Centre Interdisciplinaire de Nanoscience de Marseille

Aix Marseille université

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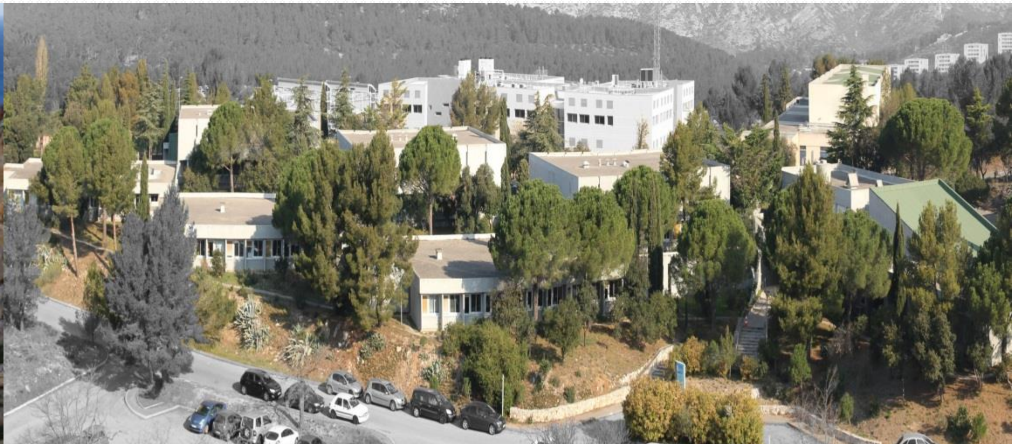
FET ion sensor with Nanometric lipid gate insulator for high sensitivity detection level

By: Ahmad Kenaan



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Introduction

❑ Heavy Metals

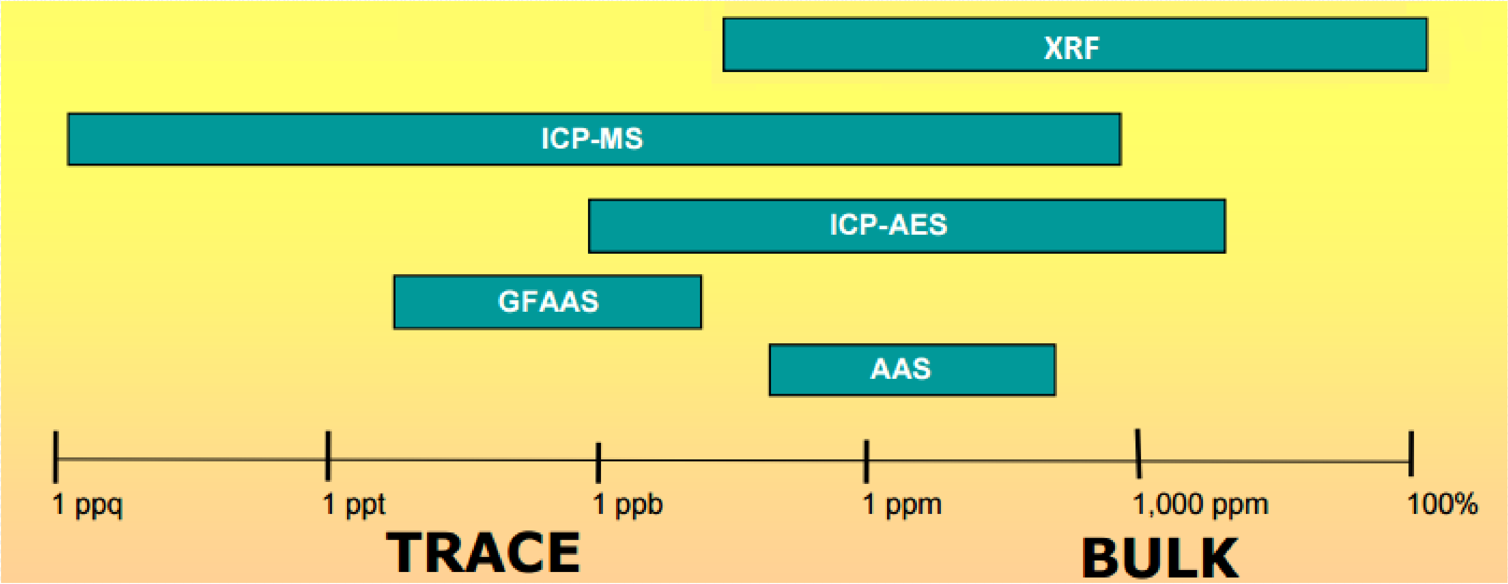
- Naturally occurring substances
- Present in environment at low levels
- Cant be degraded or destroyed
- Easily dissolved in water
  - Absorbed by aquatic organism
  - Contaminate drinking water and food
  - Affect human health

