

Deconvolution in Scanning Electrochemical Microscopy

Dr. András Kiss

Department of General and Physical Chemistry
University of Pécs, Hungary



Center for Integrative Physiology
and Molecular Medicine
Universität des Saarlandes, Homburg, Germany



Center for Integrative Physiology
and Molecular Medicine

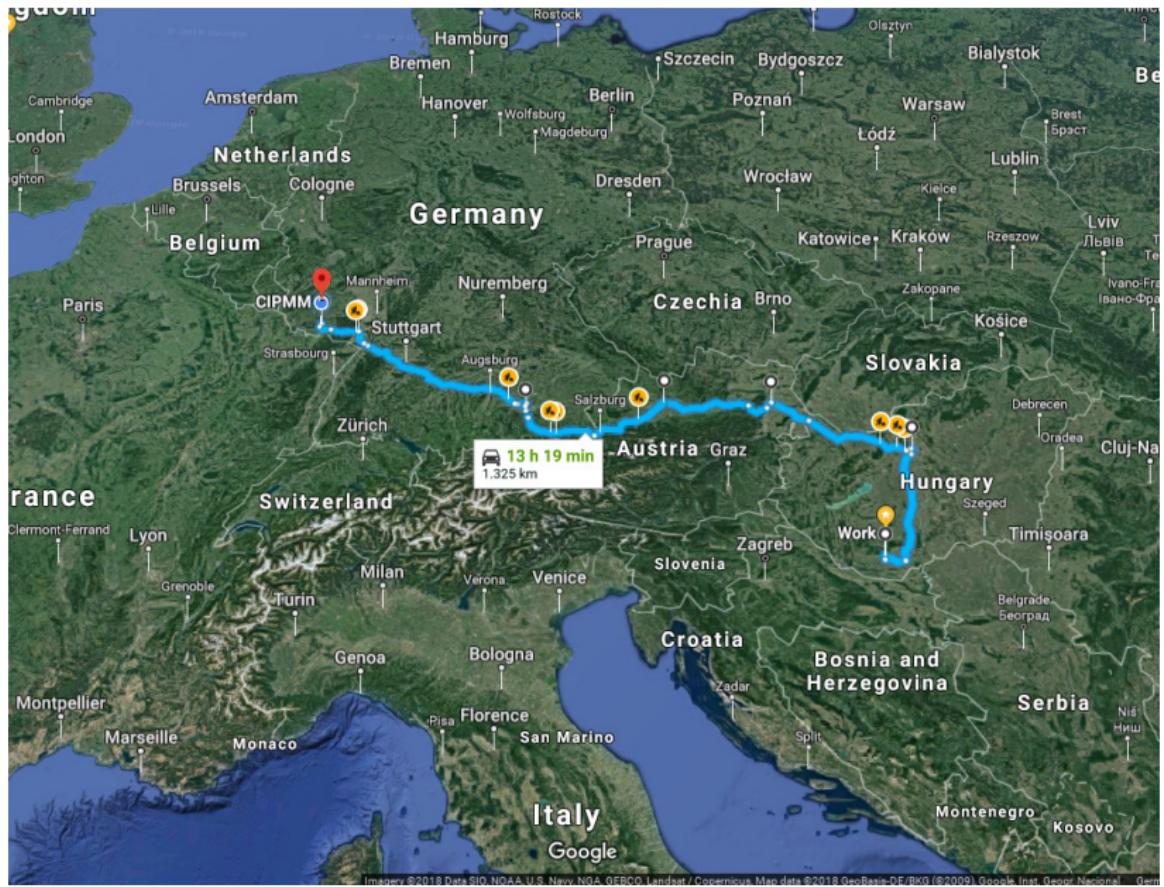
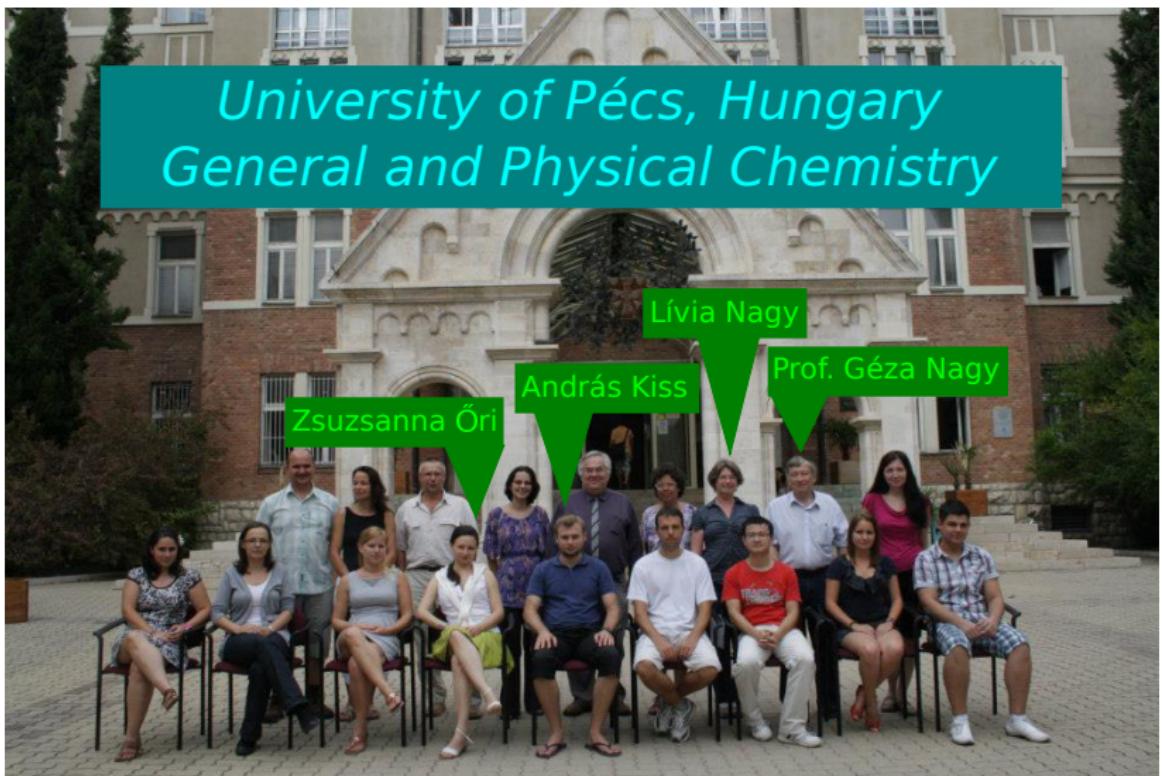


