The Cleanroom free, Cheap and Rapid Fabrication of Nanoelectrodes for Single Molecule Detection

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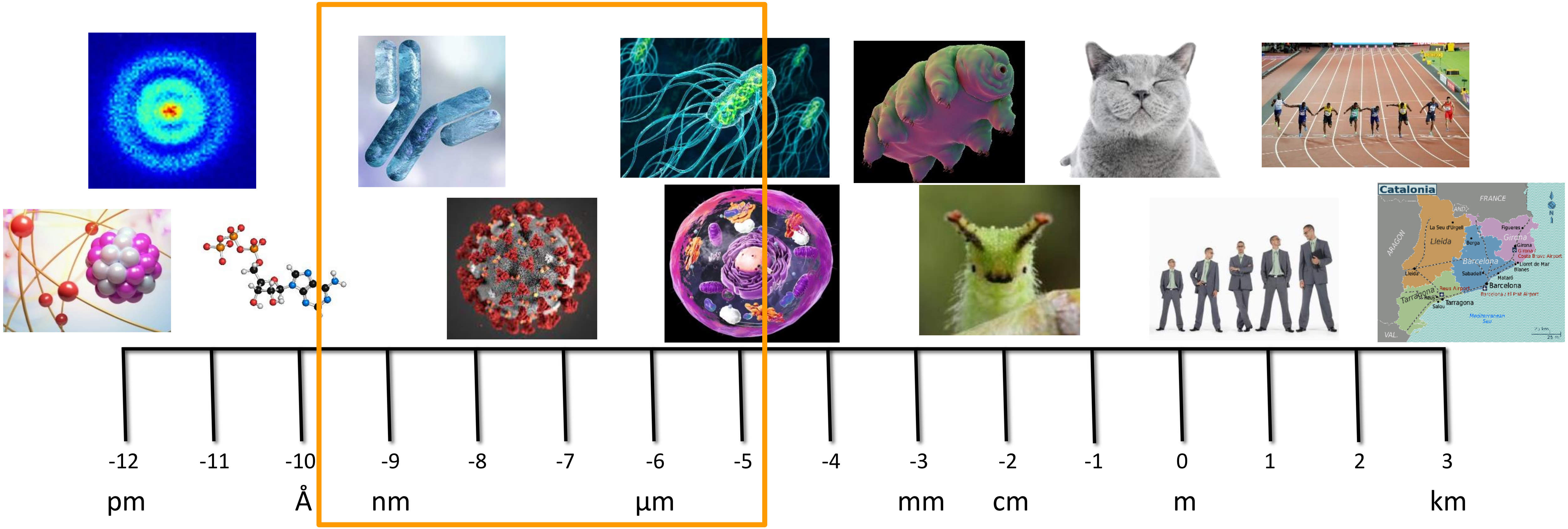
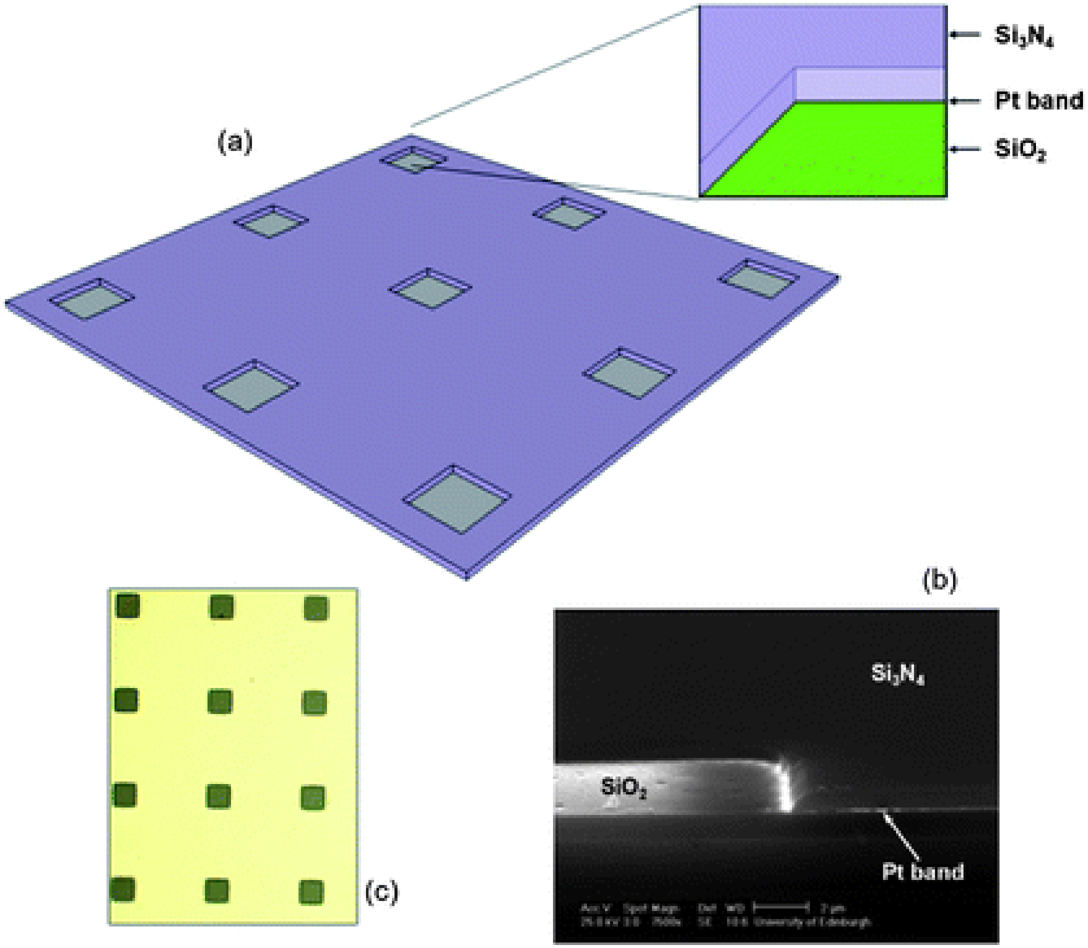
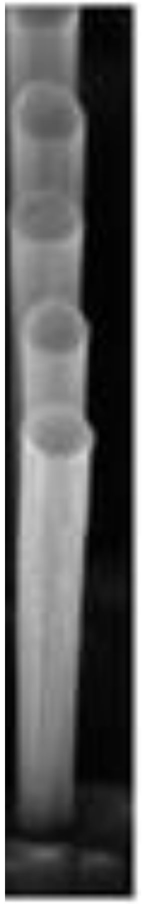
What are Nanoelectrodes?

