Macroporous nanowire nanoelectronic scaffolds for synthetic tissue

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Outline

- Introduction
- Process
- Applications

Existing intracellular sensing probes(1)

- Voltage-sensitive optical dyes
  - Rapidly interrogate action potentials with high spatial resolution
  - Limitations on SNR, phototoxicity, difficulty in differentiating single spikes

Existing intracellular sensing probes(2)

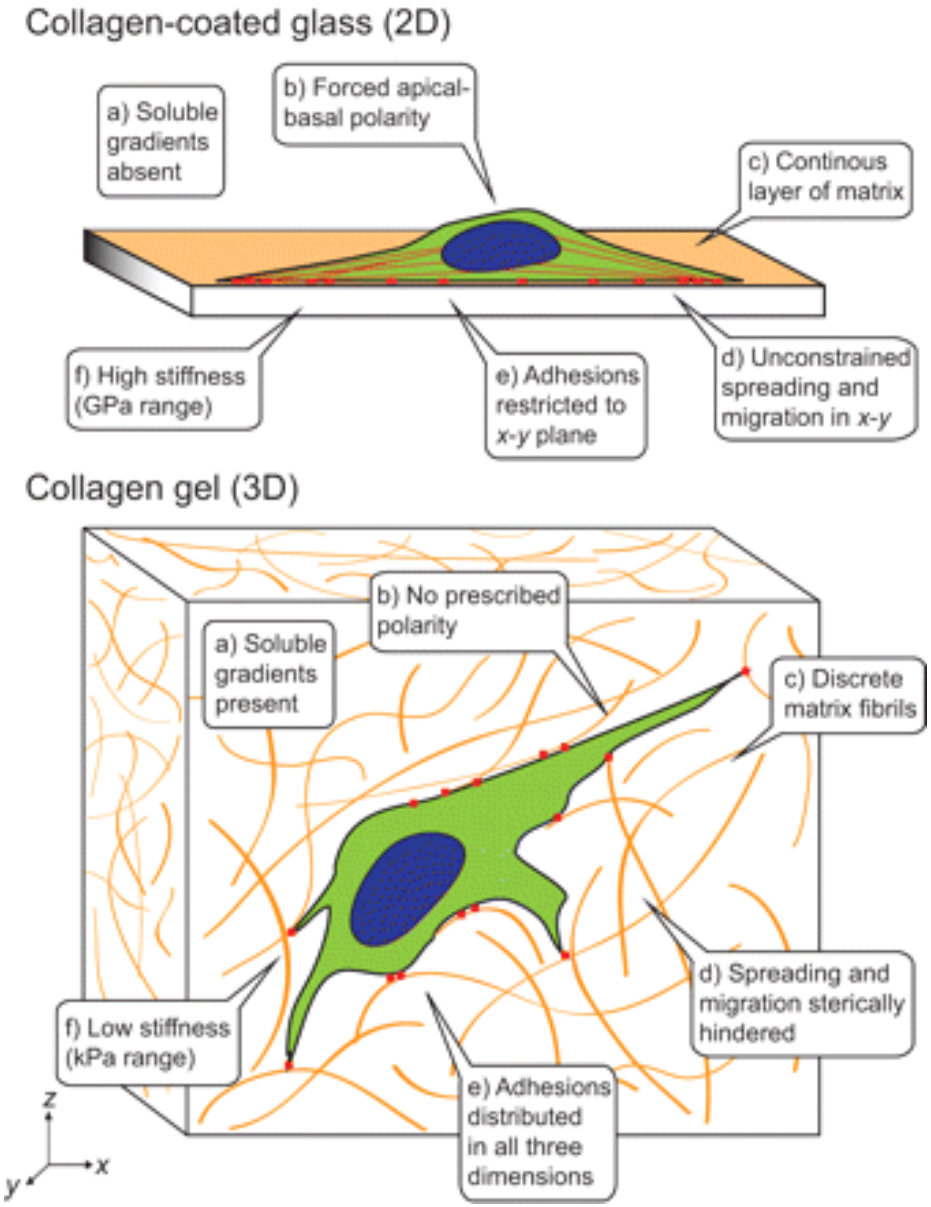
- Single-terminal glass/Carbon microelectrodes
  - Small enough to penetrate cell membrane with minimum damage(<5 μm); large enough to yield a low junction impedance(>0.2 μm)
  - Direct exposure to probe surface might induce irreversible changes to cells=>prevent long term non-invasive recordings
  - Passive=>not capable of built-in signal processing and facile integration with other circuitries