- Detection of metals in human body
- Early diagnosis of diseases (Case of Wilson disease: accumulation of copper in tissues)

Introduction

❑ Detection of metal ions

- Analytical methods:
  - ICP-MS/AAS/XRF
  - Expensive and large equipment
  - Time consuming



1ppm=1mg/l

1ppb=1μg/l

1ppt=1ng/l

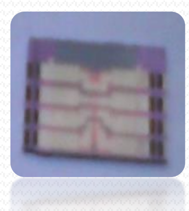
1ppq=1pg/l

Introduction

❑New sensing Device

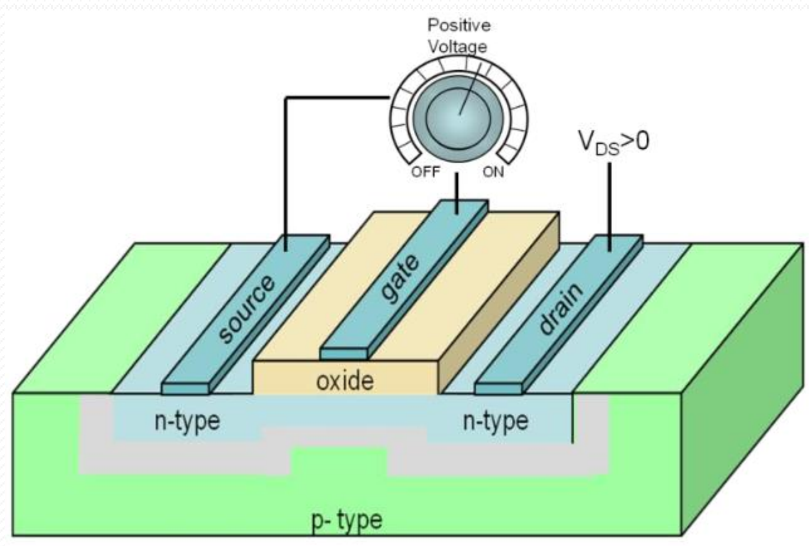
- Low cost
- Wearable , versatile
- Easy to use
- High detection level
- High specificity

❑Microdevice



➢ Based on Field Effect Transistor (FET)

