SPRING MEETING 15, Lille - May 11-15

Ink-jet printed polymer electrodes to record extracellular calcium waves produced by neuronal cell populations in vitro

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PT Inovação

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instituto de telecomunicações

creating and sharing knowledge for telecommunications

Motivation

To develop a simple, low cost, sensing device to measure cell bioelectrical activity.

Outline

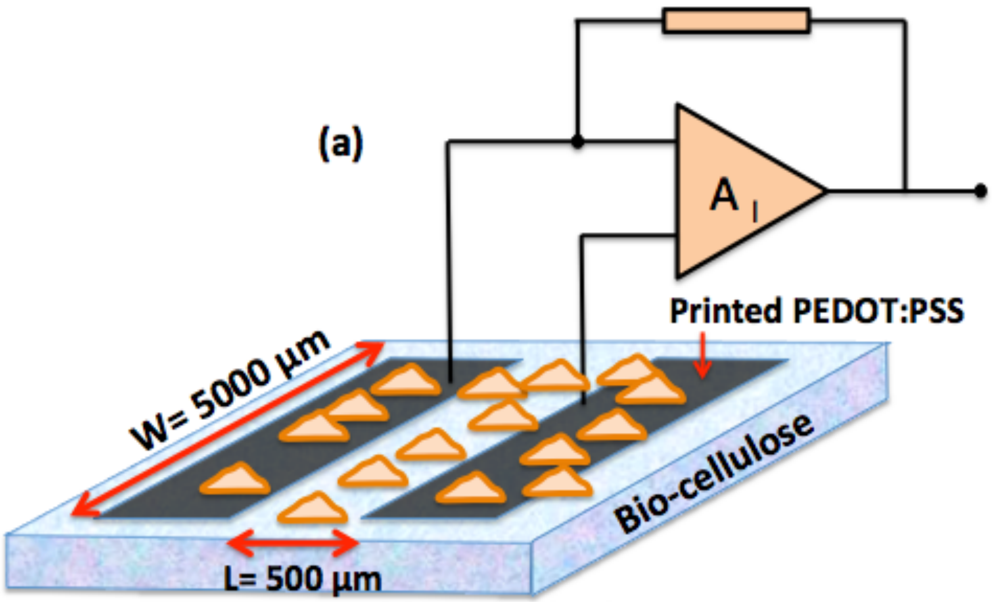
- **Sensing device**
  - **Device structure and fabrication.**

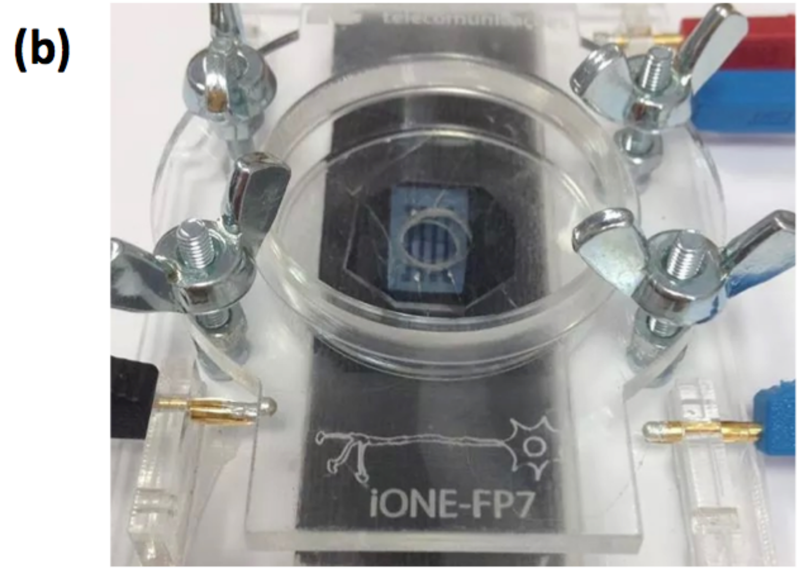
    Description of our sensing device based on large area PEDOT:PSS electrodes printed on glass or on bacterial cellulose.
- **Experimental set-up.**

    Signals recorded using cardiomyocytes and glioma cells populations *in vitro.*
- **Validation and performance.**
- **Conclusions**

(PEDOT:PSS).:poly(3,4-ethylenedioxythiophene) doped with poly(styrene sulfonic acid).

Sensing device

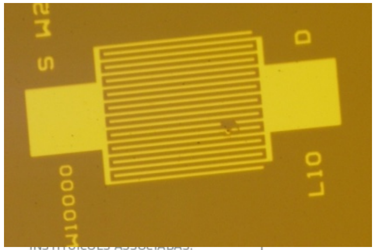




Schematic diagram of the recording system.

Sensing device connected with a commercial Petri-dish.

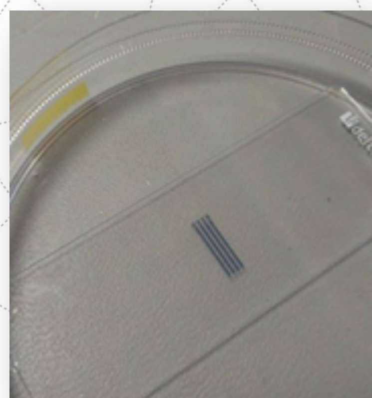
poly(3,4-ethylenedioxythiophene) doped with poly(styrene sulfonic acid) (PEDOT:PSS).



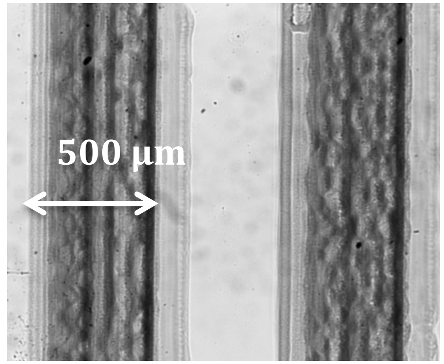
Conventional MEA (gold electrodes on silicon)

Experimental setup

Sensing device: substrates and electrodes



(a)



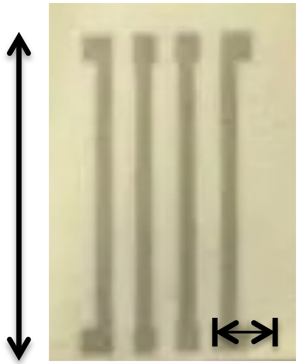
(b)

a), b) Glass substrate with PEDOT:PSS

c) Cellulose substrate with PEDOT:PSS

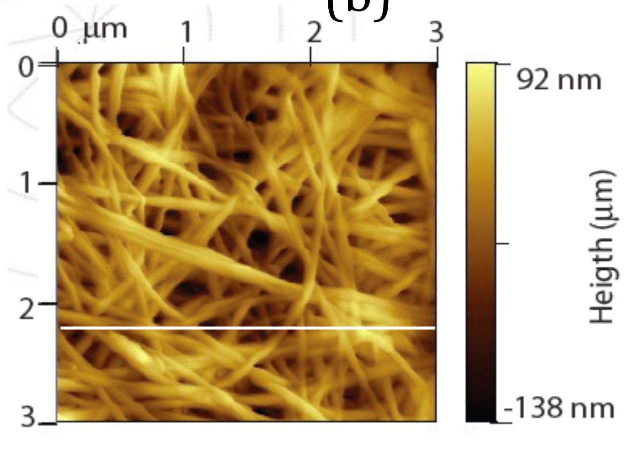
d) Cellulose

1 cm



1.5 mm

(c)



