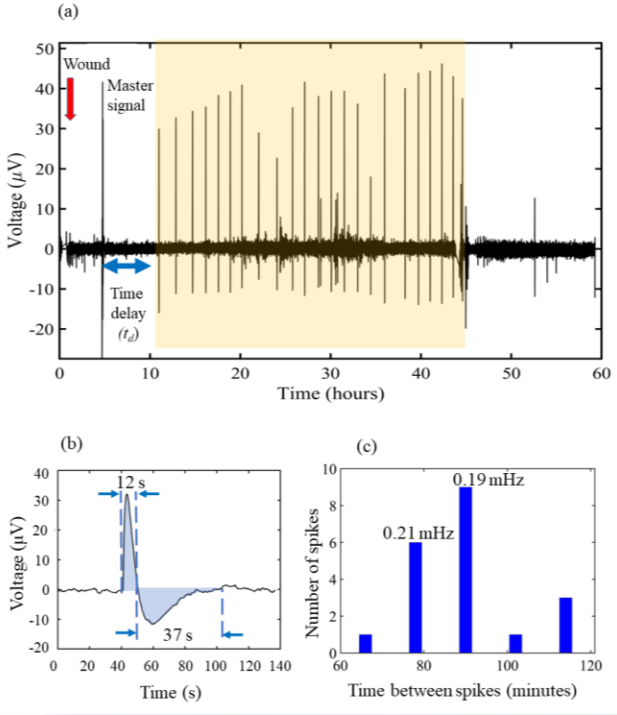
Cell monolayer forming



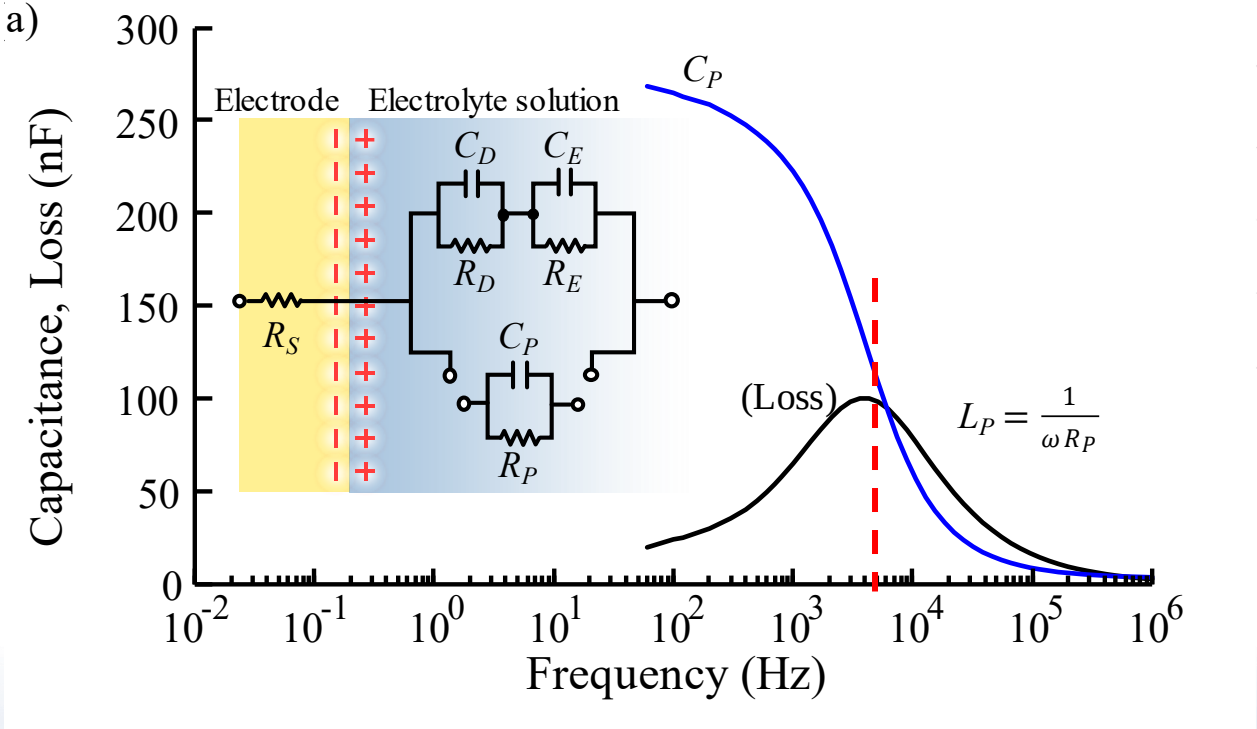




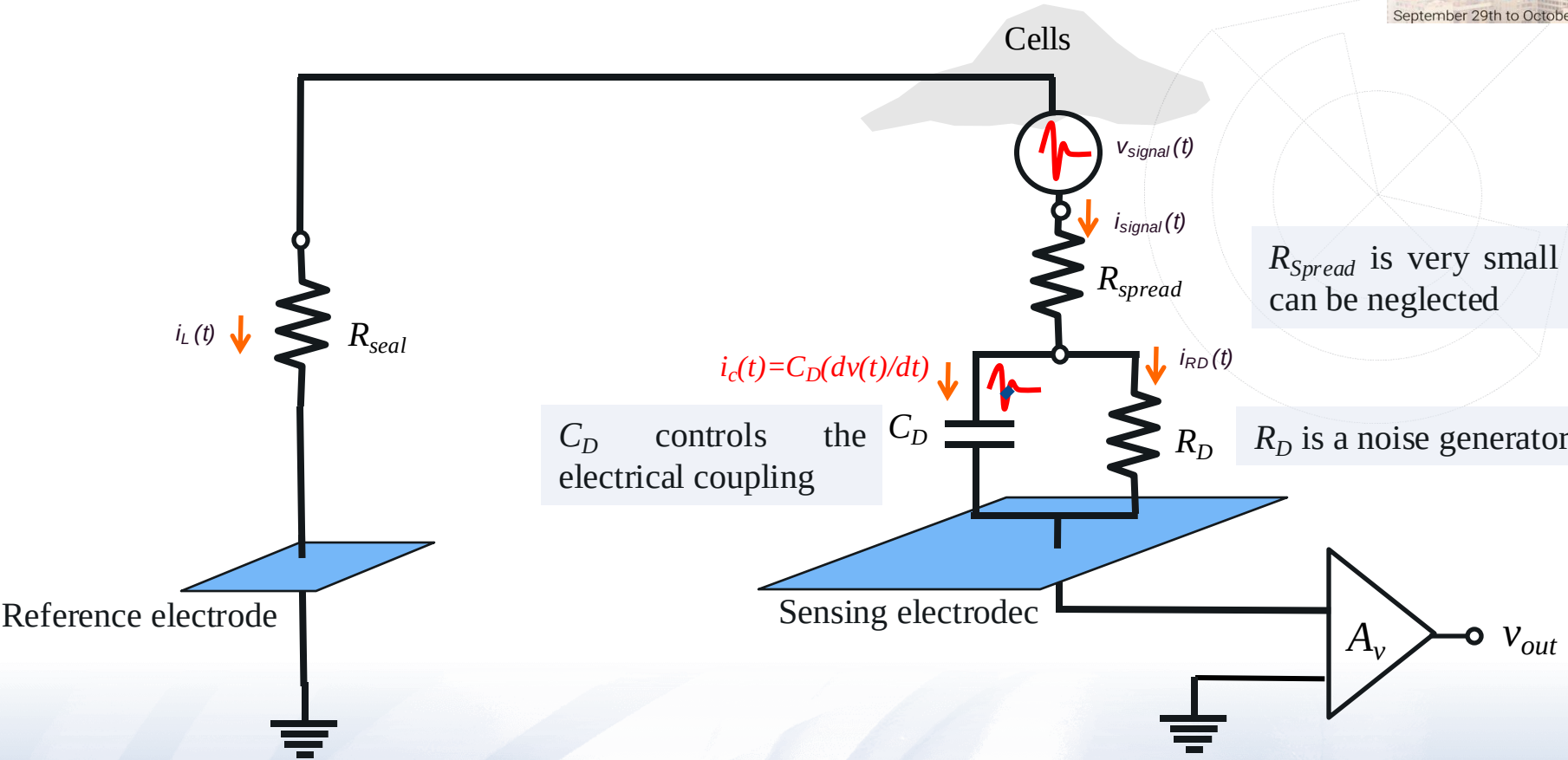
Wound repair



The impedance of the electrical double-layer



The role of the impedance on the signal detection

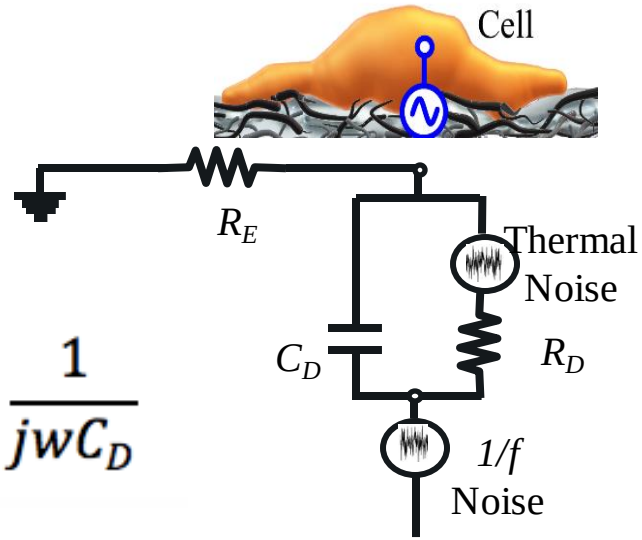