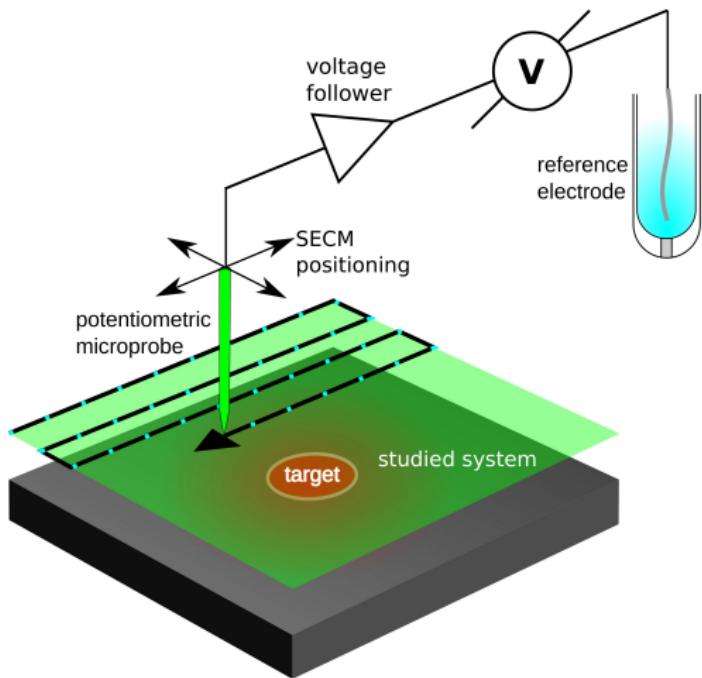
Image courtesy of NOAA/NESDIS/NGDC. Last updated: 2018-06-20T12:00:00Z