Any electrode where at least 1 of the dimensions is on the nanoscale.



Examples of Nano - Electrodes





A. Piper, A. Mount,Electrochemical Characterisation of MicrosquareNanoband Edge Electrode (MNEE) Arrays and Their Use as Biosensors,University of Edinburgh, Edinburgh 2017.

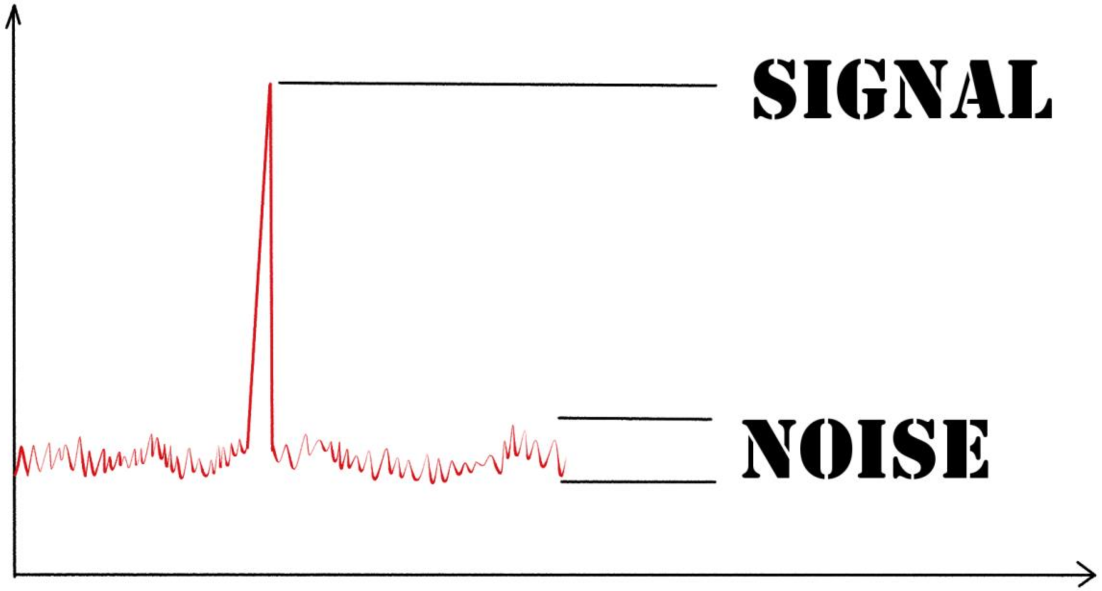
Why should I care?

no advance has changed electrochemical science to a greater degree than the advent of UMEs, which occurred principally through the independent work of Wightman and Fleischmann and their coworkers about 1980 (6, 7). These devices have extended electrochemical methodology into broad new domains of space, time, chemical medium, and methodology (6–13).