R_{Spread} is very small and can be neglected

C_D controls the electrical coupling

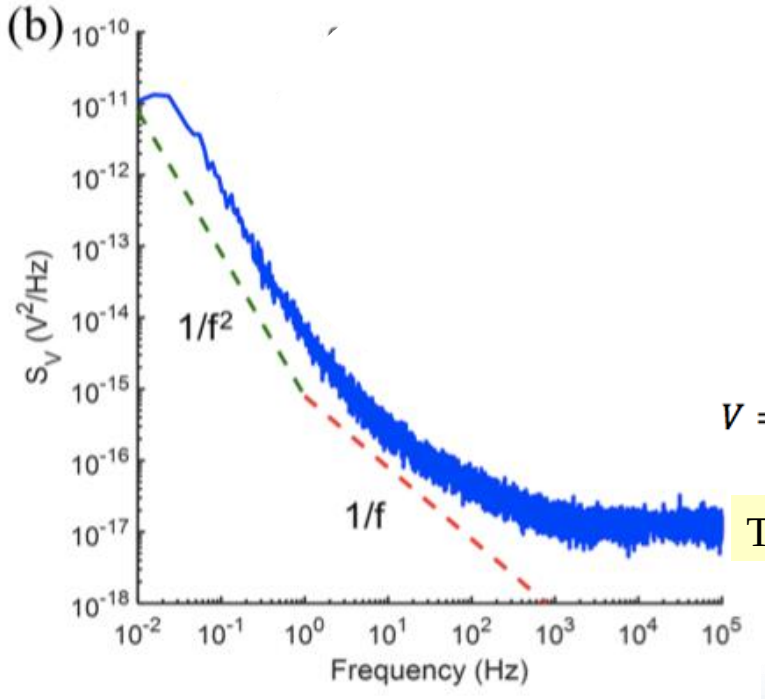
R_D is a noise generator

Noise and the electrical double-layer



$$X_c = \frac{1}{jwC_D}$$

Sensing electrode



$$V = \sqrt{4kTB_WR}$$

Thermal noise

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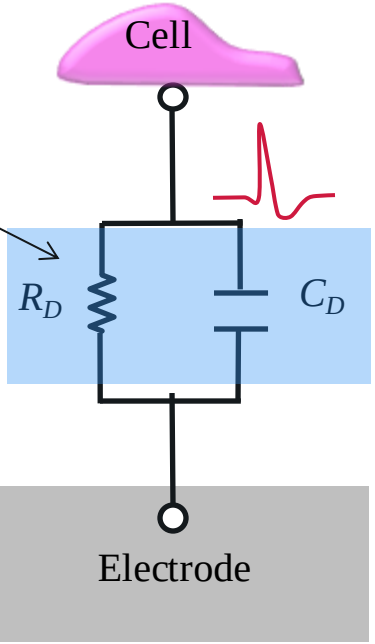