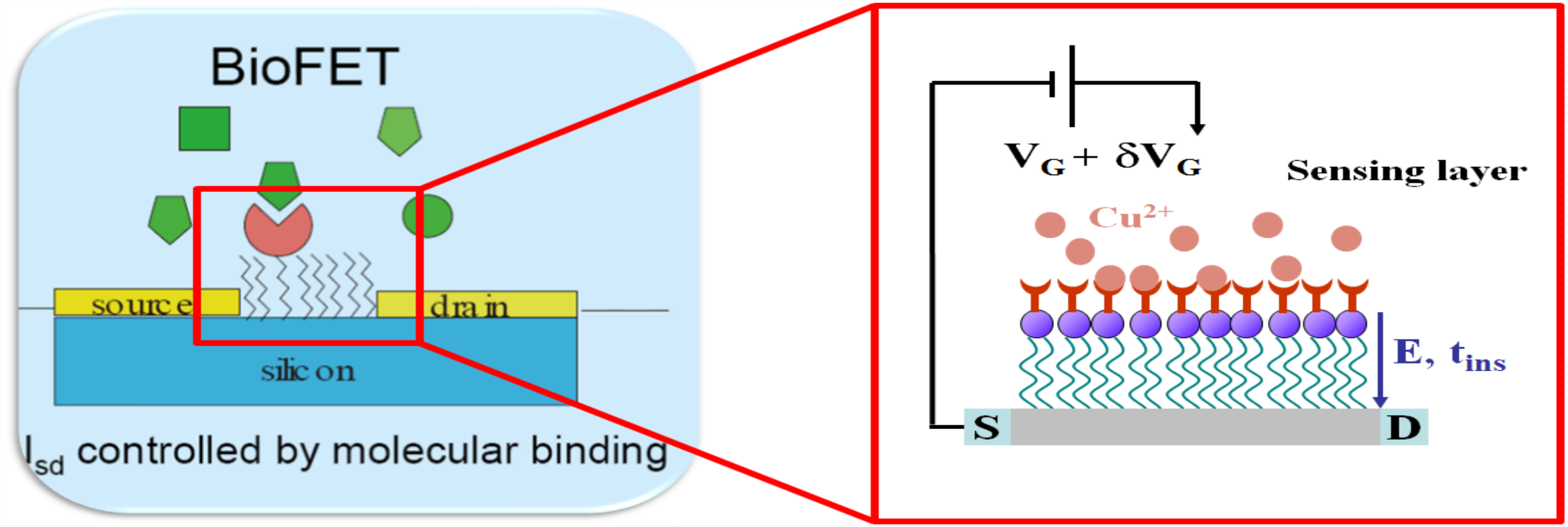
➢ Electrical detection



MOSFET

Field Effect Transistor Biosensor

❑ From FET to bio-FET



❑ Bio-FET Requirements

- Operating at low Voltage
  - Preserve organic molecules
  - Large Sensitivity $\frac{\delta V_G}{V_G}$

But!!!