2D Cellular Platform

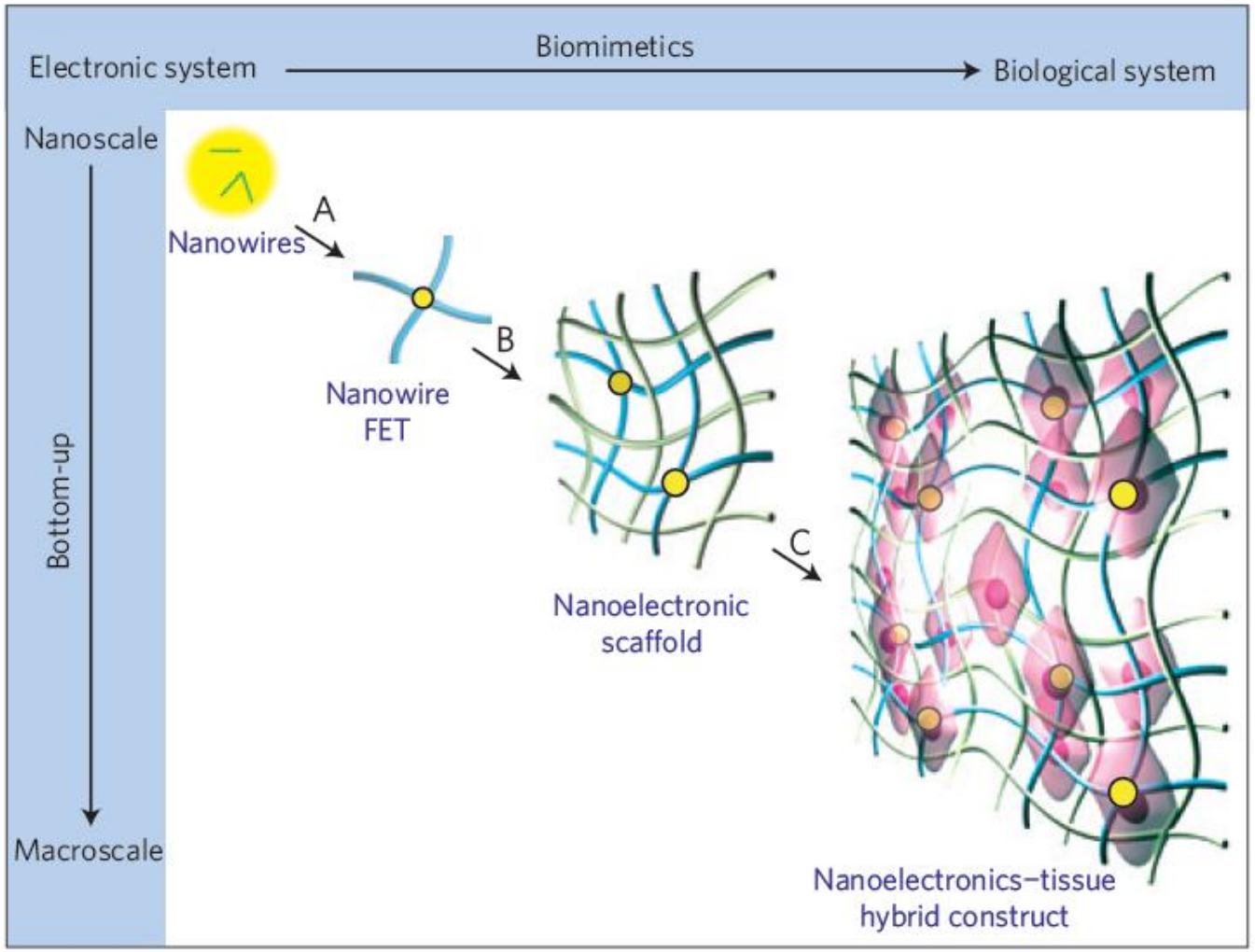
- Flat layers of cells grow on planar metal electrodes or transistors
- Probes are placed on the surface of tissues
- Do not accurately replicate natural tissue

2D->3D Cellular Platform

- Directly simulate engineered tissues and measure cellular reactions
- Able to see how cells inside the structure responds to specific drugs
- Create systems capable of sensing chemical or electrical changes in the tissue after it has been grown and implanted

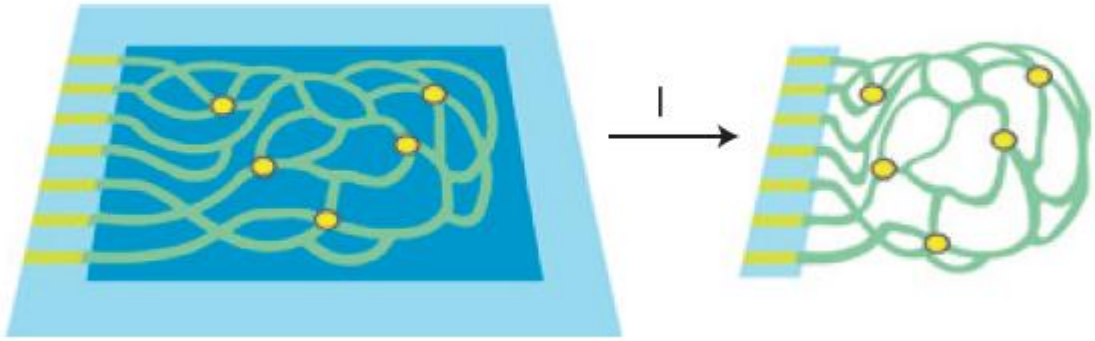

Collagen-coated glass (2D)
a) Soluble gradients absent
b) Forced apical-basal polarity
c) Continous layer of matrix
f) High stiffness (GPa range)
e) Adhesions restricted to x-y plane
d) Unconstrained spreading and migration in x-y
Collagen gel (3D)
a) Soluble gradients present
b) No prescribed polarity
c) Discrete matrix fibrils
f) Low stiffness (kPa range)
e) Adhesions distributed in all three dimensions
d) Spreading and migration sterically hindered
z
x
y

Fabrication of nanoES(1/3)