University of Pécs, Hungary General and Physical Chemistry

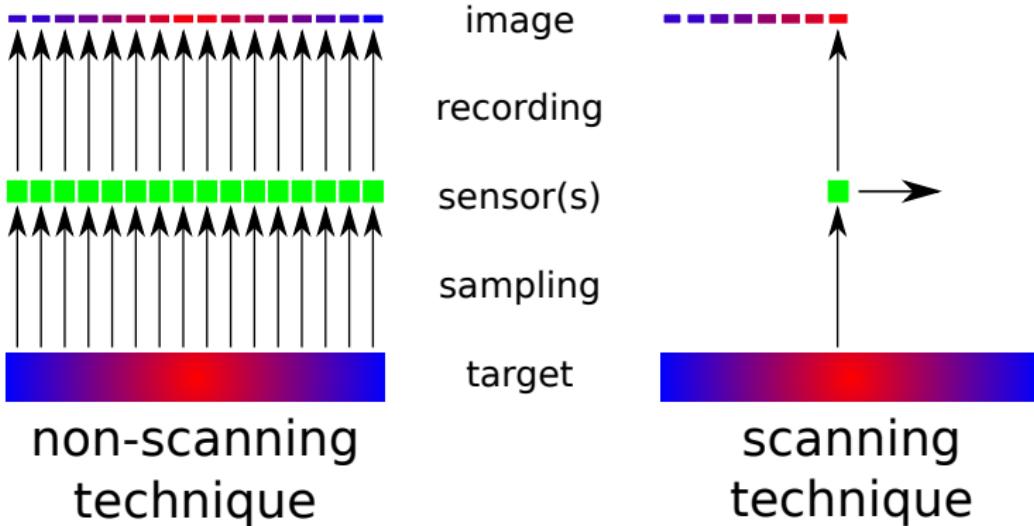


Potentiometric Scanning Electrochemical Microscopy

A Scanning Probe Microscopic technique

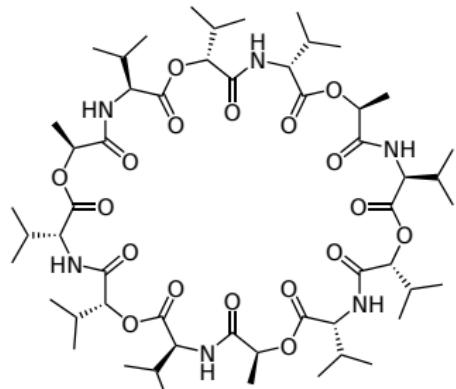
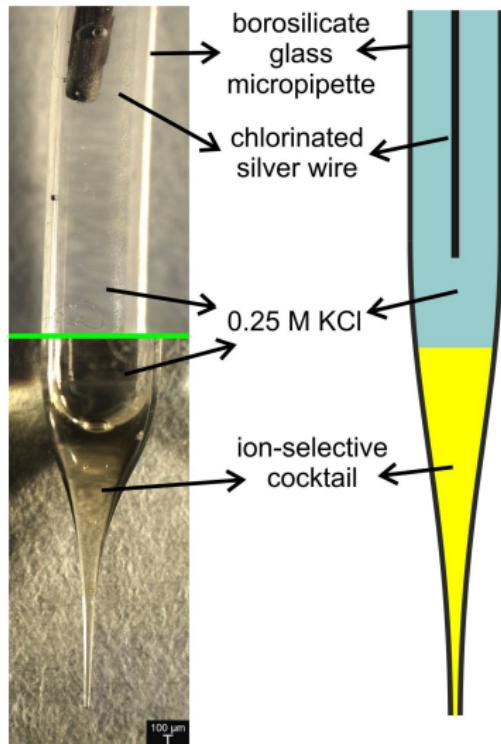