Where is the thermal noise coming from?

The beauty of a PEDOT:PSS electrode is that it establish a very low interfacial resistance



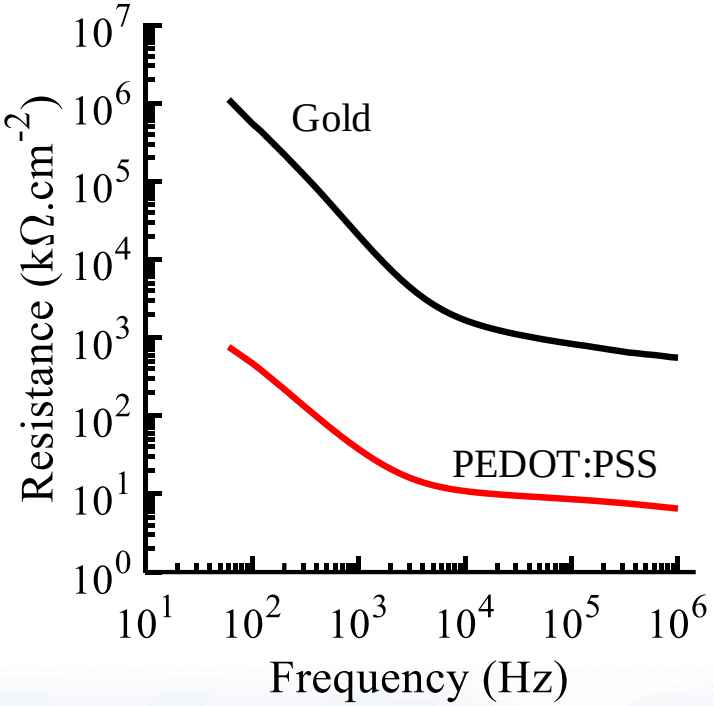
R_D is a noise generator

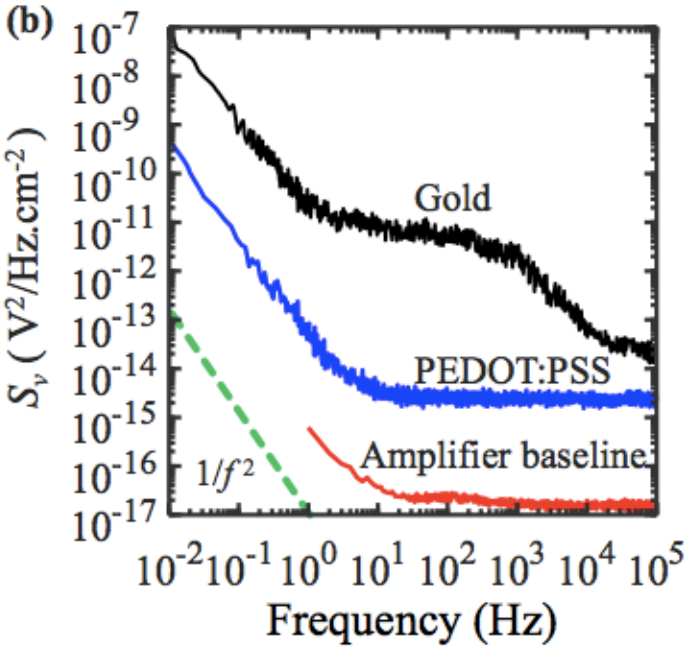
C_D controls the electrical coupling
Offers a low impedance path