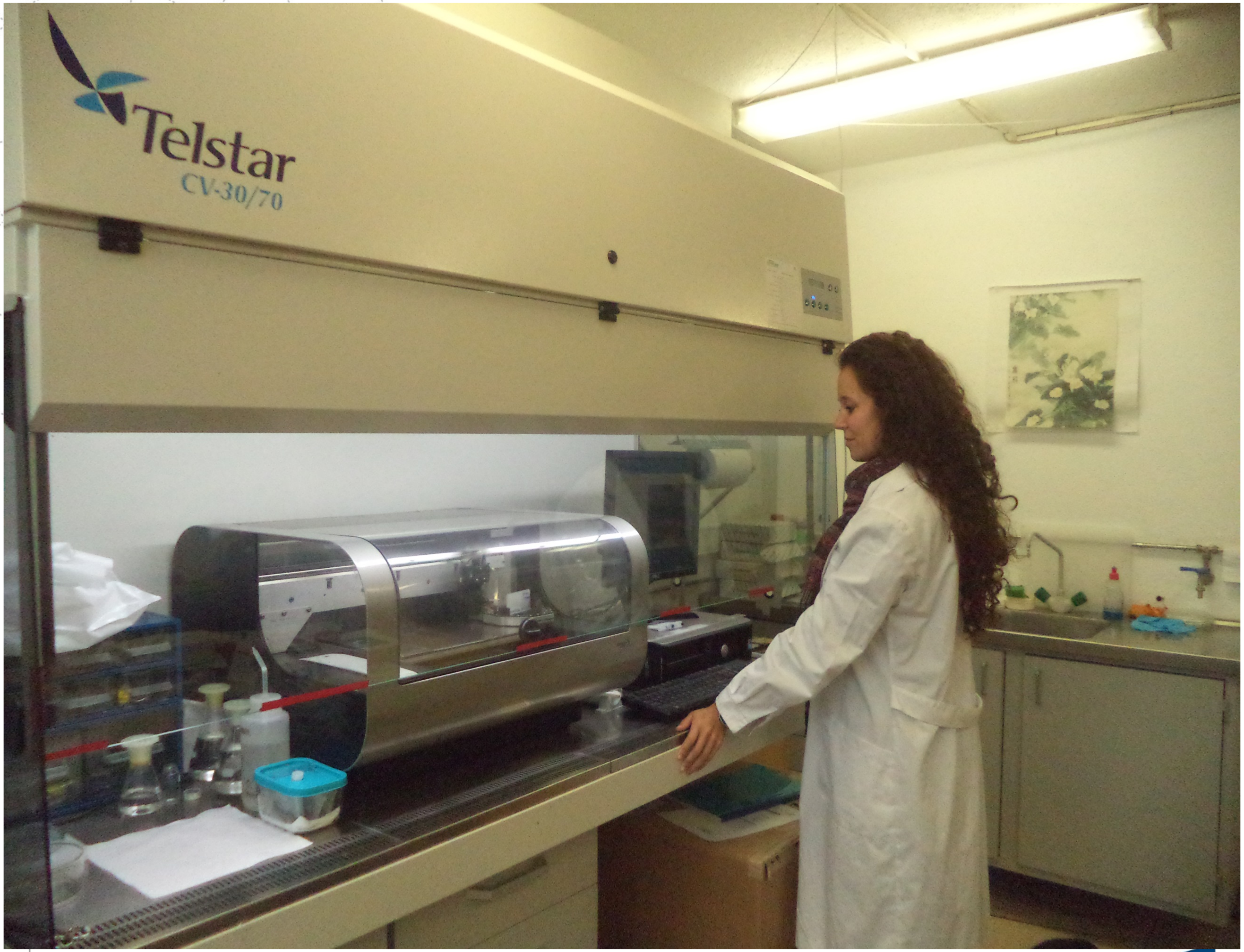
(d)