Difference between conventional and scanning microscopic techniques



Ion-selective micropipettes

As SECM probes



Valinomycin

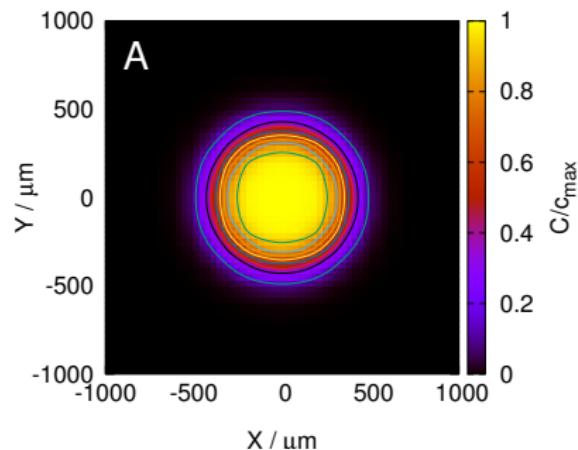
$$E = E^\theta + \frac{RT}{z_i F} \ln \left[a_i + \sum_j \left(k_{ij} a_j^{z_i/z_j} \right) \right]$$

Nikolsky-equation

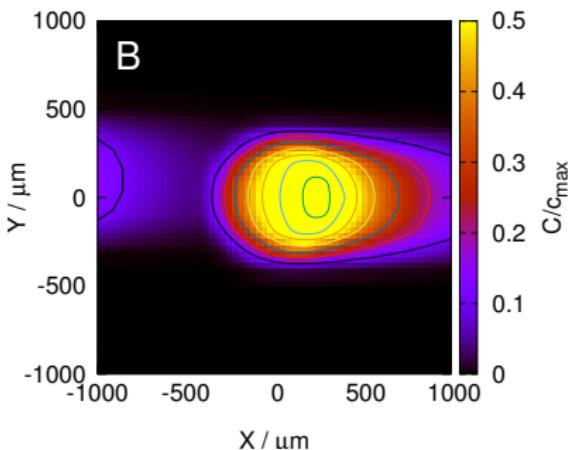
The problem with potentiometric SECM

Distortion at high scan rate

Slow