$$V = \sqrt{4kTB_W R}$$

$$X_c = \frac{1}{jwC_D}$$

Interfacial resistance and intrinsic noise

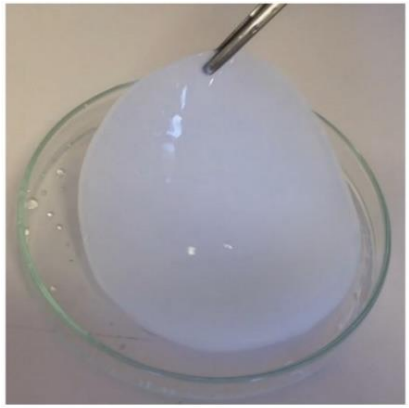




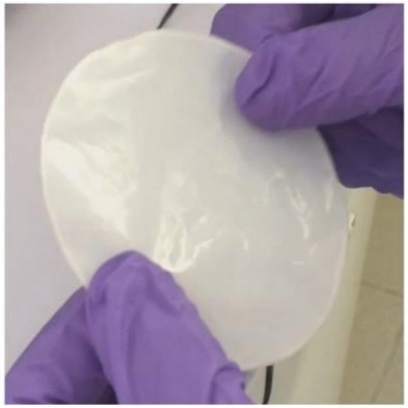
Pedro Inácio

Sanaz Asgarifar

Bacterial cellulose substrates



(a)



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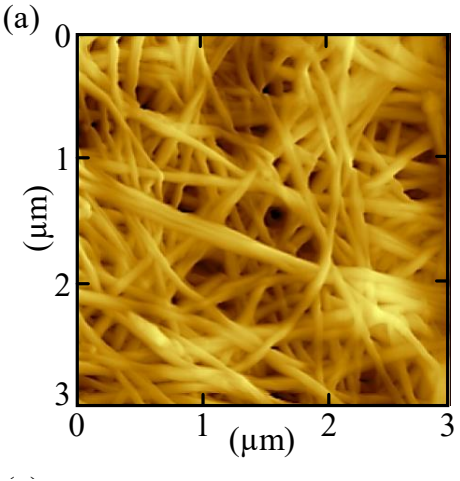
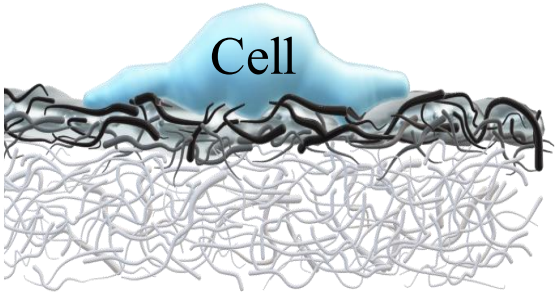
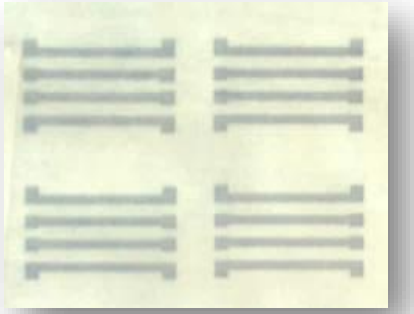
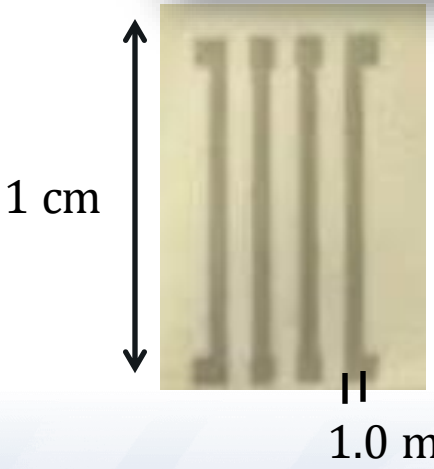
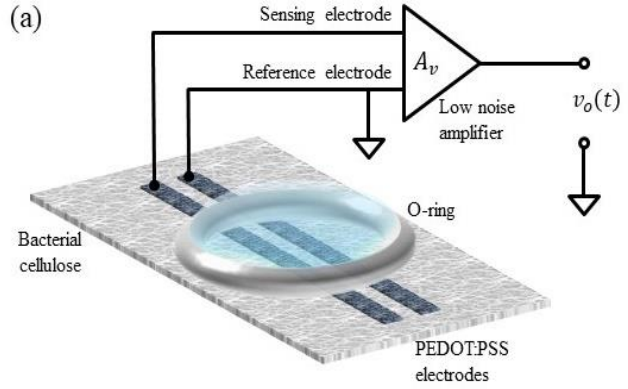