Lenght (L) – 1 cm

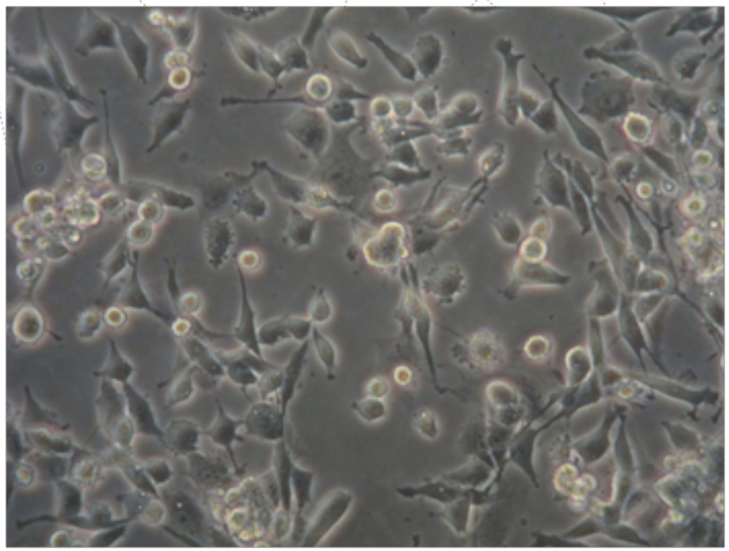
Width (W) – 500 µm

Gap – 400-500 µm

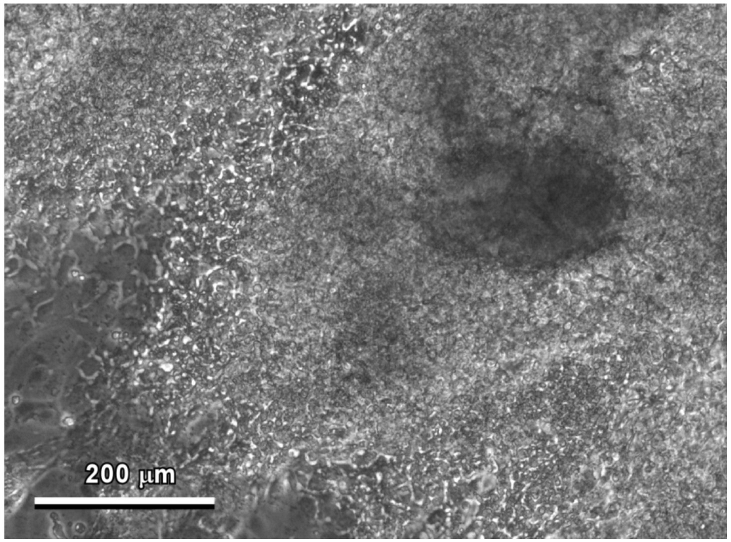
Sensing device: ink-jet printer



Cells used



Rat glioma C6 cells



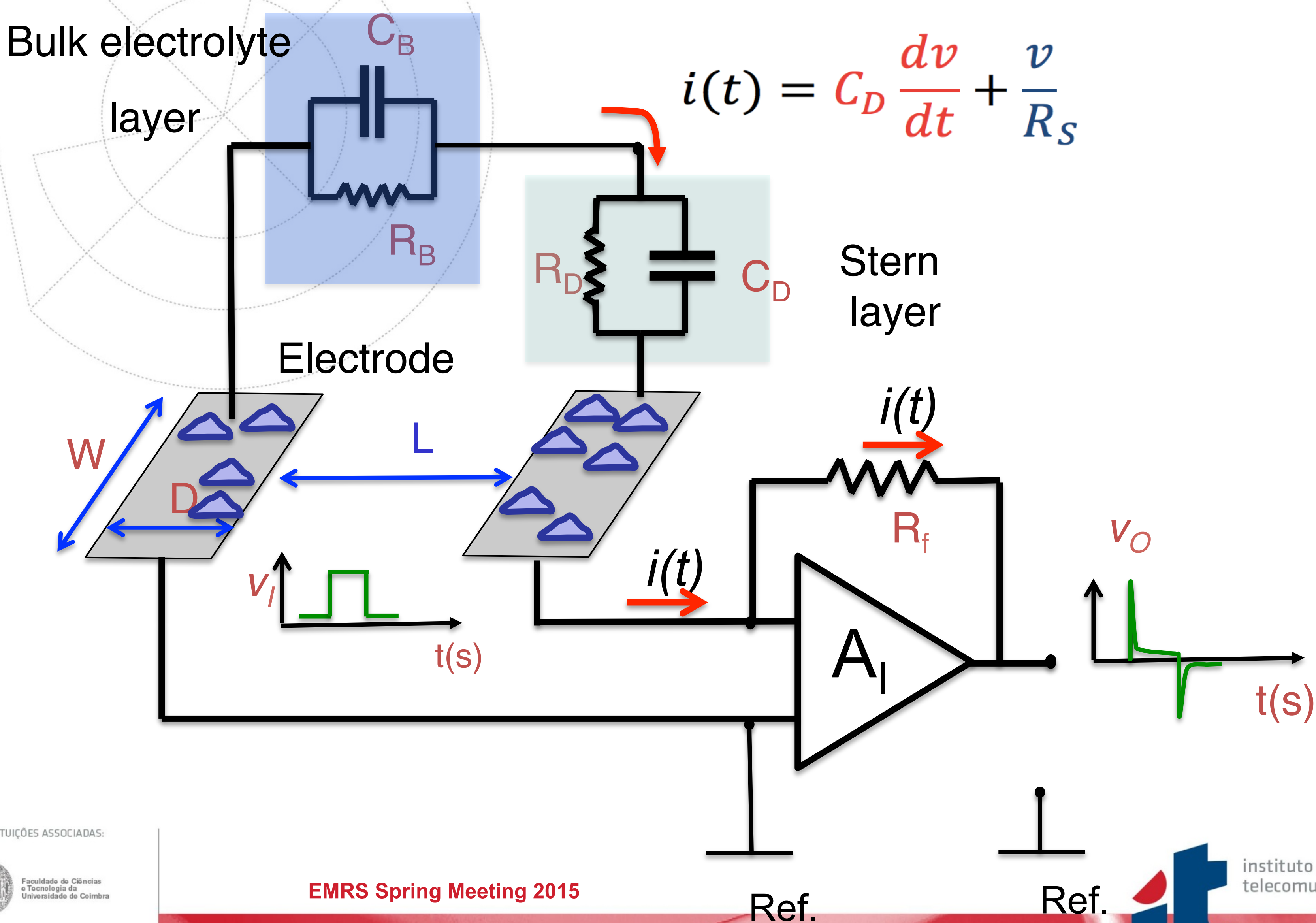
Cardiomyocytes

Ideal tool for testing device performance:

- **They engage into synchronous activity (extracellular calcium waves)**
- **They start activity a few hours after being adherent to a device**.

Experimental Set-Up (Electrical equivalent)

$$i(t) = C_D \frac{dv}{dt} + \frac{v}{R_S}$$



Experimental Set-Up

Advantages:

Increased Sinal to Noise Ratio (SNR)

We minimize the electrical noise of the system and lower the detection limit.

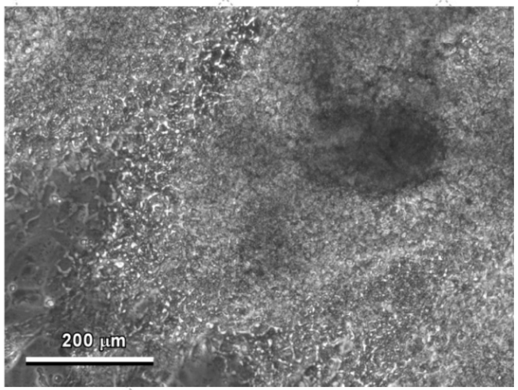
- Large area polymer electrodes minimize the electrical noise.

$$Noise = kT / C$$

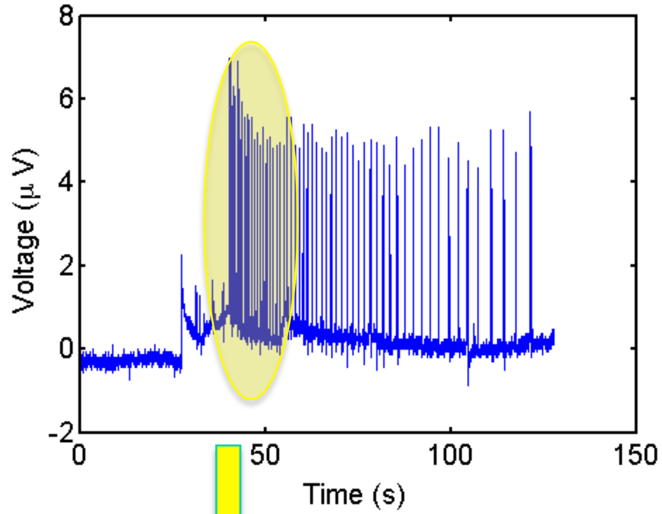
- By measuring in current the capacitance act as amplifying factor of the small voltage fluctuations.