Electrochemical Methods - Fundamentals and Applns 2nd ed - A. Bard, L. Faulkner (Wiley, 2001)

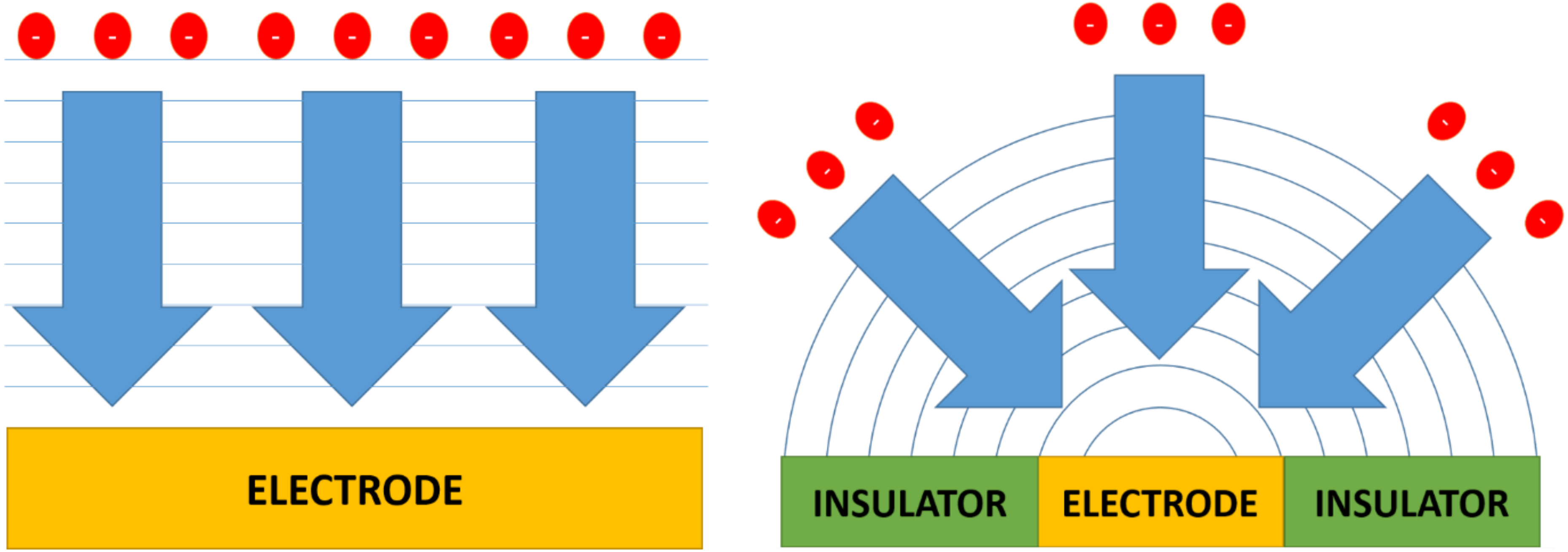
Nanoelectrodes are worth the effort!

The only commercially available POC sensors detect biomarkers present in extremely high concentrations. To detect many diseases we need more sensitive sensors. As electrodes get smaller, their signal to noise ratios improve.