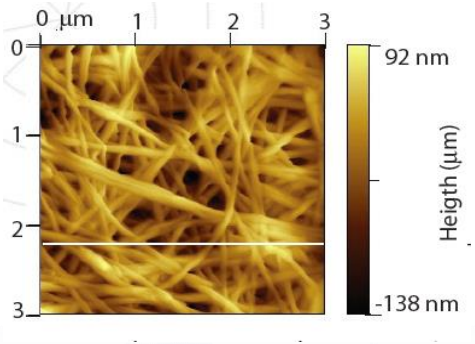


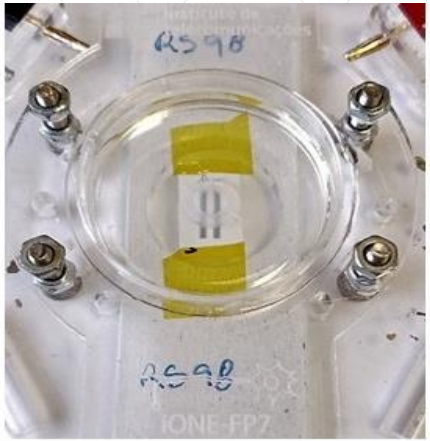
Devices made by ink-jet printing



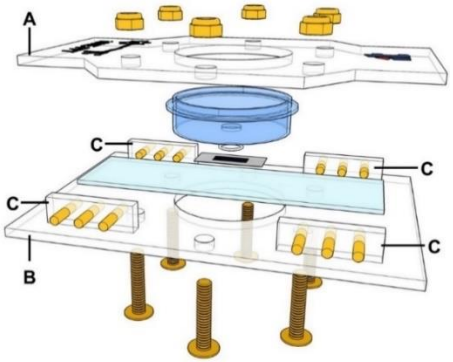


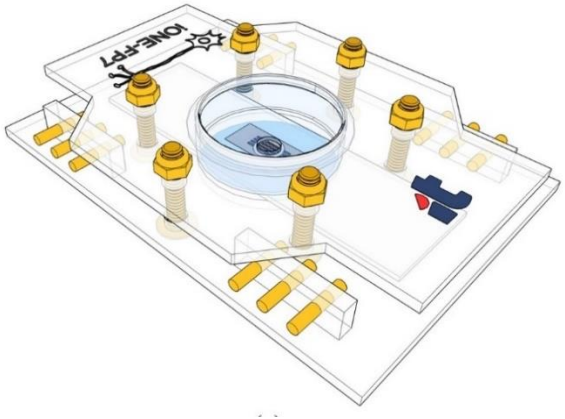


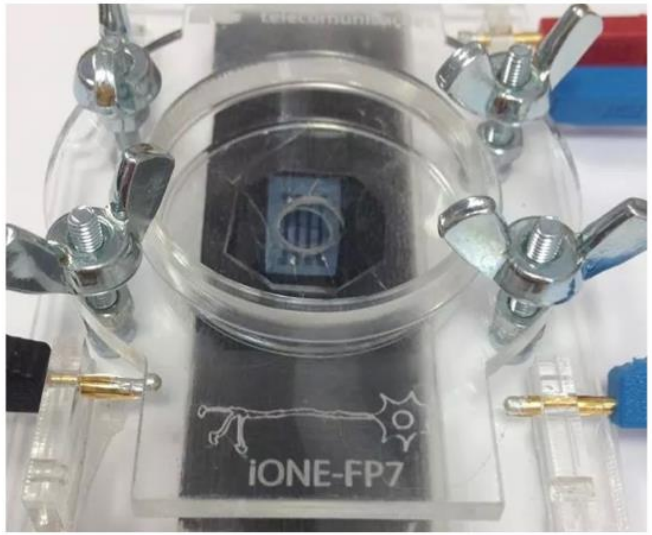




Ink-jet printed electrodes for electrophysiological sensing







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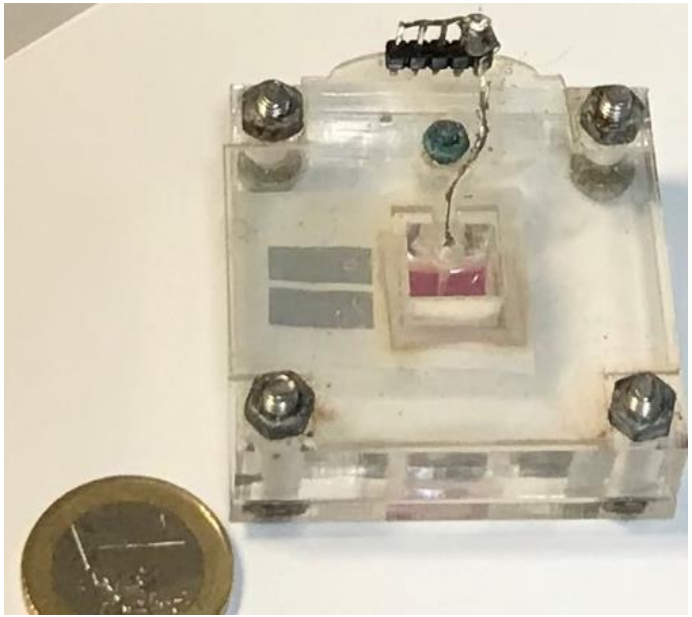