E must be Large

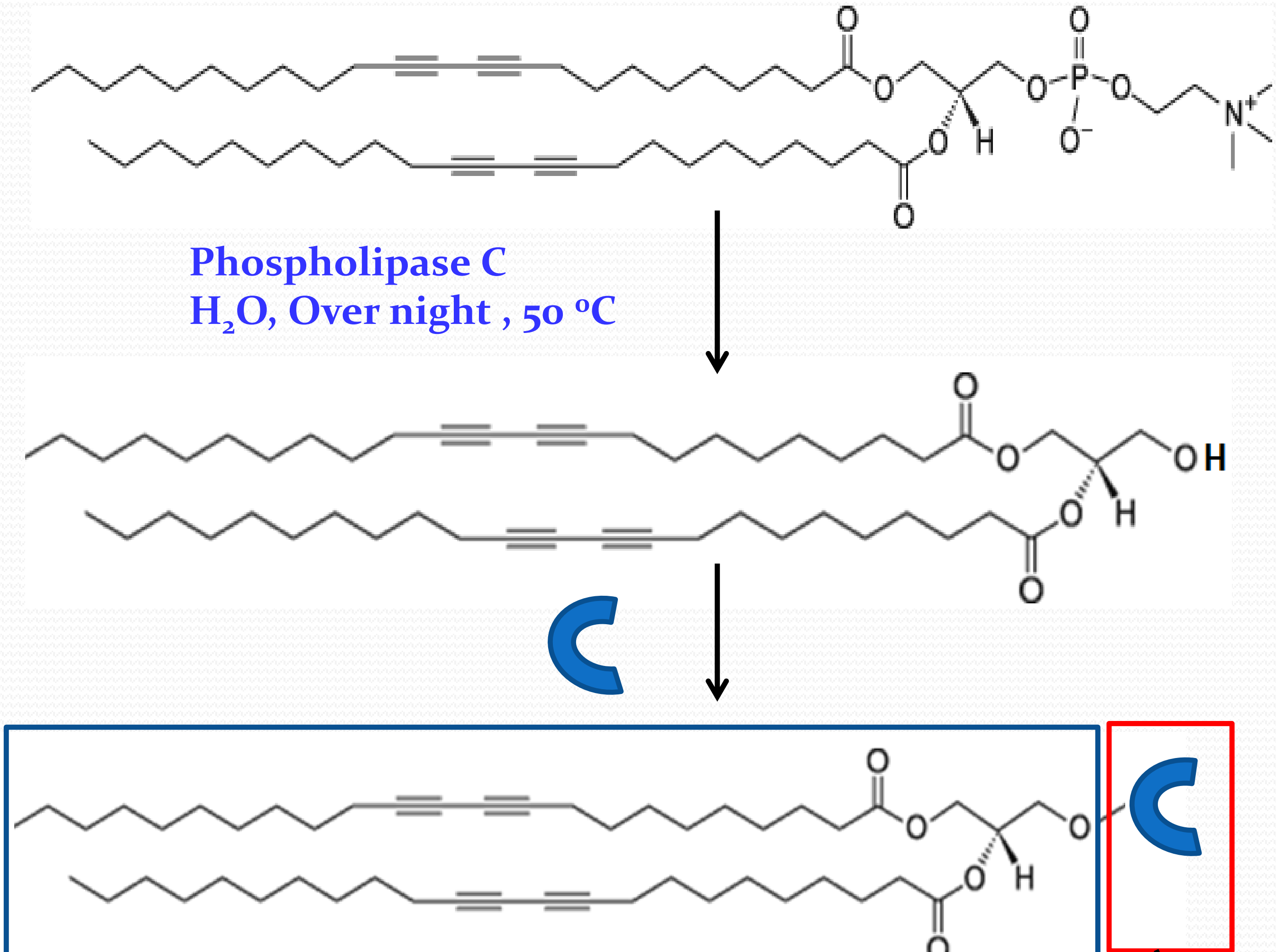
$$E = \frac{V}{t_{ins}}$$

Large (E), Small (V), Small (t_{ins})

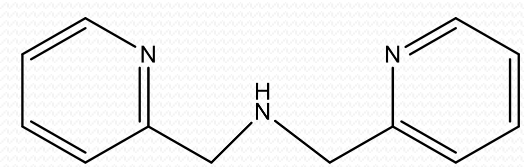
- **Lipid Monolayer**
  - Thickness: ~2.5 nm
  - Natural ion barrier
  - Dielectric properties (High electrical resistance R~1 GΩ)
  - Functionalization

Phospholipid

❑ Functionalized lipid



DCPC:2-Di-(10Z,12Z-tricosadiynoyl)-sn-Glycero-3-Phosphocholinephospholipid



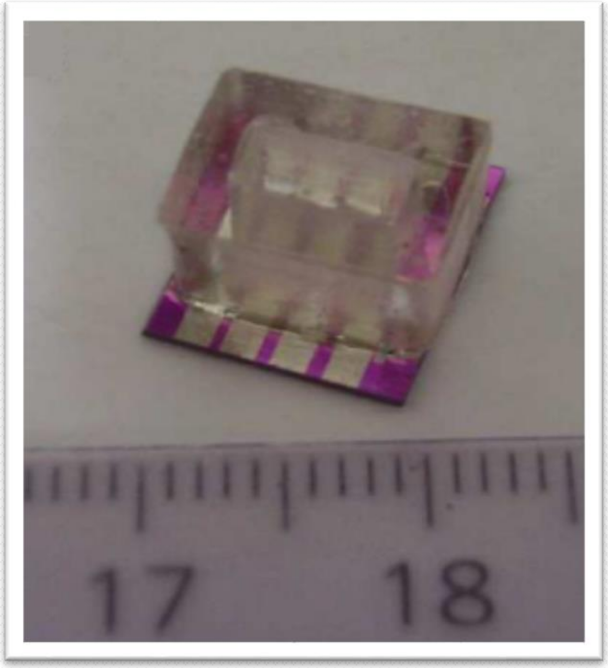
Dpa (dipicolylamine)