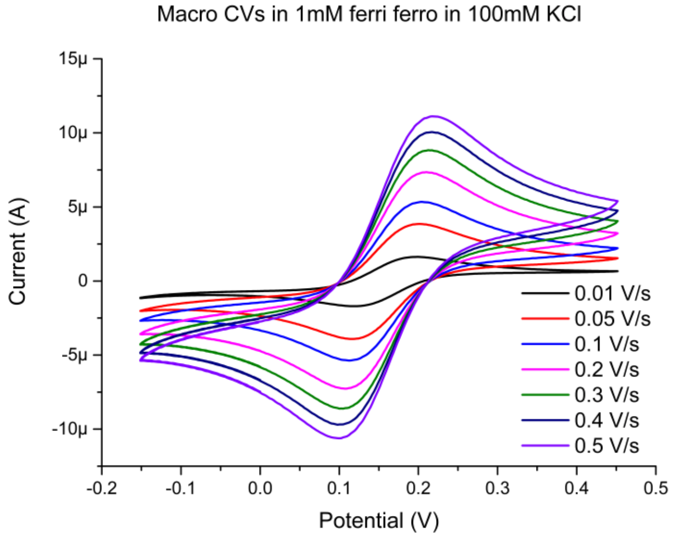


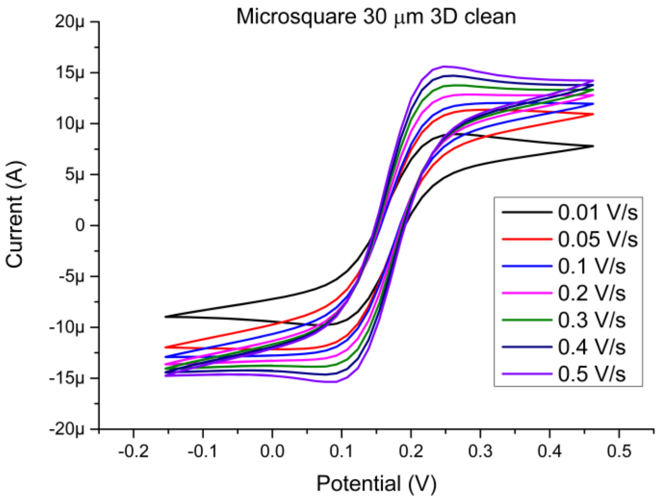
Why are Nanoelectrodes more sensitive?

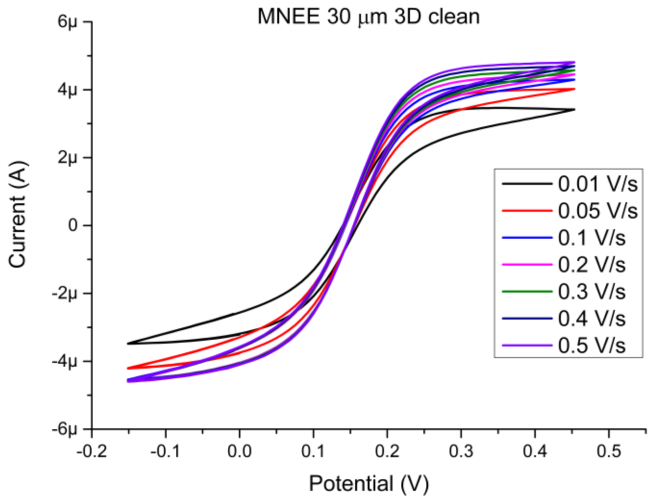
Non-linear diffussion



This difference in diffusion changes the electrochemistry







$$i = \frac{nFAD_O^{1/2}C_O^*}{\pi^{1/2}t^{1/2}} + \frac{nFAD_OC_O^*}{r_0}$$

$$i_{ss} = nFAm_0c_0$$

TABLE 5.3.1 Form of m_O for UMEs of Different Geometries

Band[a]	Cylinder[a]	Disk	Hemisphere	Sphere
$\frac{2\pi D_O}{w\ln(64D_Ot/w^2)}$	$\frac{2D_O}{r_O \ln \tau}$	$\frac{4D_O}{\pi r_O}$	$\frac{D_O}{r_O}$	$\frac{D_O}{r_O}$

[a] Long-time limit is to a quasi-steady state.