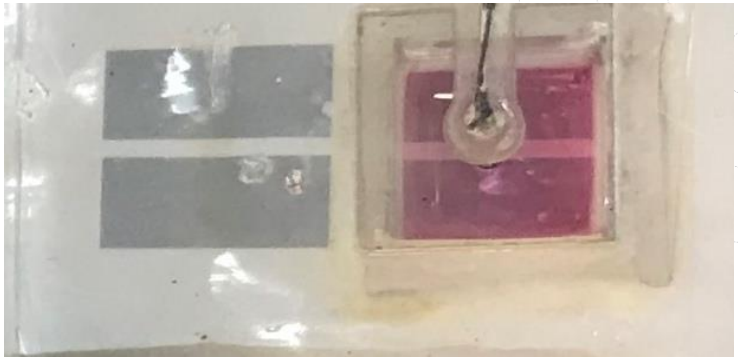

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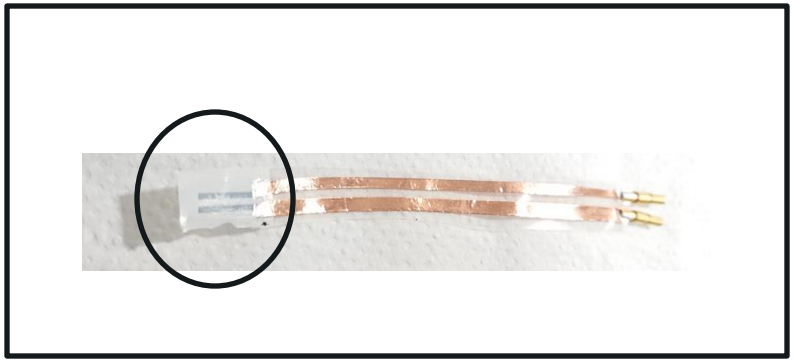
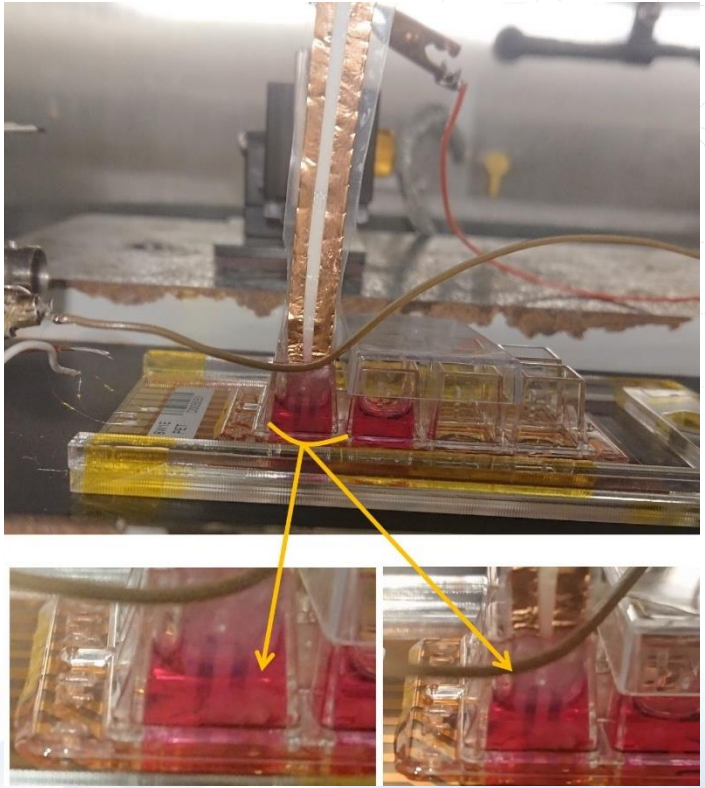
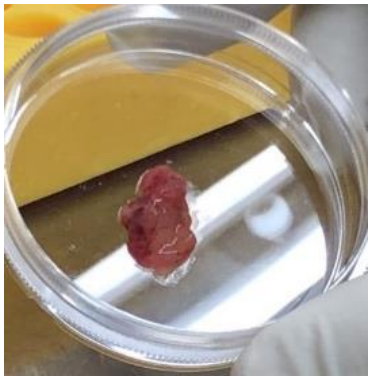
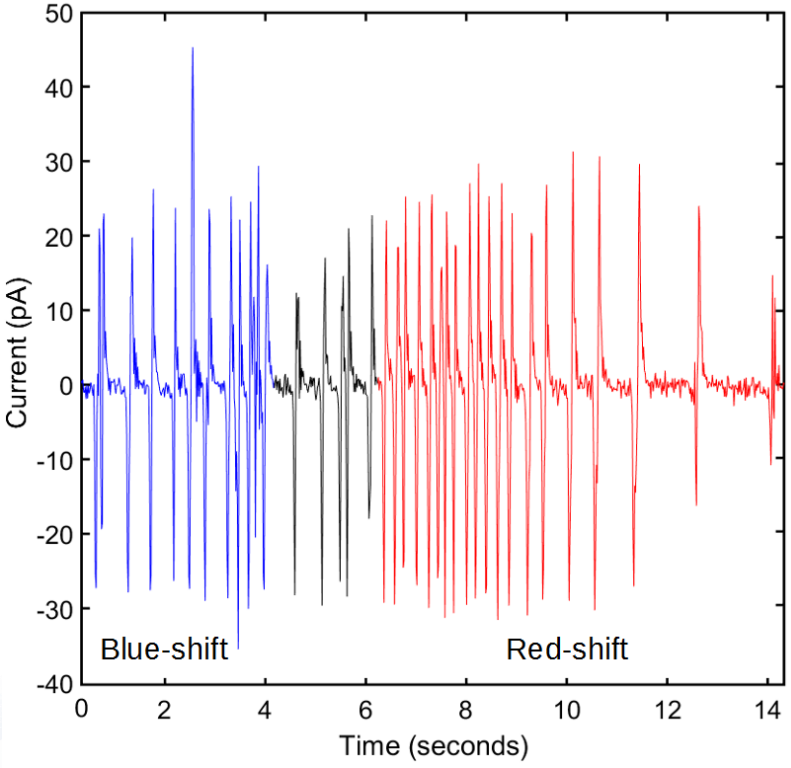