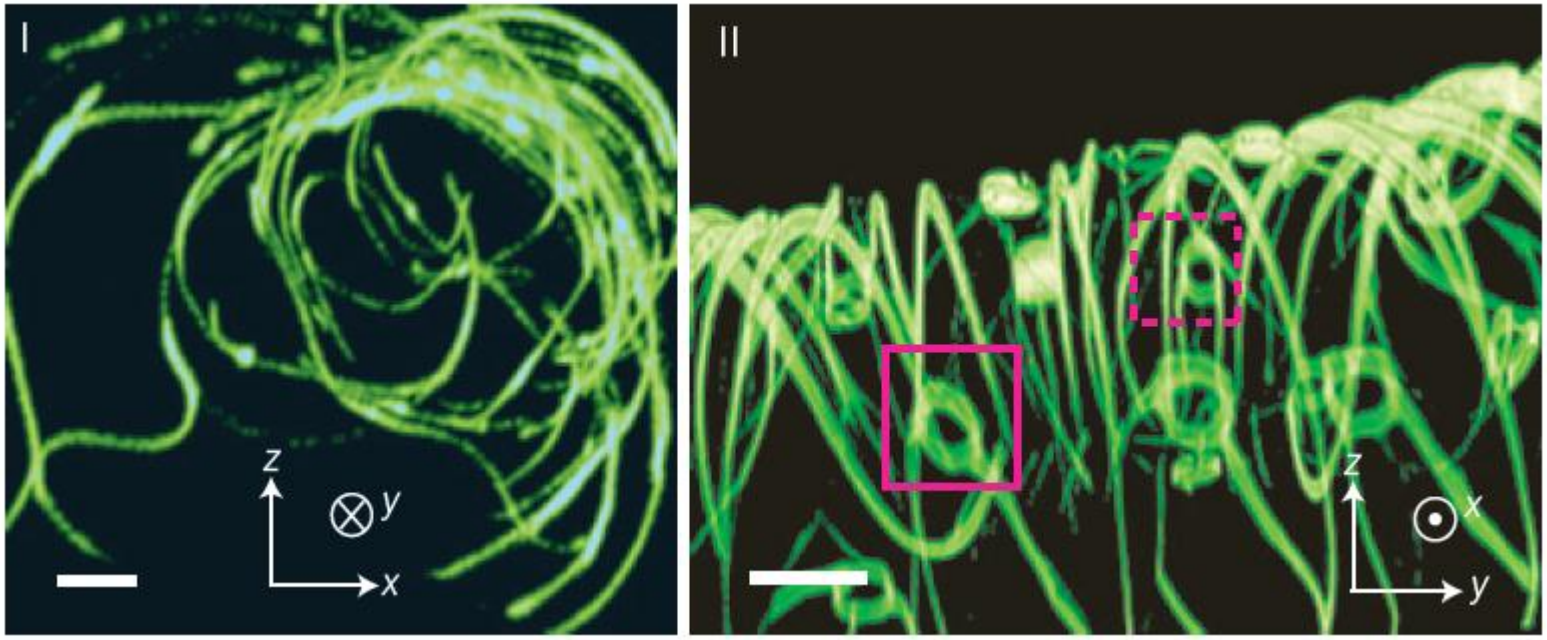
Fabrication of nanoES(2/3)

- A layer of negative photoresist SU-8(green) was coated on a nickel layer(blue).
- A solution with nanowires(yellow) was deposited.
- SU-8 was patterned by lithography.
- Metal contacts deposited as well.

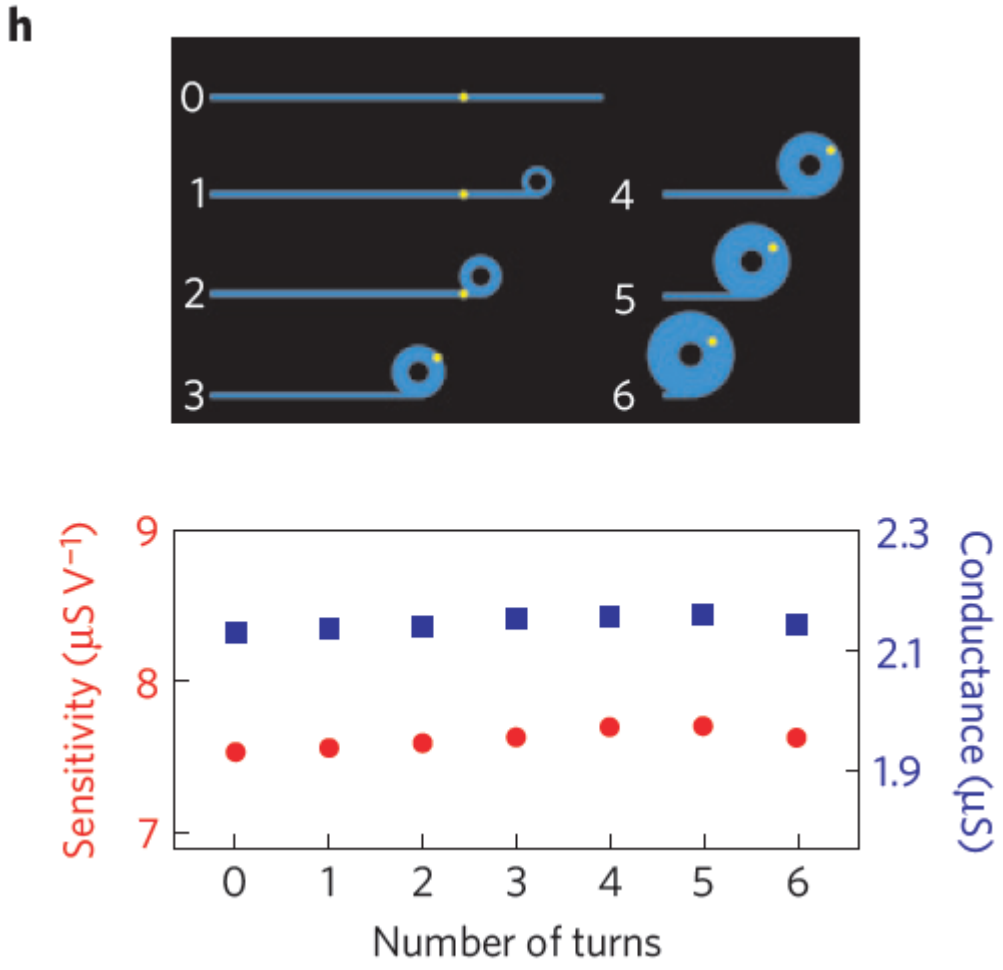


Fabrication of nanoES(3/3)