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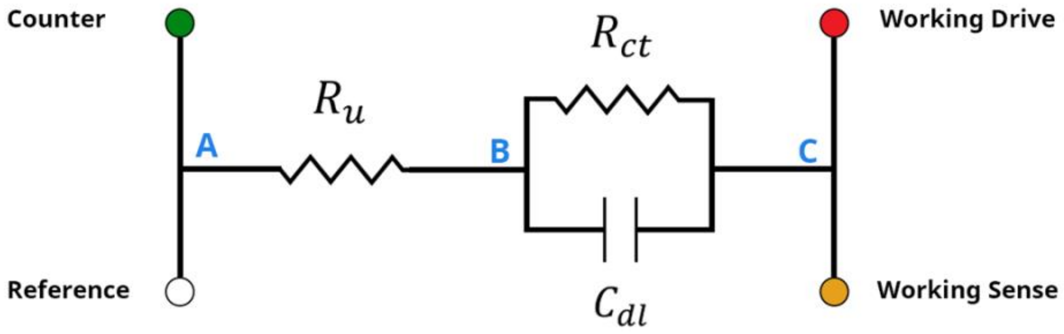
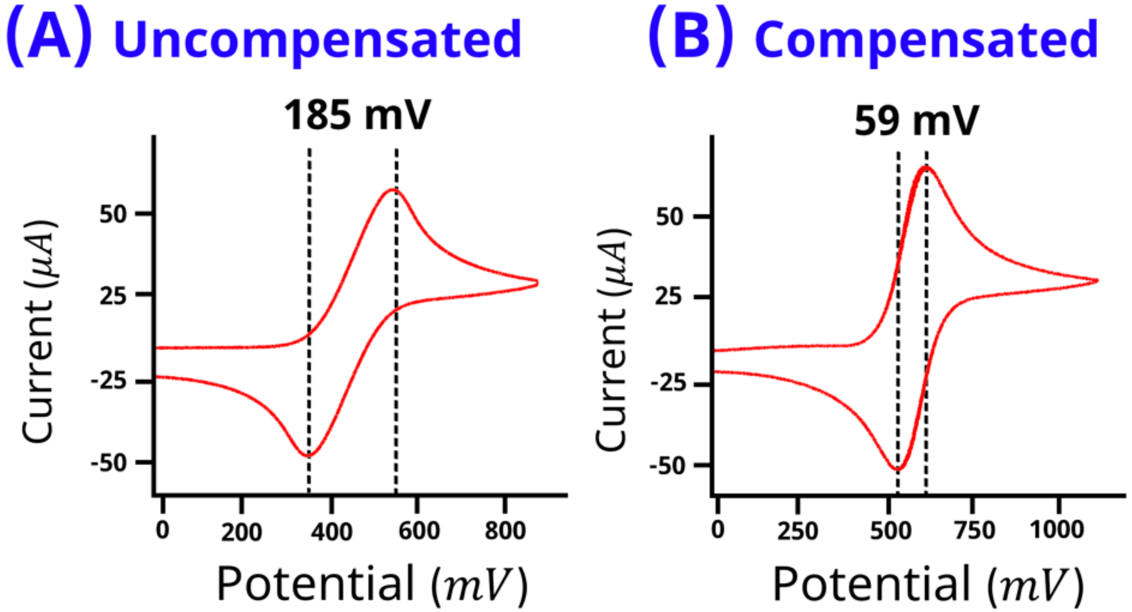
Smaller iR Drop (R_s)

The iR drop decreases as the electrode area decreases. This means a greater proportion of the signal we measure comes from Rct, and iR drop corrections are seldom required.





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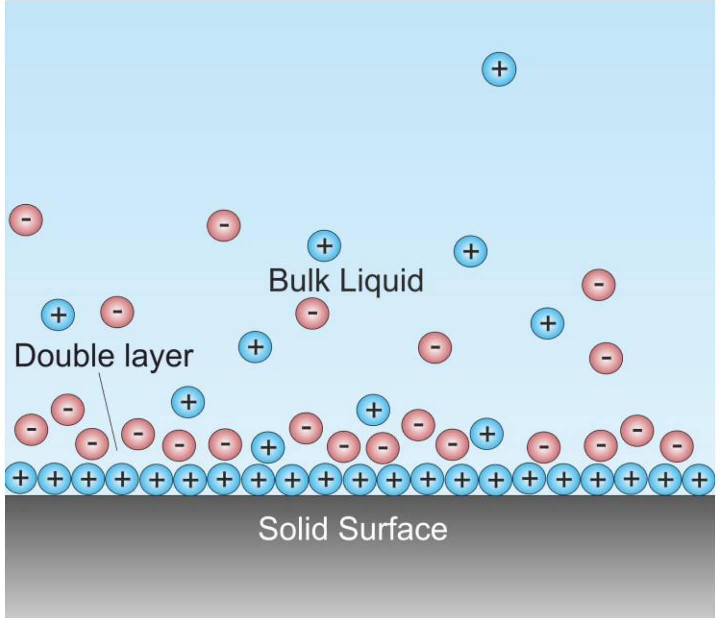
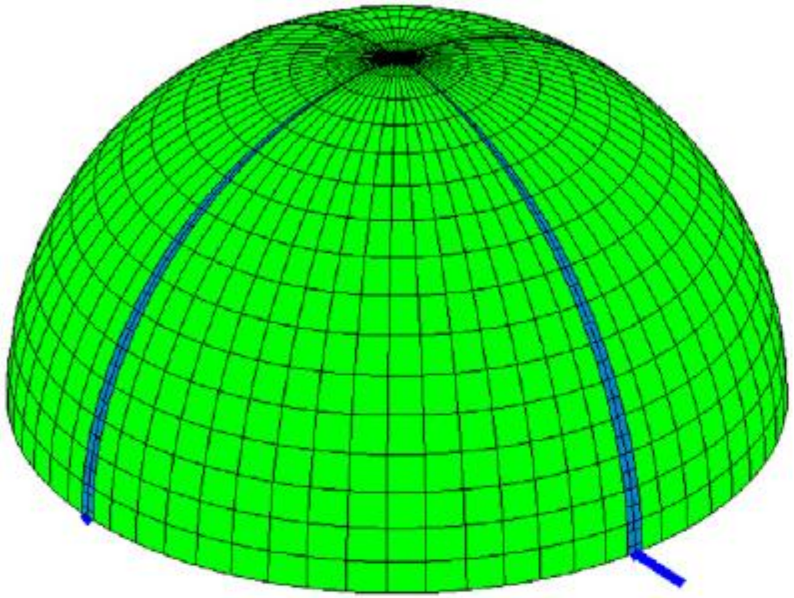
The Capacitance Double Layer (C_{dl})