Ex-vivo measurements in Human glioblastoma

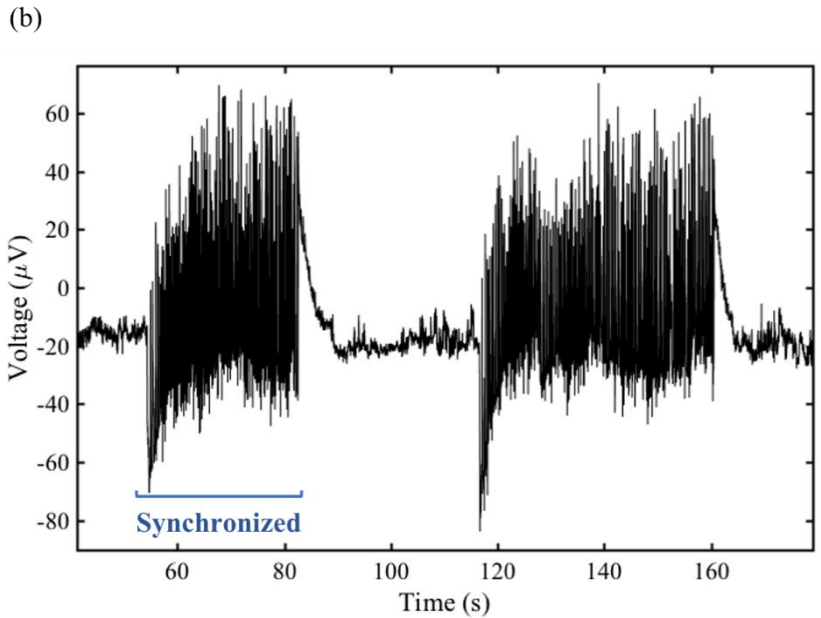


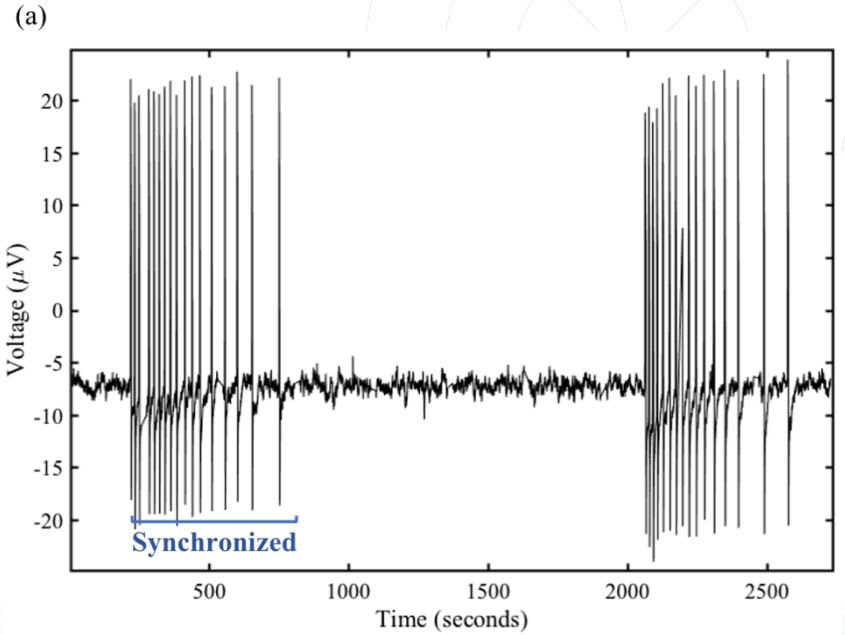
Glioblastoma



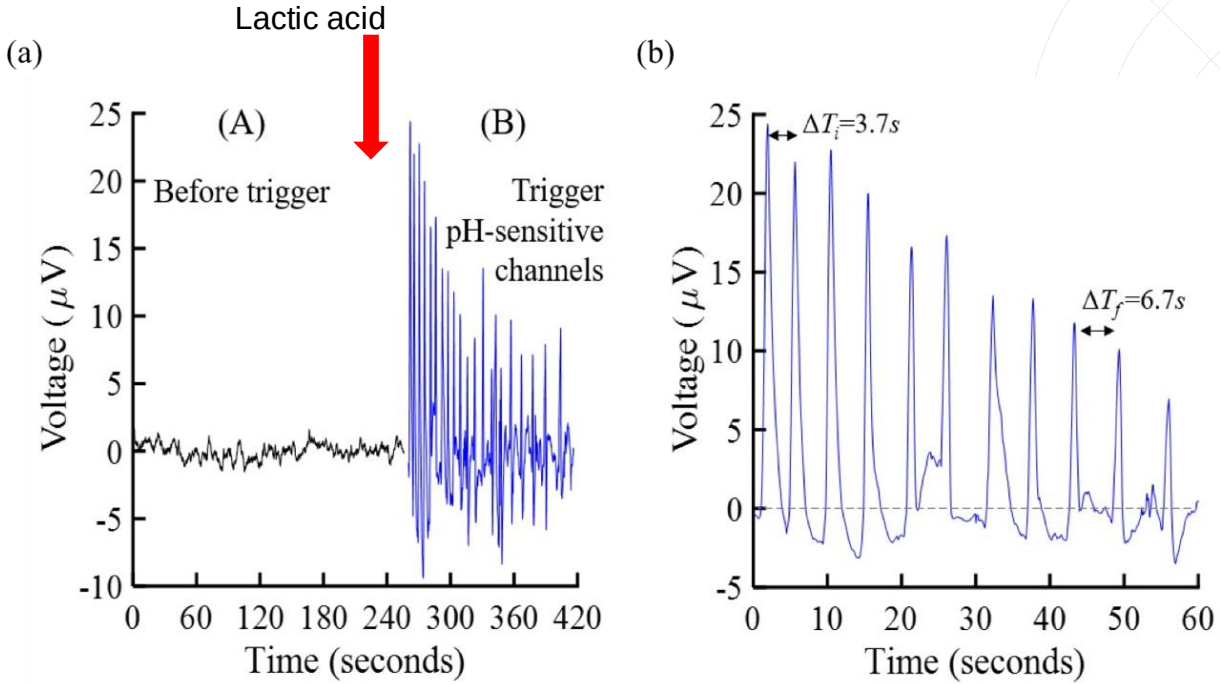
Ana Mestre

Application;
bioelectrical activity of a glioblastoma (ex-vivo)