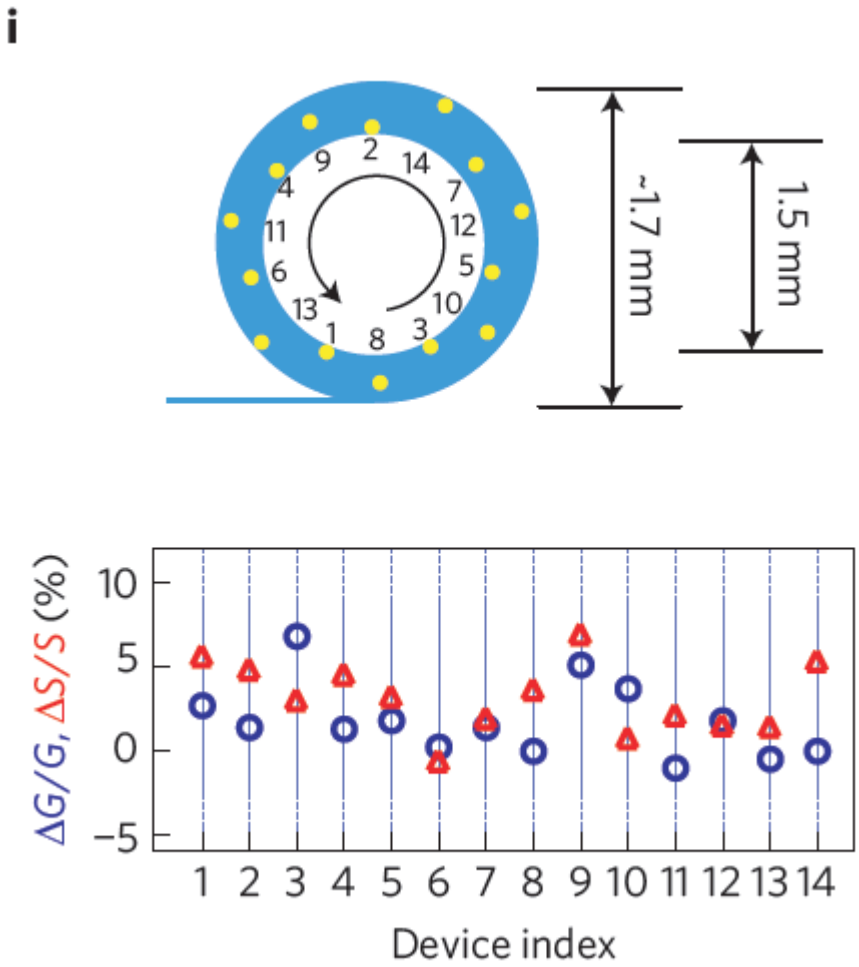
- The resulting nanoES can be rolled up manually or by self-organization, with bending elements predefined.



Stability of nanoES(1/2)



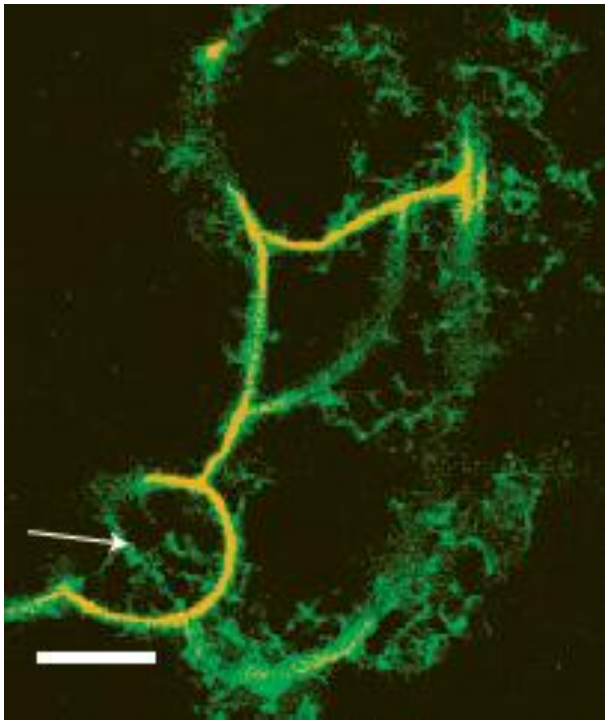
Stability of nanoES(2/2)