As the double layer scales with area, the smaller the electrode the less double layer charging that we get. Therefore a greater proportion of the current we measure is Faradaic:

$$Total\ current\ measured = \uparrow (Faradaic) + \downarrow (Non - Faradaic)$$





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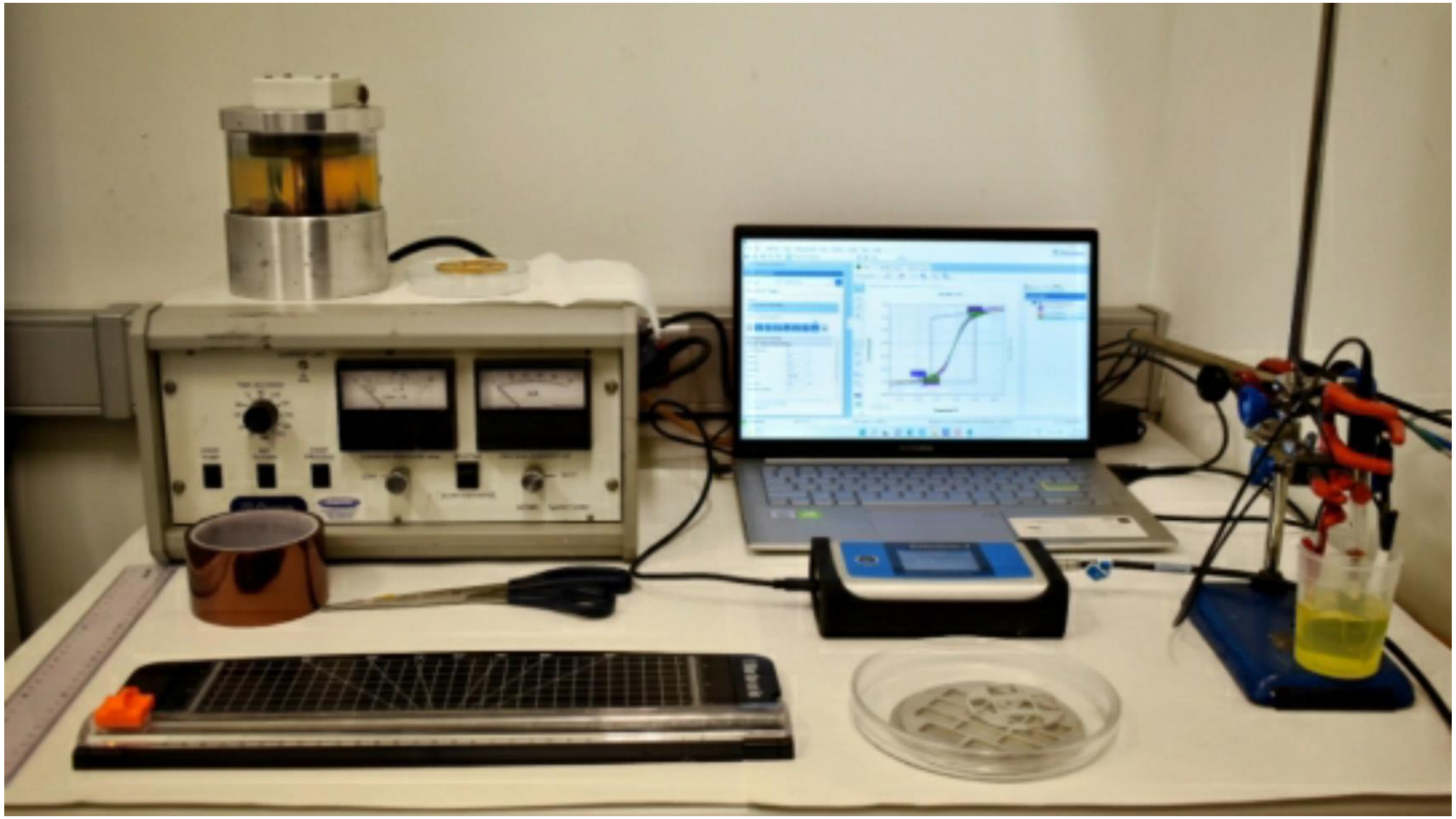
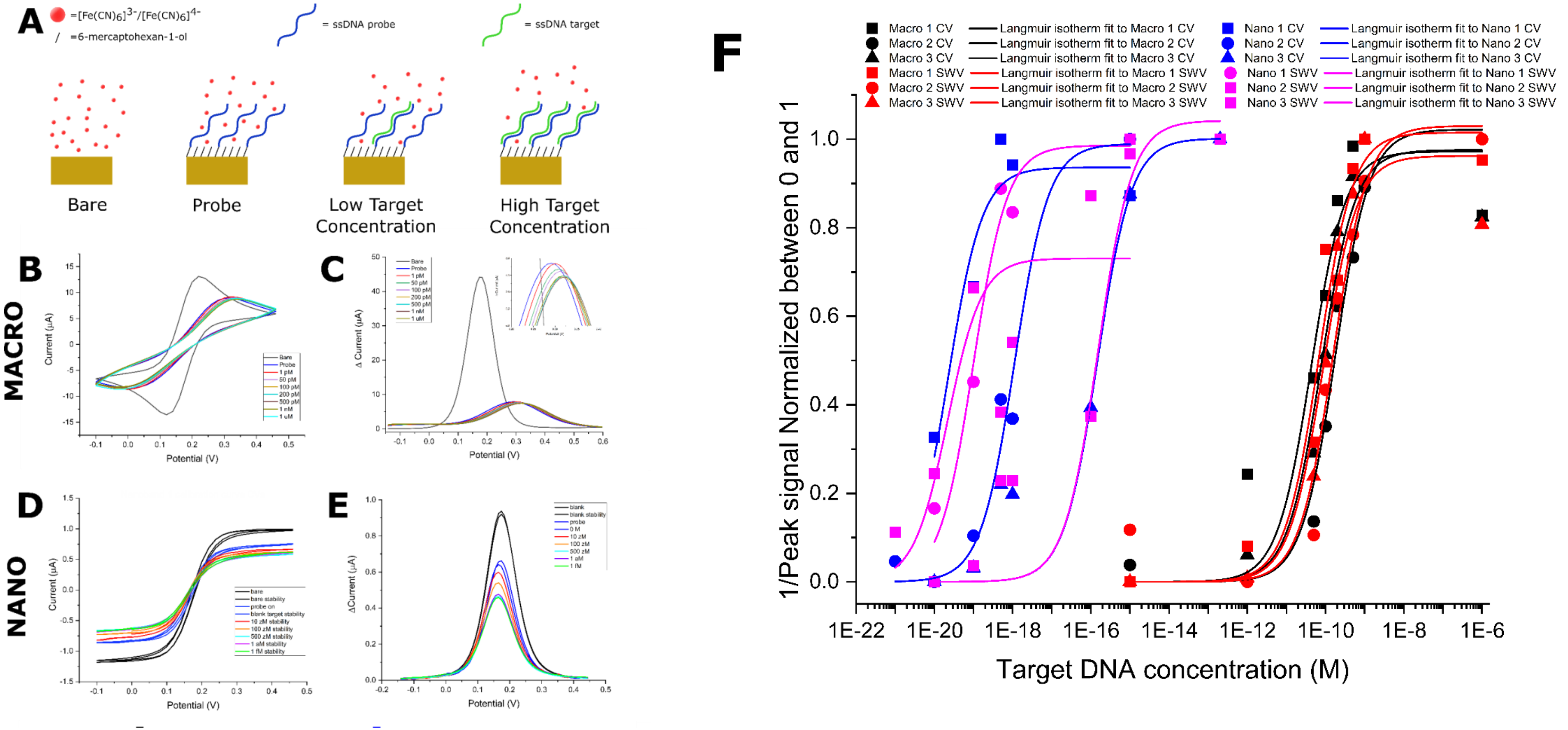
If nanoelectrodes are more sensitive, why are they not more commonly used?