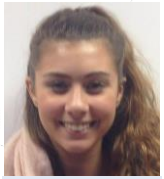




Application:
Bioelectrical activityof a glioblastoma (ex-vivo)

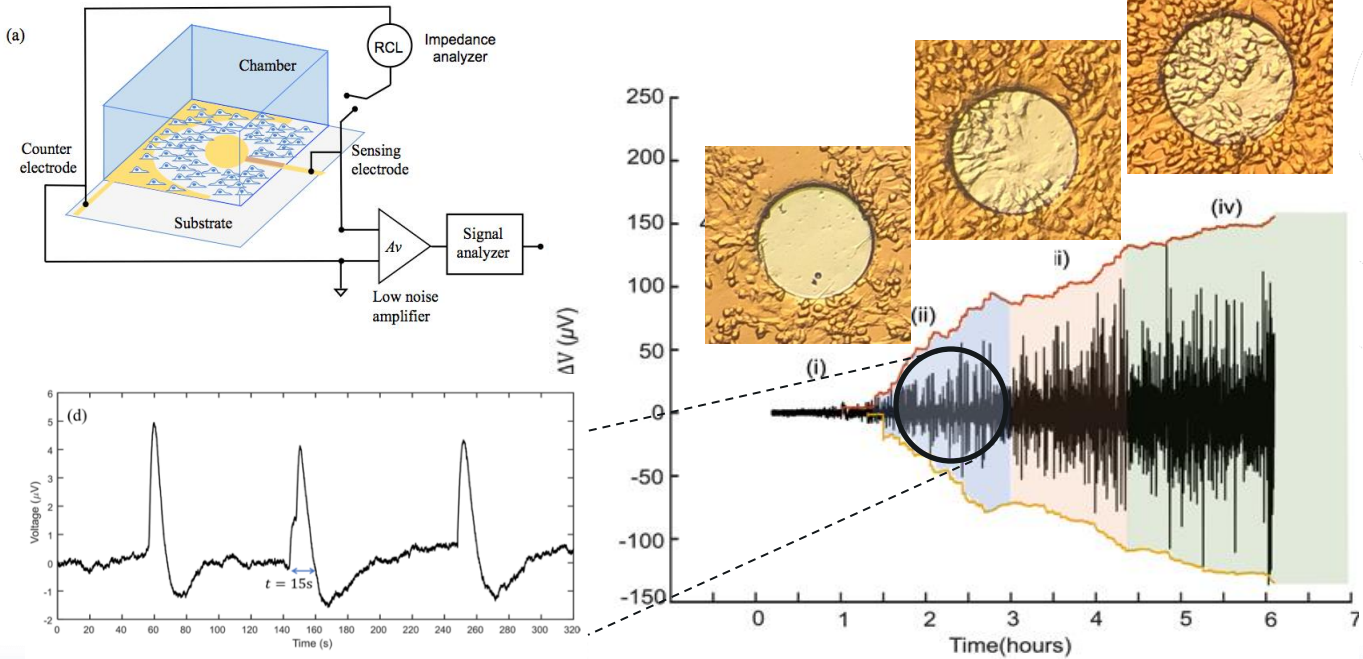


Rute Félix



Rita Monteiro

Application: Cancer cell migration



Sanaz Asgarifar

S. Asgarifar, et al. Biosensors and Bioelectronics 145 (2019) 1117082

Summary

- Slow mobility semiconductors (**ZnO, conjugated polymers**, etc.) and conductors (**PEDOT:PSS**) are ideally suited for recording ultra-slow signals (minutes, hours).

- To minimize the intrinsic noise, we must increase the electrode area. Deposition in porous nanofibrous substrates is appealing.

- Printing (**inkjet, screen printing,** etc.) are suitable technologies for large - area devices.

In summary: **We can create cutting-edge ultra-noise sensing devices using cost-effective processing techniques and materials.**

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Coimbra

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Coimbra–Brasil connection

D. Francisco Lemos de Faria Pereira Coutinho

Nasceu em 1735 no Rio de Janeiro. Foi Reitor durante 31 anos

Reitor Reformador

José Bonifácio de Andrada e Silva

O seu nome esta associado à descoberta do lítio.

Andrada e Silva decobriu 12 novos minerais.

Henrique Leonel Gomes (hgomes@uc.pt)

Joint us this July in beautiful Coimbra

XXII B-MRS Meeting 2024
September 29th to October 3rd


Natalie Stingelin


George Malliaras


Thomas Anthopoulos


Henning Sirringhaus


Osvaldo Novais


Thuc-Quyen Nguyen

Henrique Leonel Gomes (hgomes@uc.pt)

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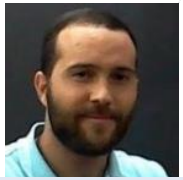
Youssef Elamine


Sanaz Asgarifar


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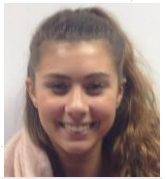
Rita Monteiro

Thank for you attention

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Experimental set-up