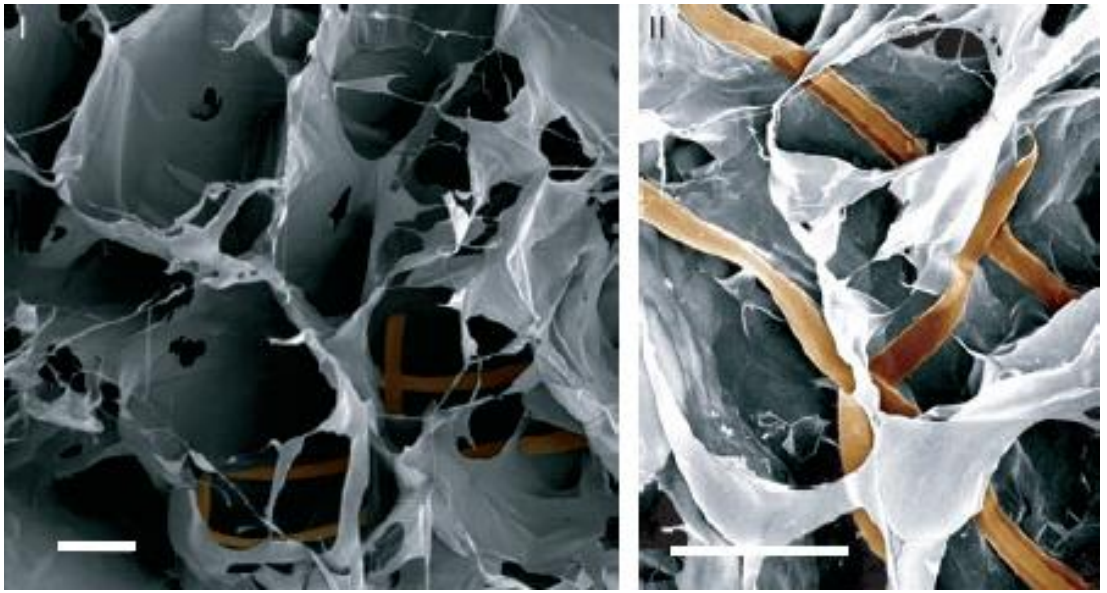


Remark of nanoES fabrication

- Bottom-up process provides minimally invasive integration of electronics and cells.
- Process compatible with the mature integrated circuit process.
- The stability during rolling makes it possible for recording of dynamic and deformable system.
- The 3D structure of nanoES provides information of the whole tissue culture, a huge improvement to the traditional biomaterial, which is of 2D structure, providing information only on surface.