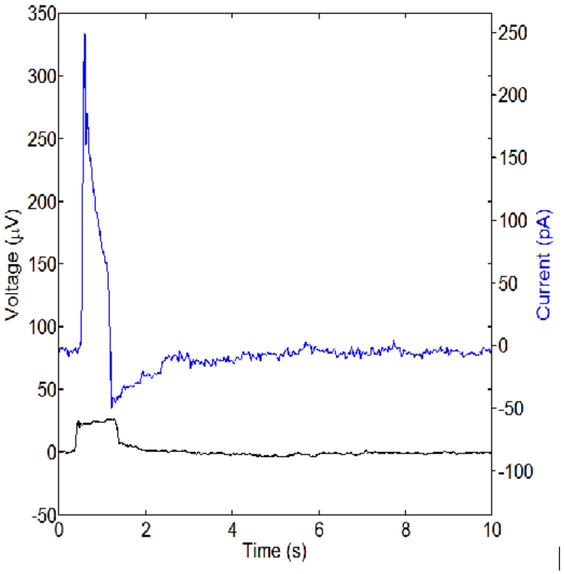
$$I = C(dv / dt)$$

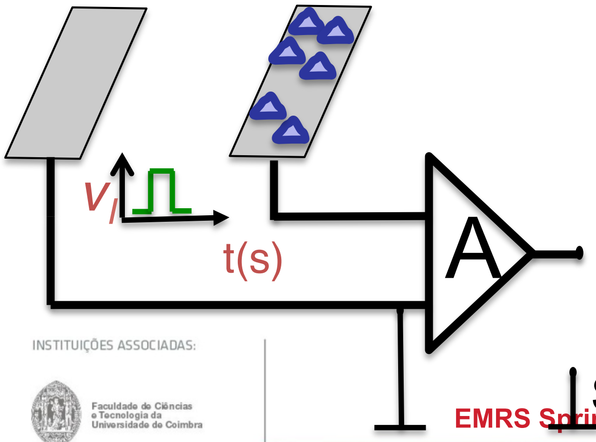
Signals from cardiomyocytes

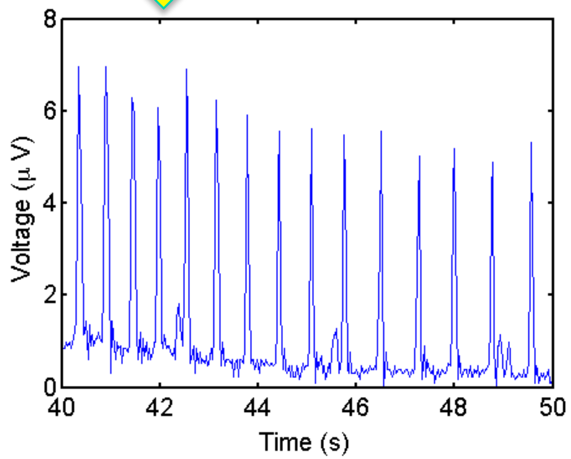


cardiomyocytes









Comparison between a voltage and a current signal

Signals recorded in voltage mode

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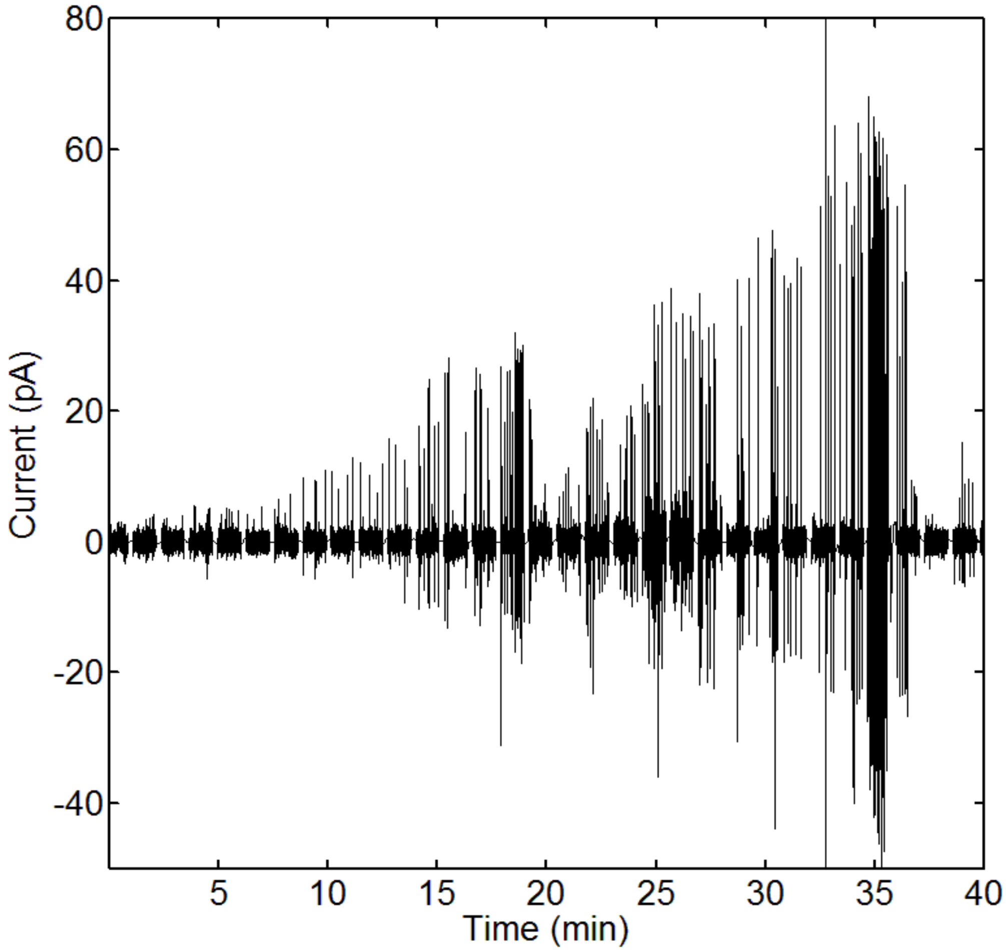
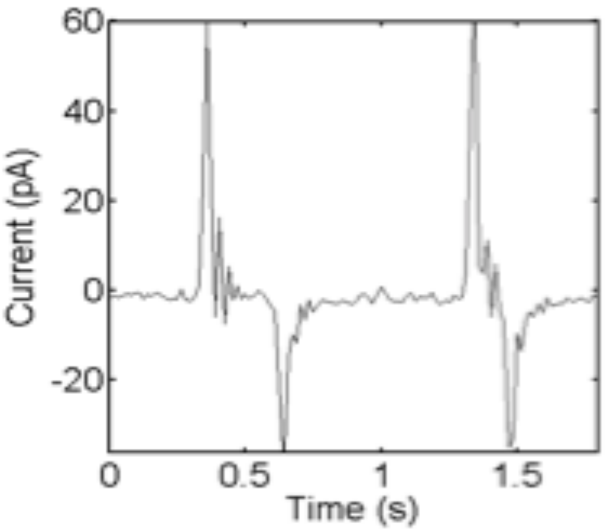
C6 bioelectric measured signals