Insulating part

Sensing part

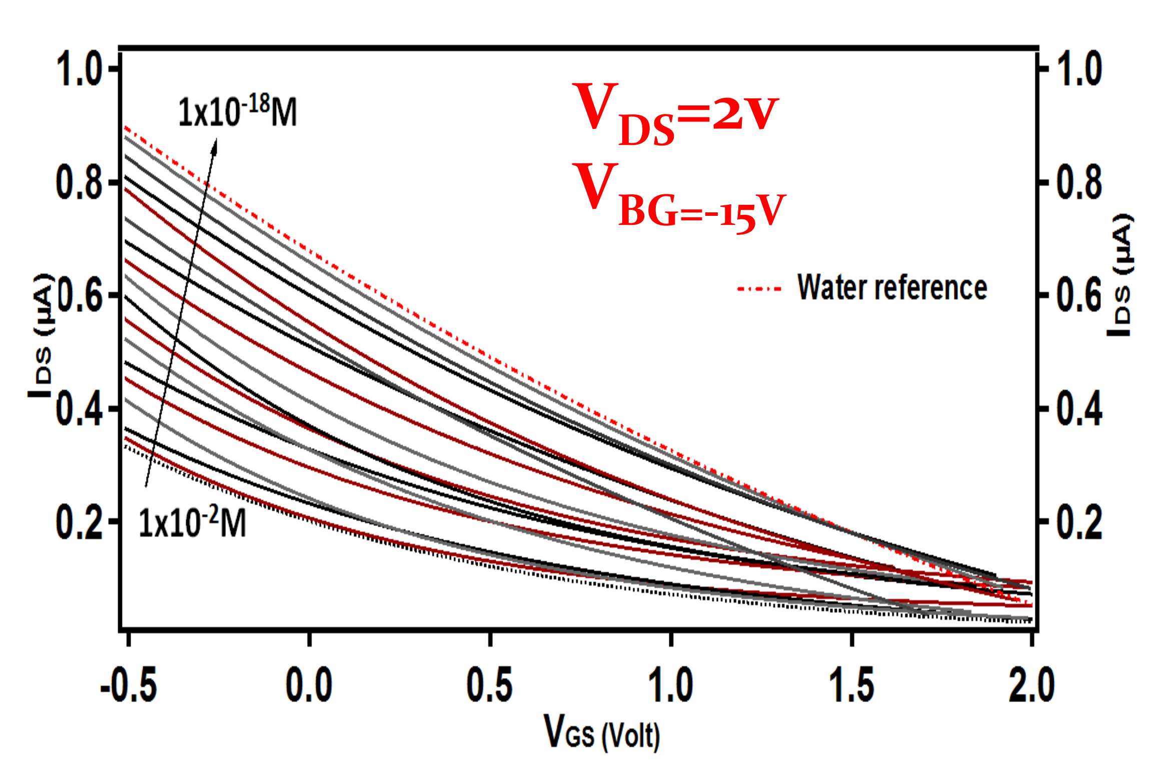
Our Devie

- 4 different separated Transistors with different channel length (600, 400, 200, 100 µm)
- PDMS ring



Sensitivity measurements

- Sensitivity measurements

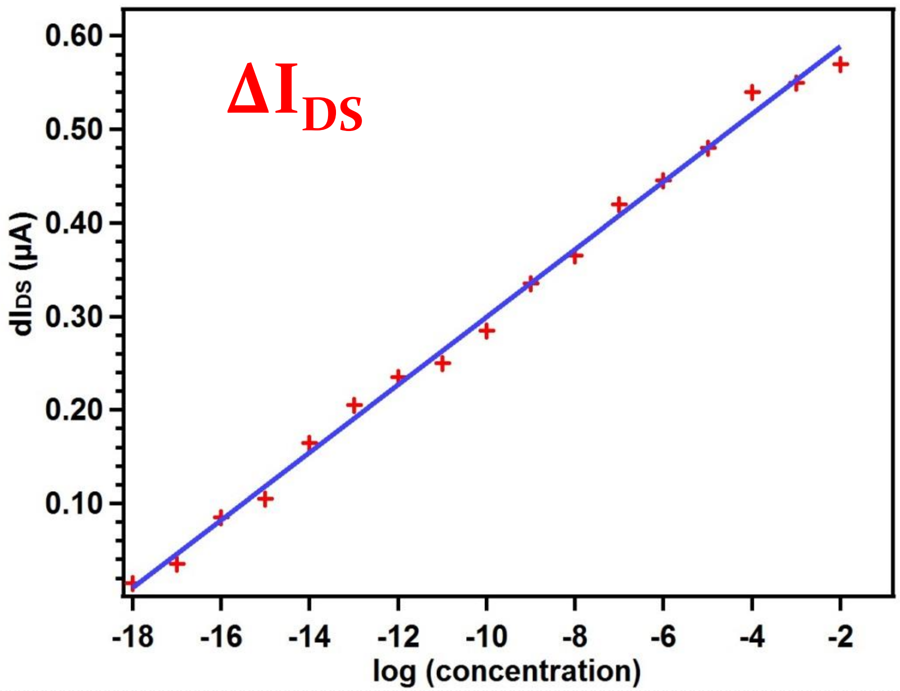


Variation of current (I_{DS}) vs V_{GS} with the increase in the concentration of copper (II)