Combination with biomedical material

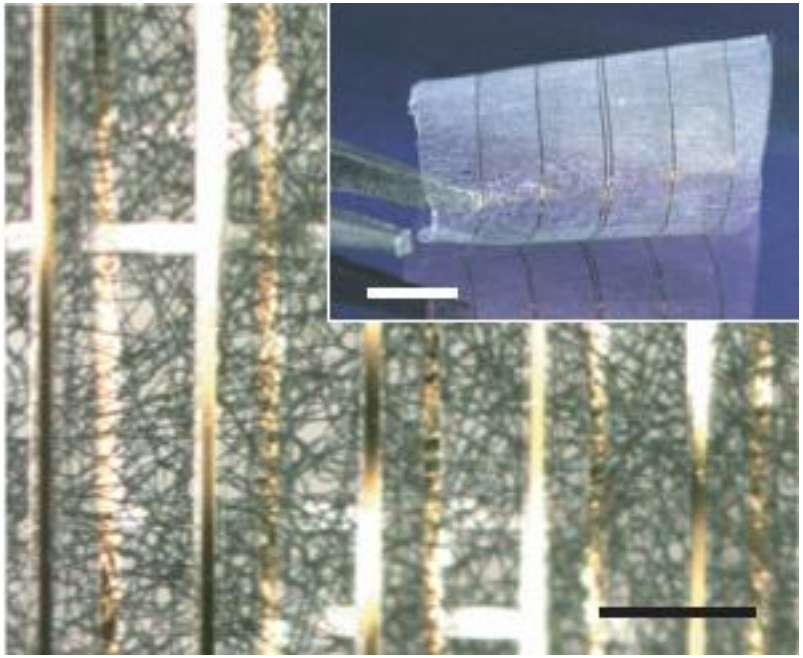


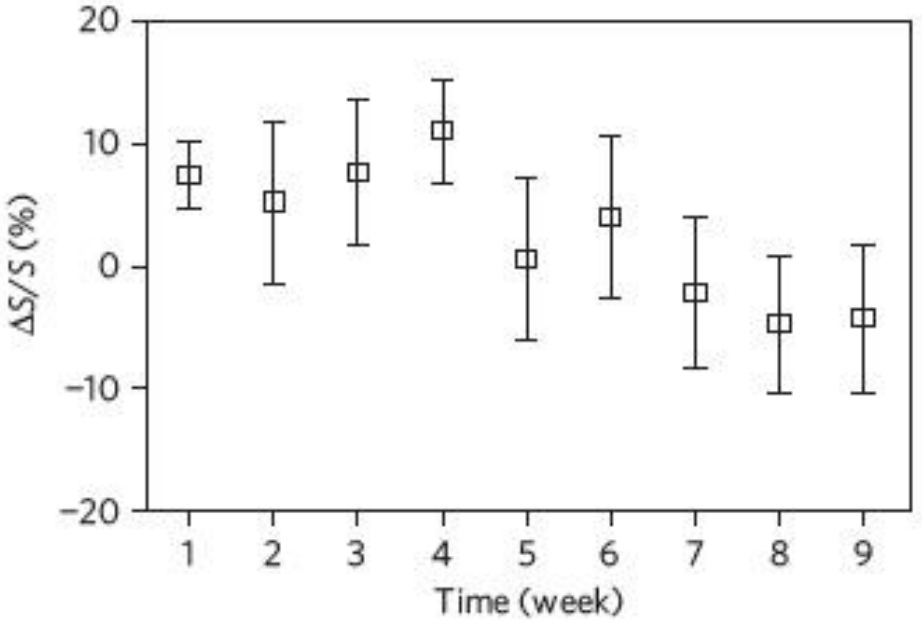


- green → collagen
- arrow → nanoES

- brown → nanoES
- gray → alginate

Combination with biomedical material

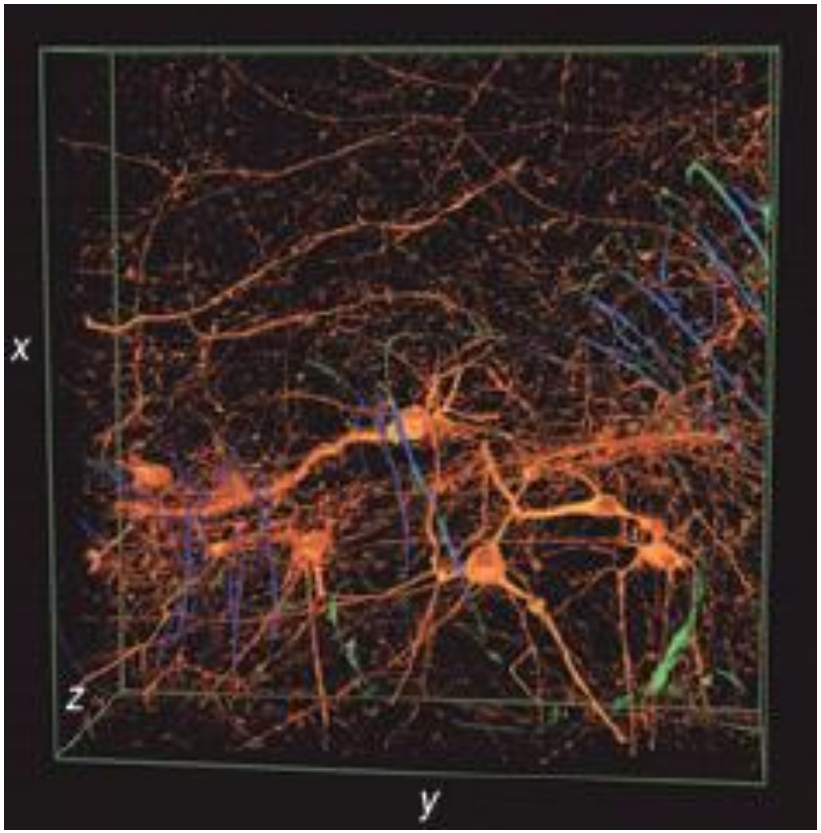




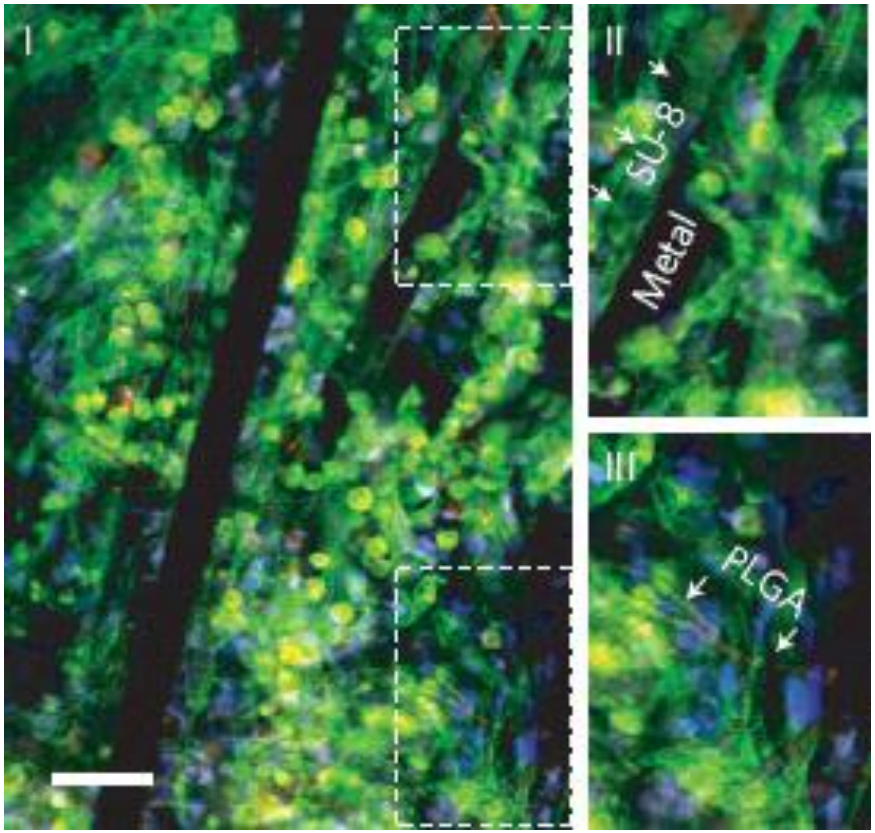
- Bright lead → nanoES
- Green mesh → PLGA