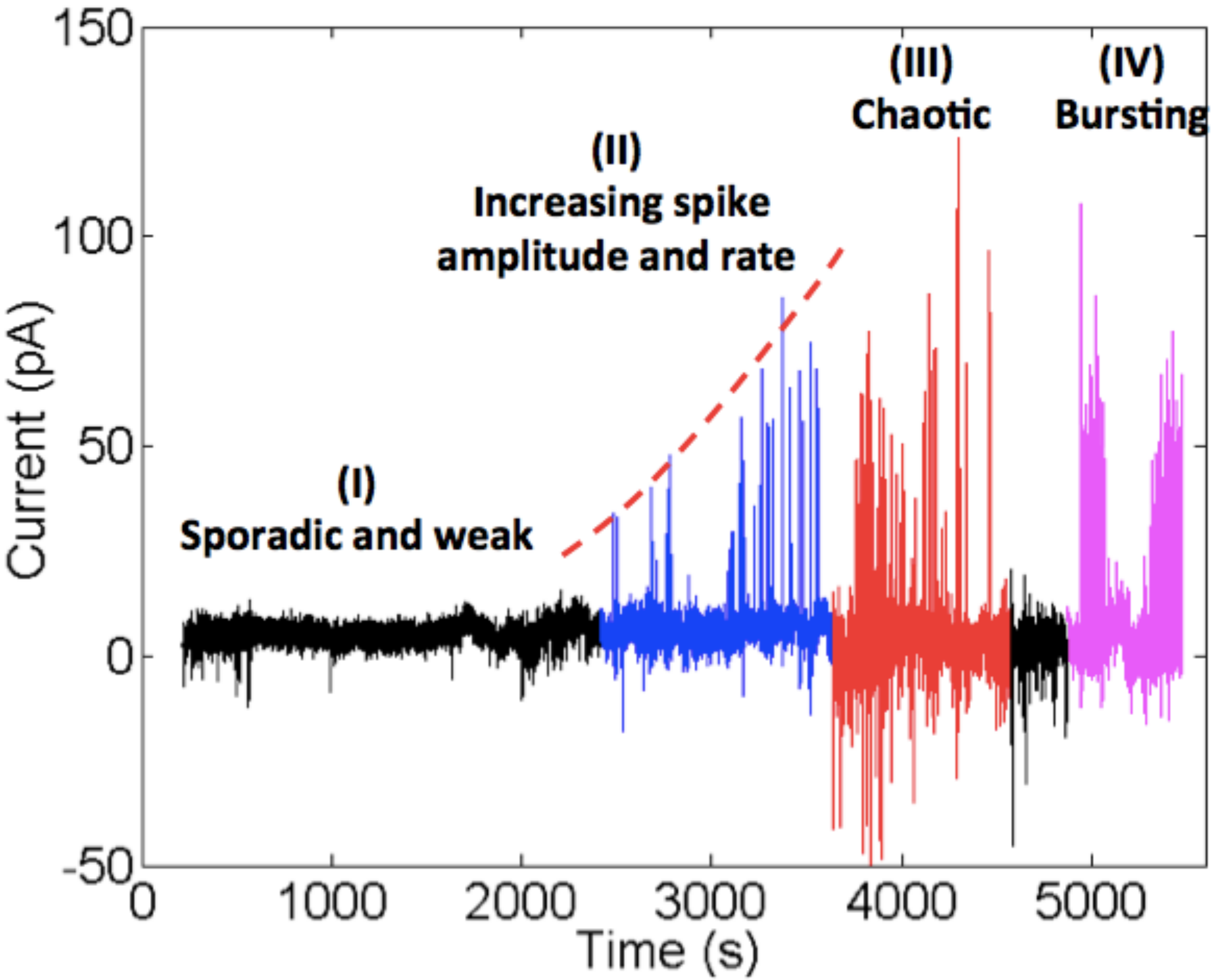




Detailed view of individual signals

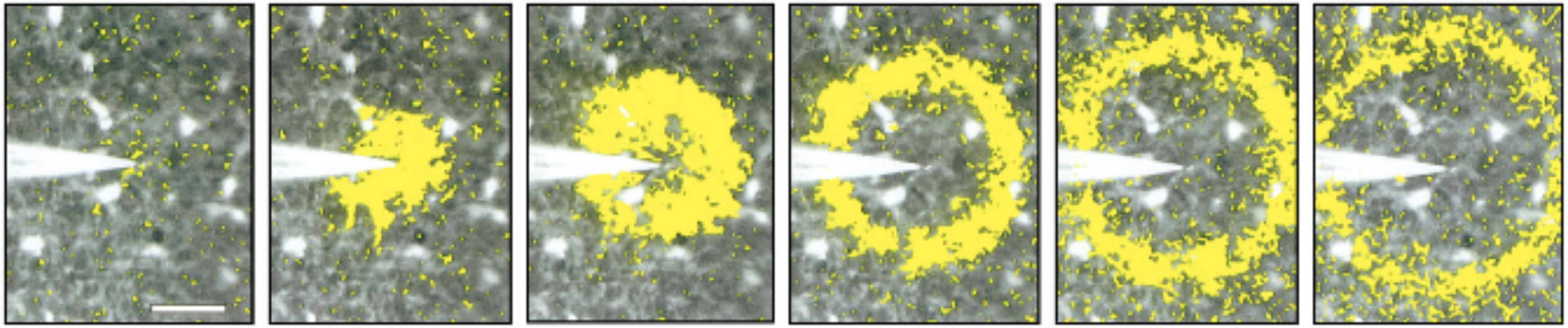
Long term recording of cell population activity

C6 biolectric measured signals



Calcium wave

Fluorescence imaging



Propagation of Ca^{2+} waves in glial cells.