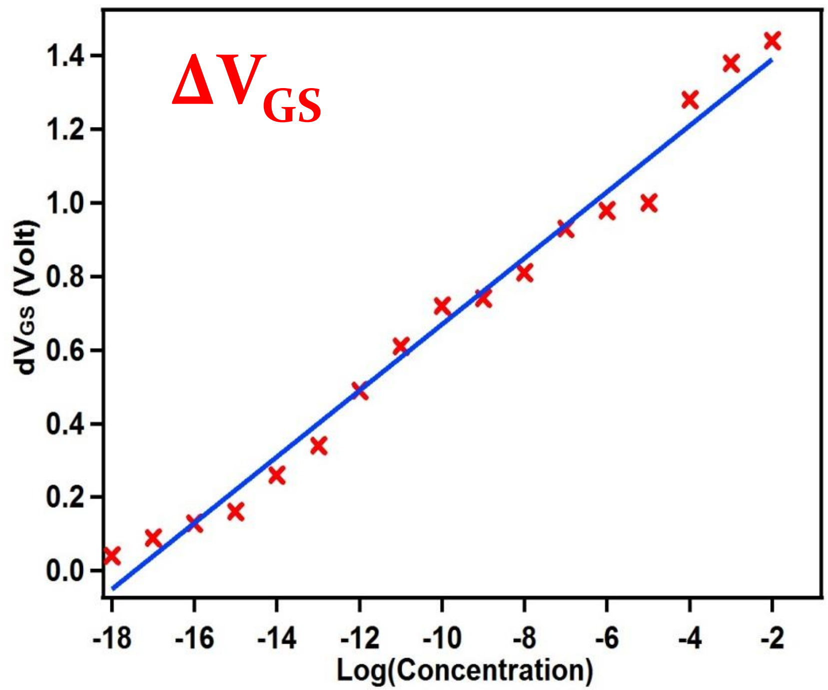
Detection range: 10^{-2}M (0.635g/l) to 10^{-18}M (1.57fg/l) ➡ **Super High sensitivity**

Sensitivity measurements

- Sensitivity measurements



Variation of (ΔI_{DS}) with the increase in concentration of copper at V_{GS}=-0.5v



Variation of (ΔV_{GS}) with the increase in concentration of copper at I_{DS}=0.482μA

I_{DS}=0.037μA/decade

V_{GS} = 90mV/decade

Nernst Limit

Nernst equation

relates the potential of the sensitive ion electrode after capturing ions and the logarithm of the ion concentration in the bulk solution

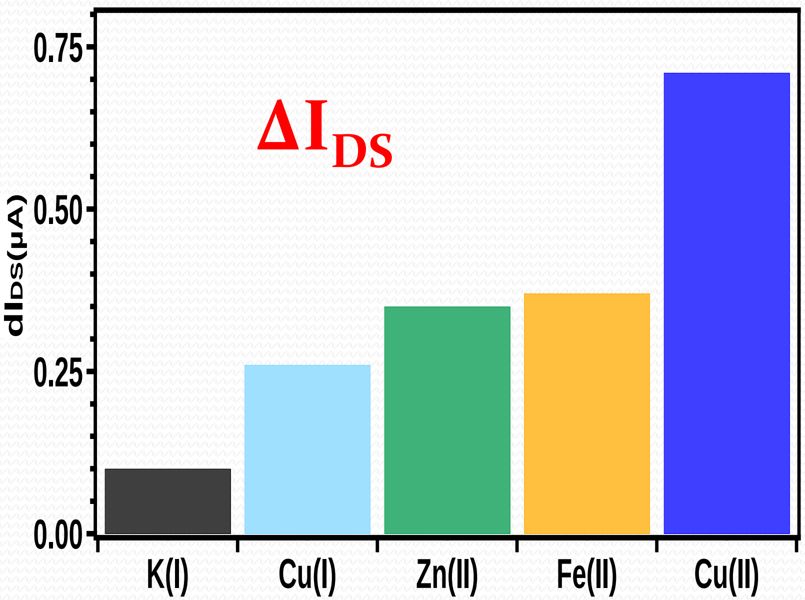
$$\Delta V = -2.3\frac{k_B T}{ze}\alpha.\Delta pl$$

ΔV : detectable change in electrochemical potential
Δpl: = -log[ion]
Z: Charge carried by the ion
k_B :Boltzmann constant
T : Temperature
e :electrical charge
α: Sensitivity parameter