Low cost nanoband electrodes



Maroli, G., Abarintos, V., Piper, A., Merkoçi, A., The Cleanroom-Free, Cheap, and Rapid Fabrication of Nanoelectrodes with Low zM Limits of Detection. *Small* 2023, 2302136.

Proof of concept, Covid-19 detection?



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Conclusions and Future Outlook

The enhanced sensing performance of Nanoelectrodes, coupled to their small size allowing their integration into various nanotechnological applications, means that they will be a part of the future world of sensing.

Over the last 40 years most of the fundamental groundwork in nanoelectrode development and understanding has been achieved. Going forward there are still a few unanswered fundamental questions, but mostly there is a requirement for large scale, reproducible low cost manufacturing methods, as well as development to address unmet applications.

ICN2 Institut Català de Nanociència i Nanotecnologia

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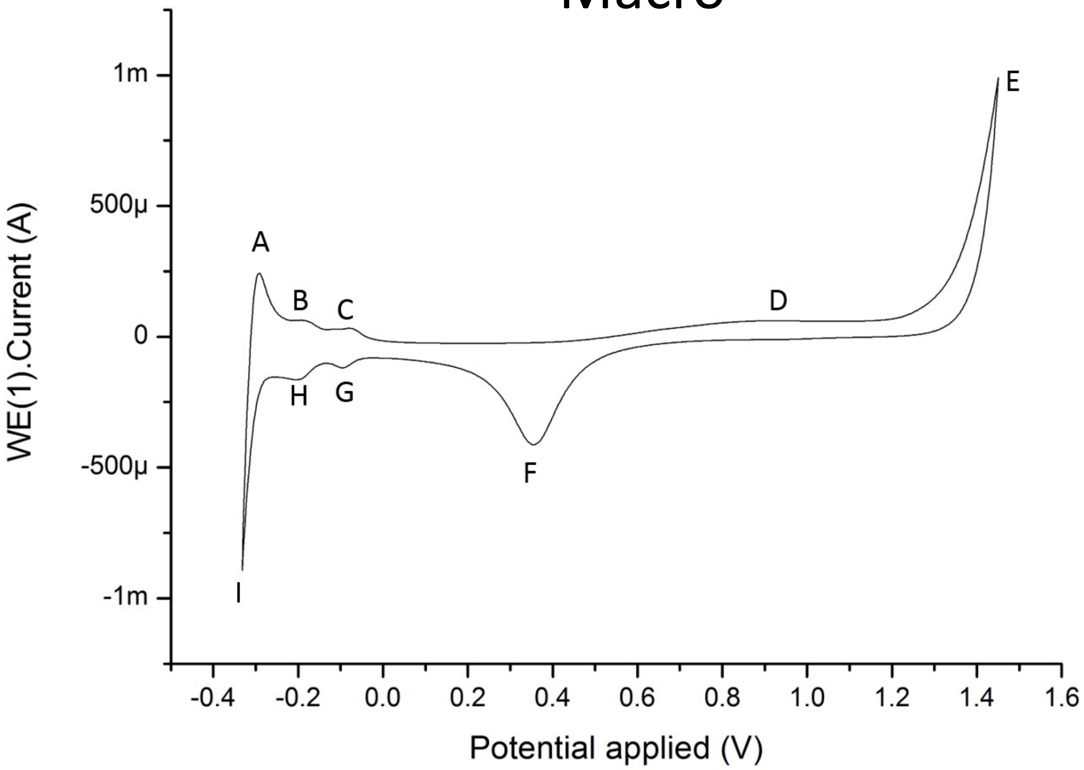
Thank you for listening

Quantifying electrode cleanliness

Macro



Nano