Speed= 23 micrometers per second

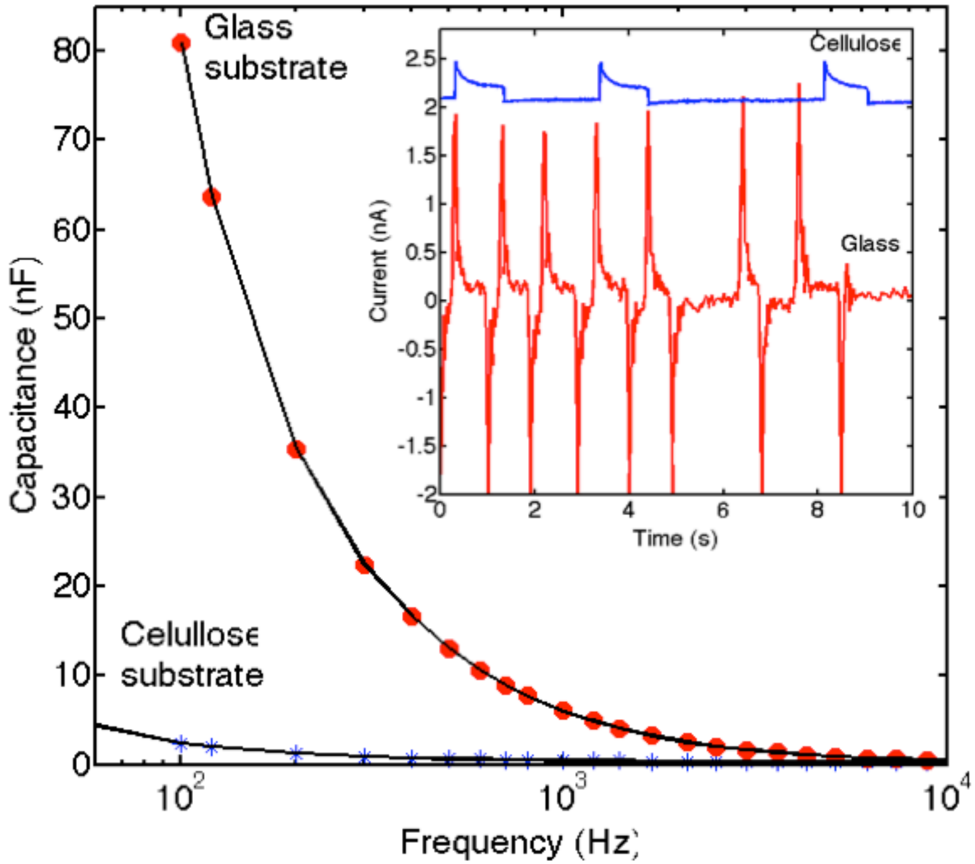
FROM:

Calcium Waves in Retinal Glial Cells

Eric A. Newman* and Kathleen R. Zahs

SCIENCE VOL. 275 ,7 FEBRUARY 1997

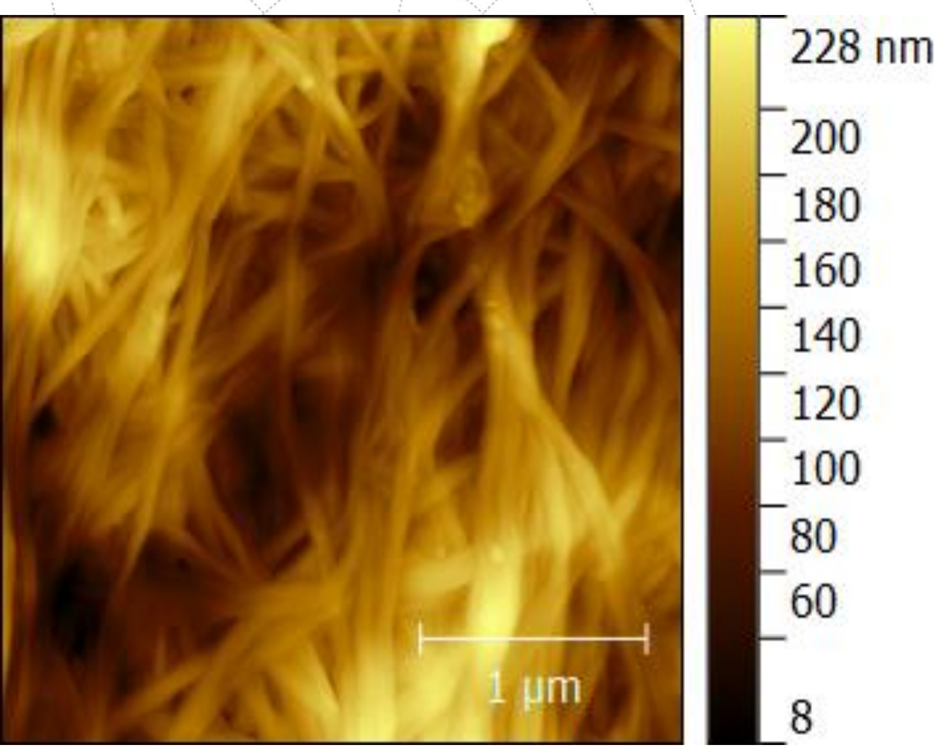
The role of the capacitance



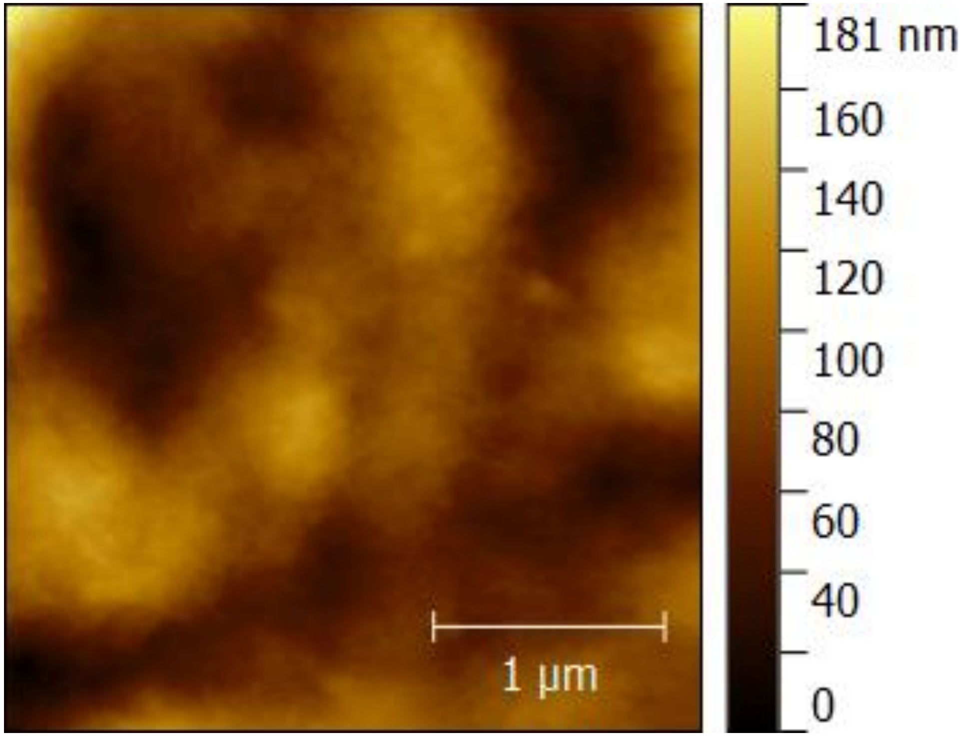
$$I = C(dv/dt)$$

Comparision between capacitance of the PDEOT on bacterial cellulose with the PDEOT on Glass. Inset shows signals recorded using the PEDOT:PSS on biocellulose and PEDOT:PSS on glass. For the sake of clarity, the lines were intentionally shifted along the *yy* axis.