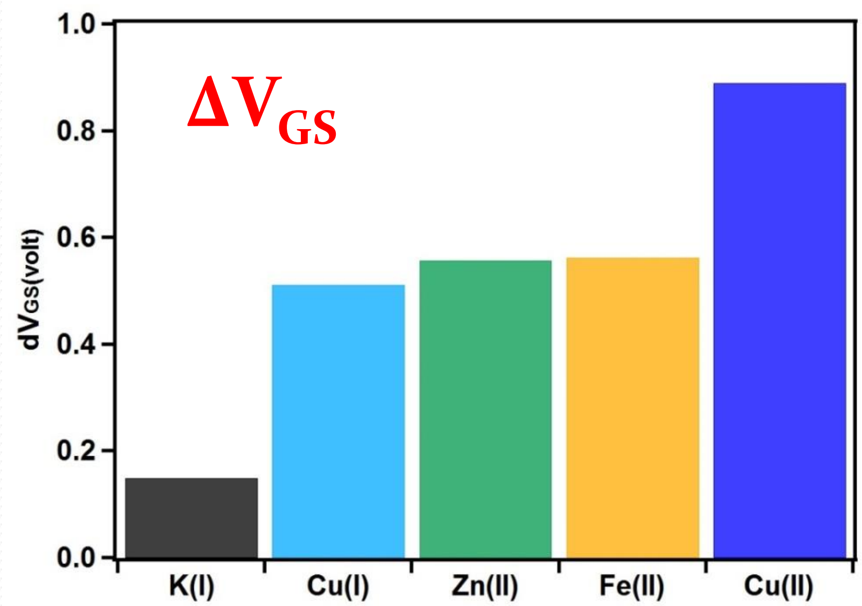
- Max detectable change in electrochemical potential according to Nernst equation for a divalent ion: ΔV=29.5mV/Decade
- Our device: ΔV=90mV/Decade

Super sensitivity exceeding Nernst limit

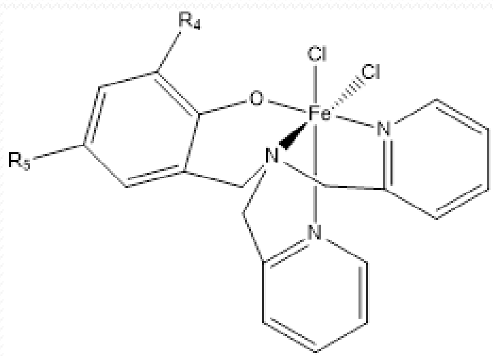
Selectivity measurements

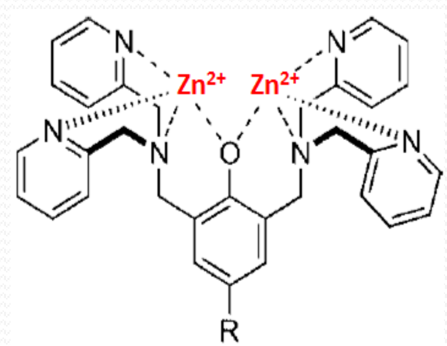


Variation of (ΔI_{DS}) for different types of ions at V_{GS}=-0.5v



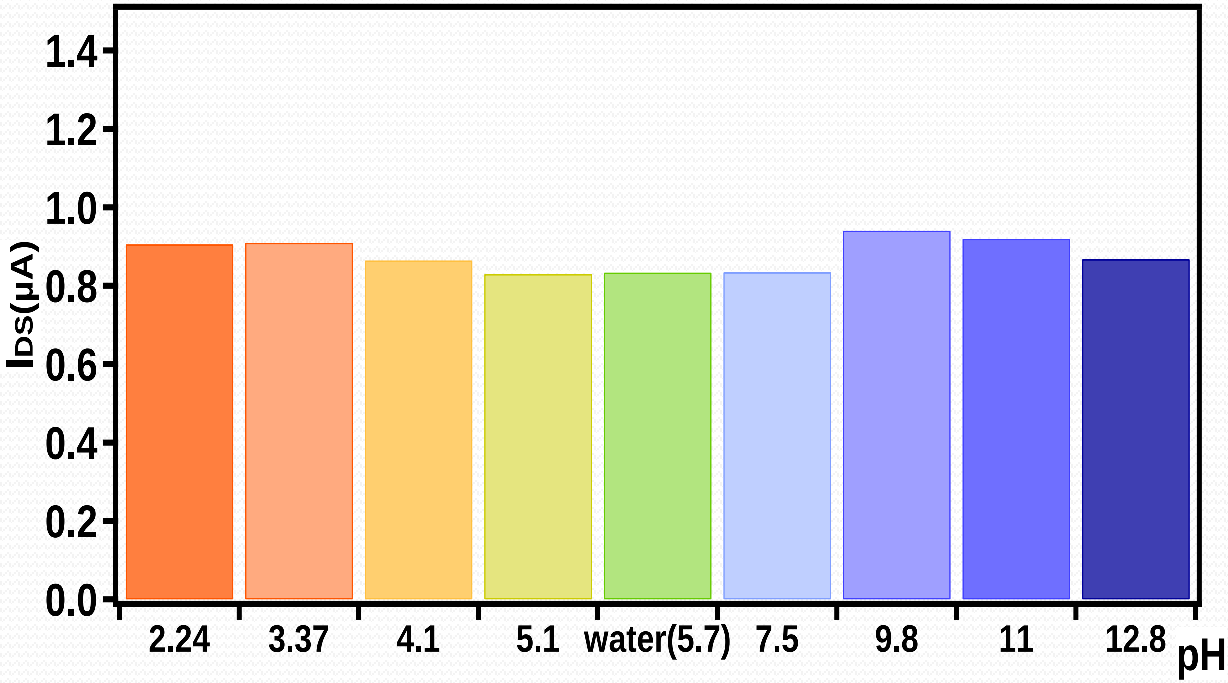
Variation of (ΔV_{GS}) for different types of ions at I_{DS}=0.6μA