Stability

Cultivate cells in nanoES

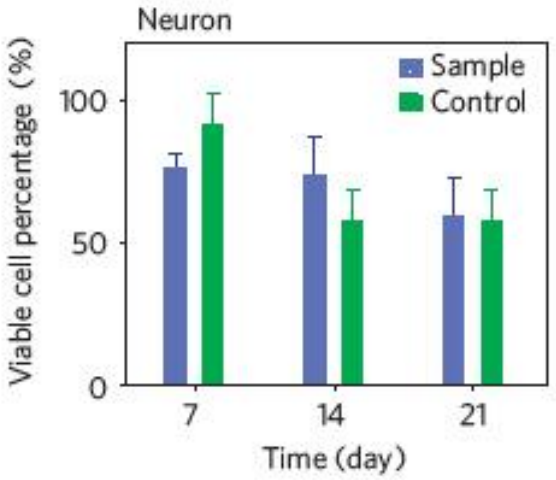


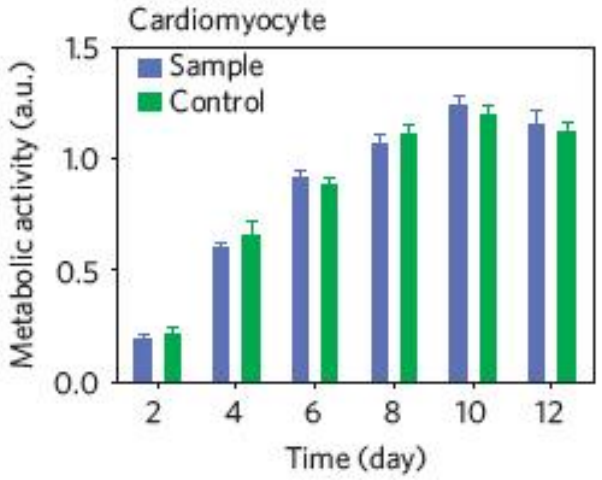
Neuron cells



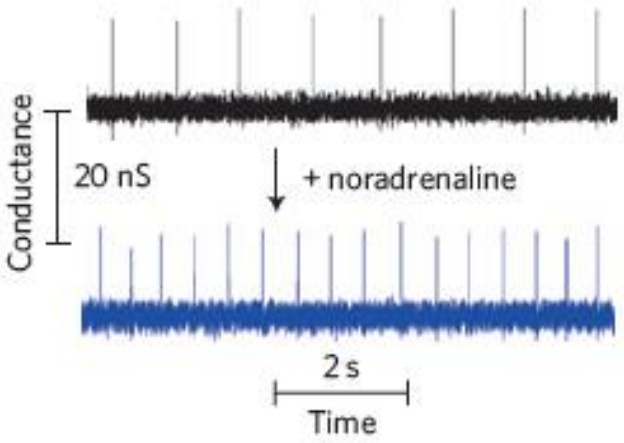
Cardiac cells

Signal monitoring

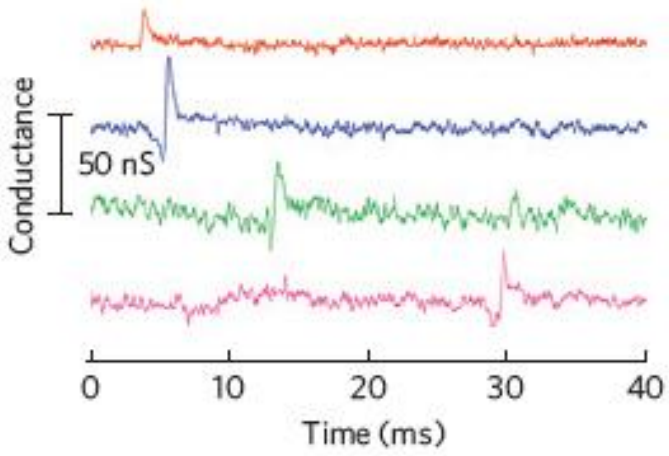




State of cells



single sensor



multiple sensors

Embed nanoES in vascular

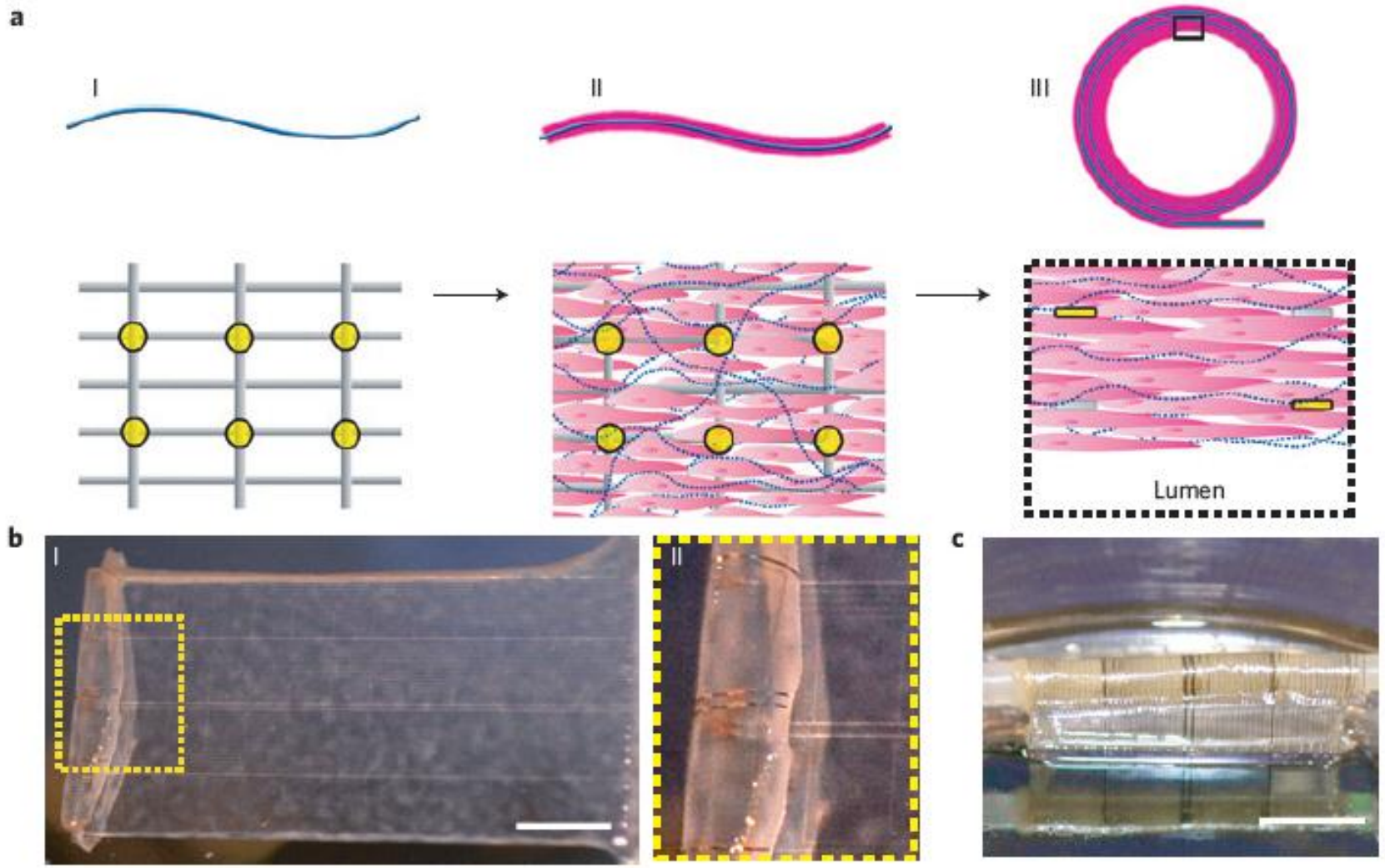
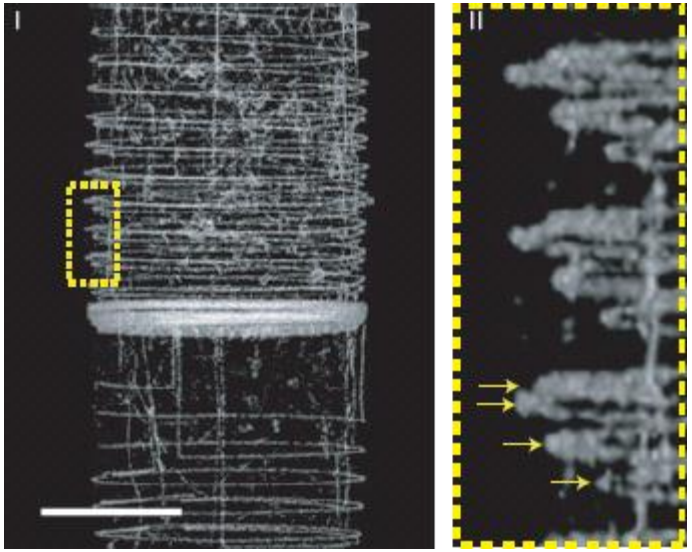
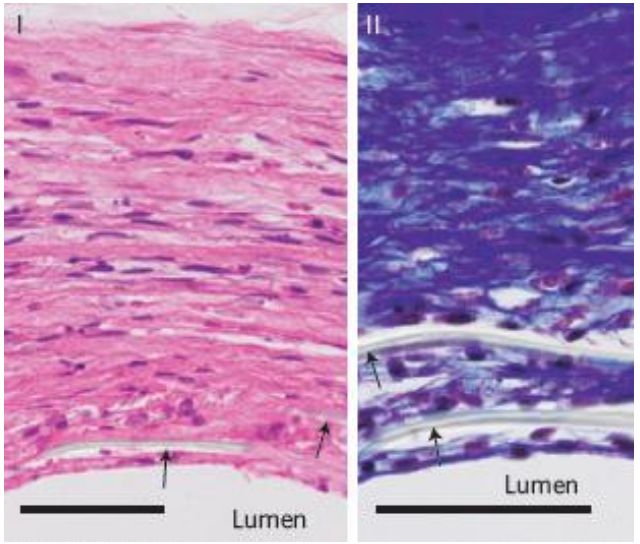