Bacterial cellulose morphologies

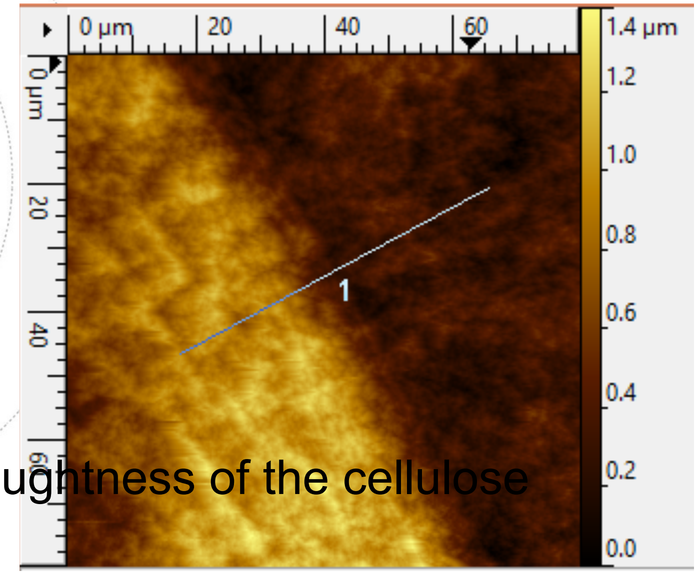


Uncoated

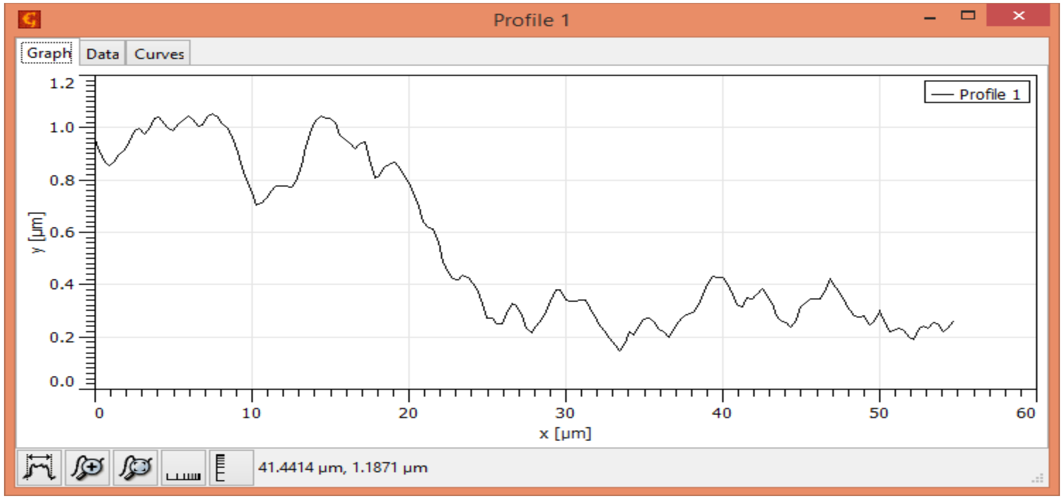


Coated with PEDOT:PSS

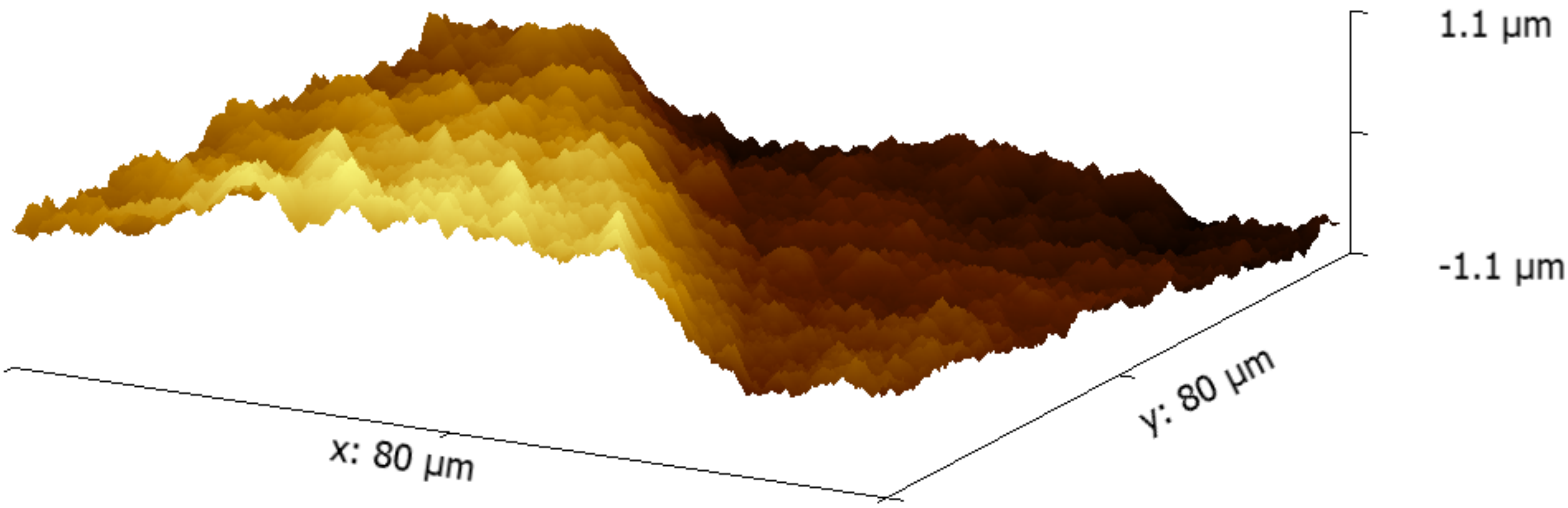
Bacterial cellulose morphologies



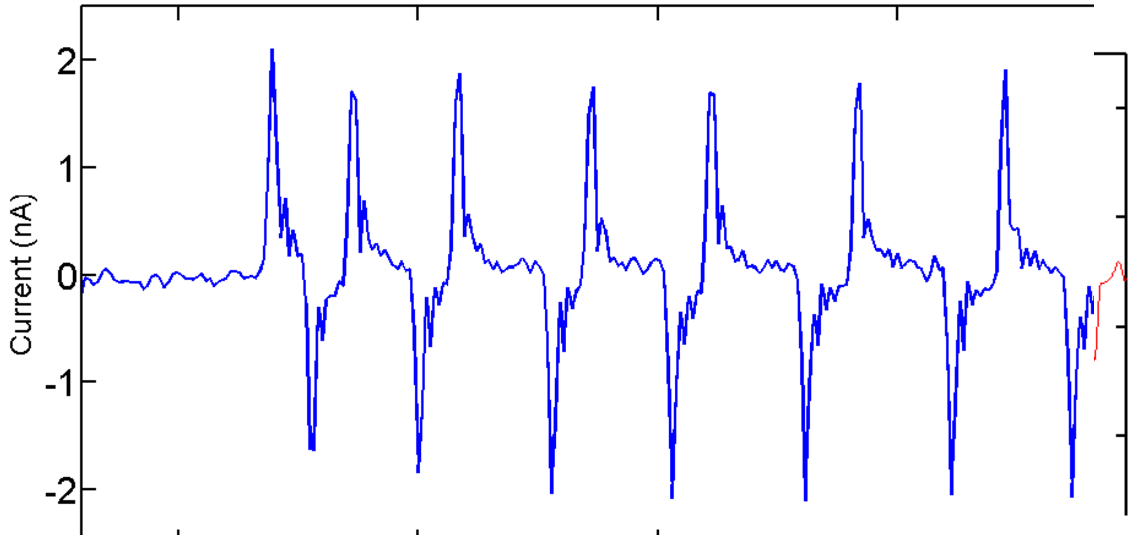
PEDOT swooths the roughtness of the cellulose

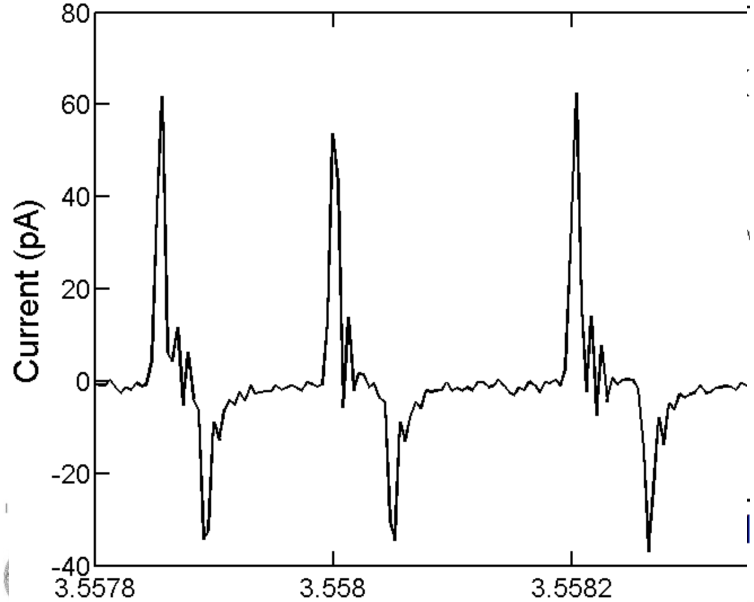


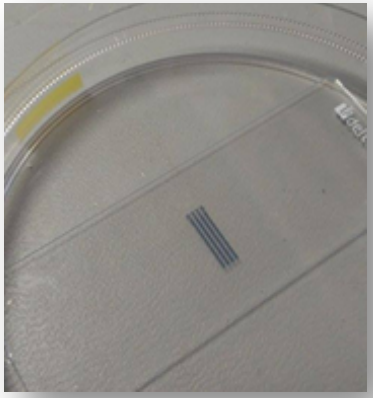
Bacterial cellulose morphologies



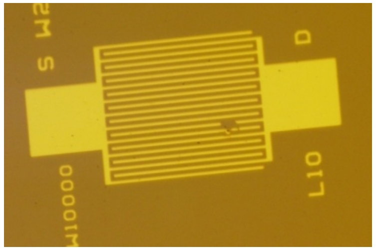
Comparing signals







PEDOT:PSS



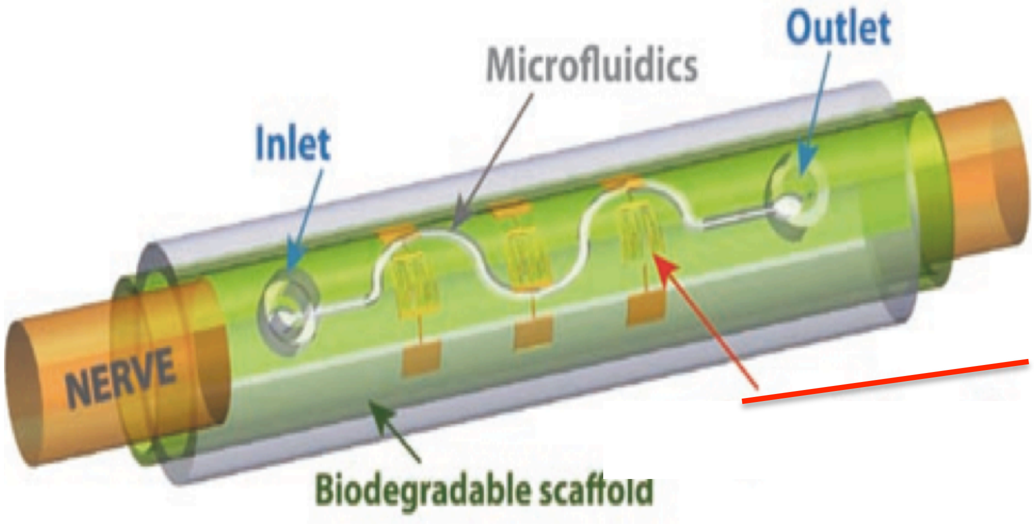
On gold

Conclusions

- Large area printed polymer electrodes are suited to measure cell activity.
- Simple planar sensing devices can be fabricated in glass or in biocompatible substrates such as bacterial cellulose.
- We have demonstrated the applicability of these printed electrodes to measure *in vitro* a population of contractile cells(cardiomyocytes) and quasi-periodic oscillations in Glioma cells.
- Our sensing device can be used in a drug screening platform.

Implantable Organic Nanoelectronics

The objective of iONE-FP7 project is develop a flexible organic electronics for the treatment of Spinal Cord Injury (SCI)

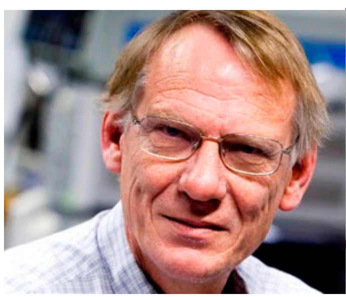


Bi-directional transducer capable to record and send electrical signals to the cells.

We have to make it simple and robust.

Schematic layout of an active multifunctional Implantable Device (AMID)

Acknowledgments



Dago de Leuuw

Paulo Rocha

iONE-FP7

SEVENTH FRAMEWORK PROGRAMME

MAX PLANCK INSTITUTE FOR POLYMER RESEARCH

2015

Thank you for your attention !