pH sensitivity

❑Effect of pH change

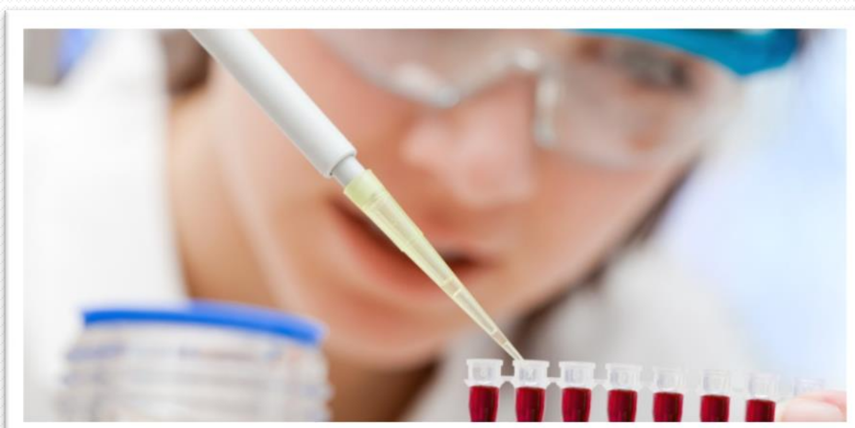


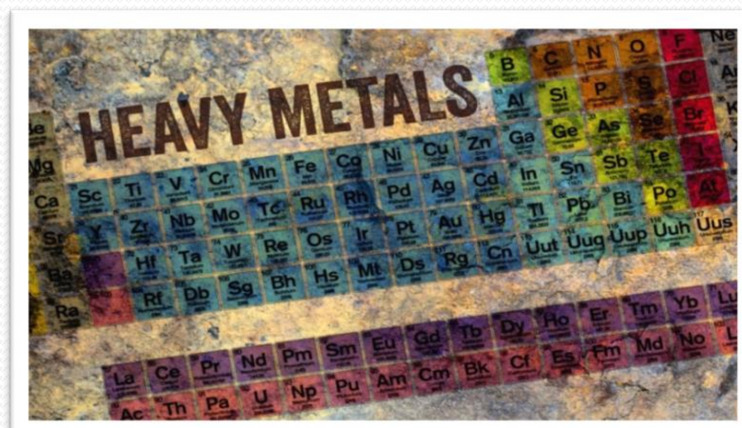
Variation of (IDS) at different pH medium ranging from highly acidic to highly basic solution at VGS=-0.5v

Conclusion and perspective

- **Fabrication of BioFET device with super high sensitivity (detection range of Cu(II) from 10^{-2}M to 10^{-18}M) that exceeds Nernst limit**
- **Reasonable Selectivity toward Cu^{2+}**
- **Very stable under pH change**

- **Medical application: Test the device with biological sample (urine, blood, …)**
- **Extend the measurements toward different ions**





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cnrs dépasser les frontières

Région
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RENATECH
French national nanofabrication network