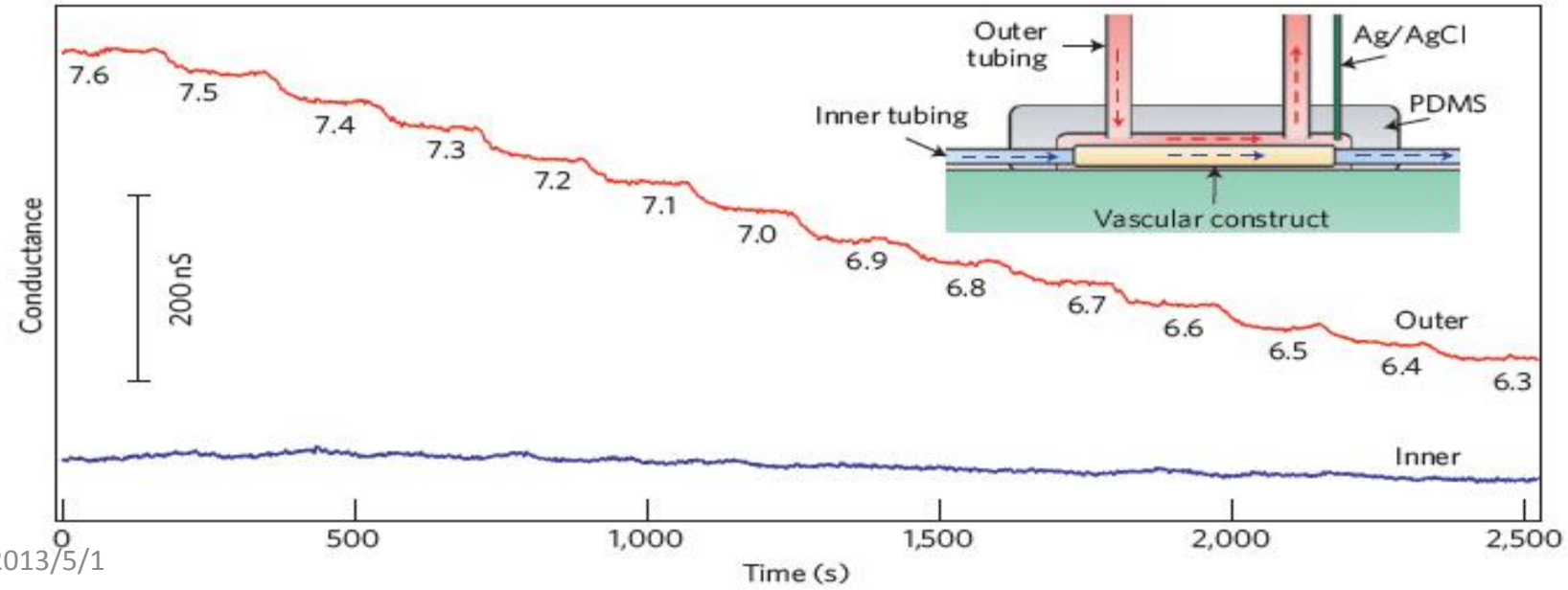
Image of artificial vascular construct



← microCT

→ dying





Future development

- Monitor the pharmacy result
- Monitor physiological signals
- Moreover, try to inject signals into body(from passive to active)