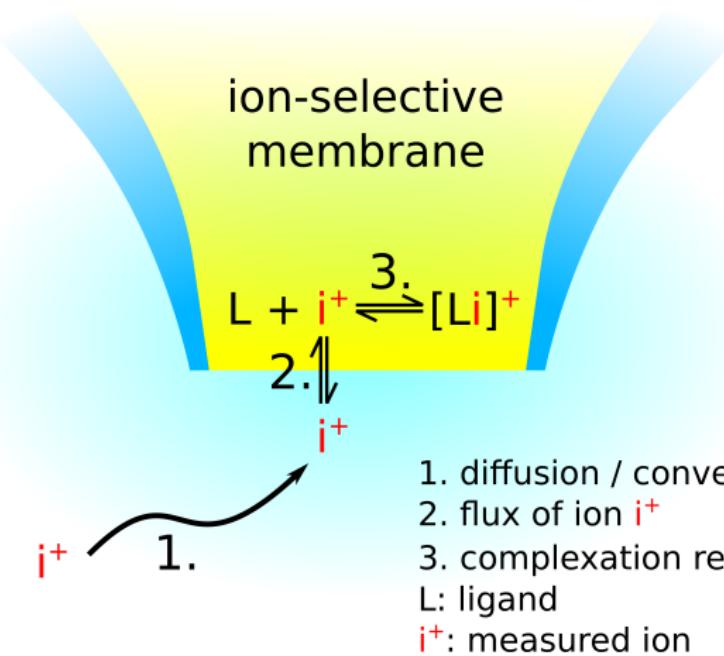


Fast



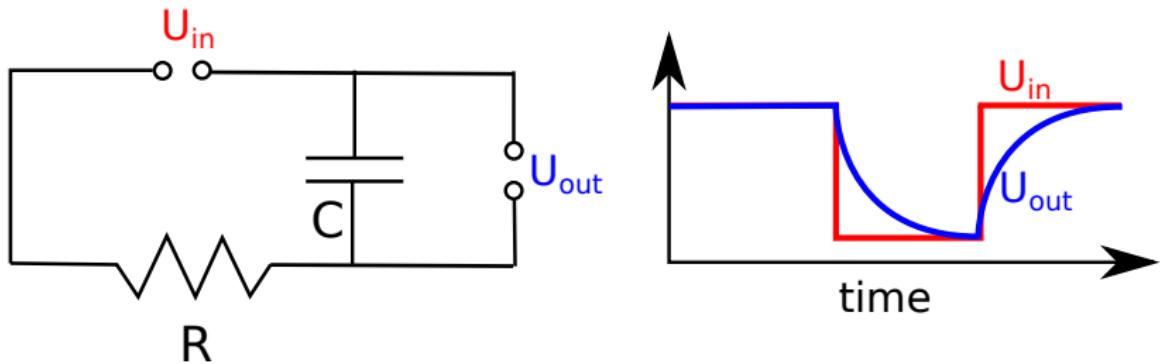
Why is the image distorted?

Possible contributors to the lag



Why is the image distorted?

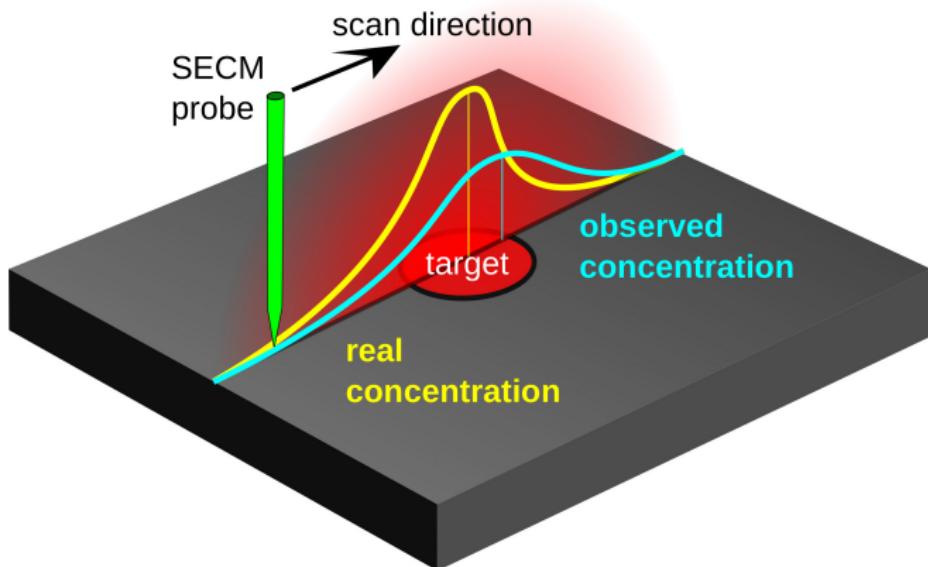
The RC time constant



τ is the time that is required to charge
the capacitor by $\approx 37\%$ ($1/e$).

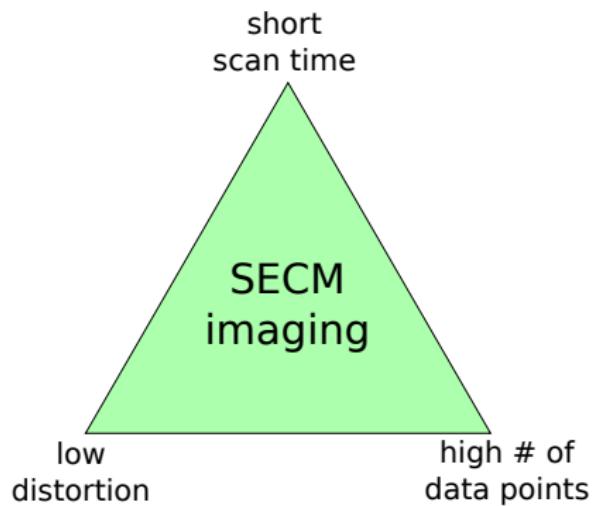
Distortion of potentiometric imaging

In the case of a linescan

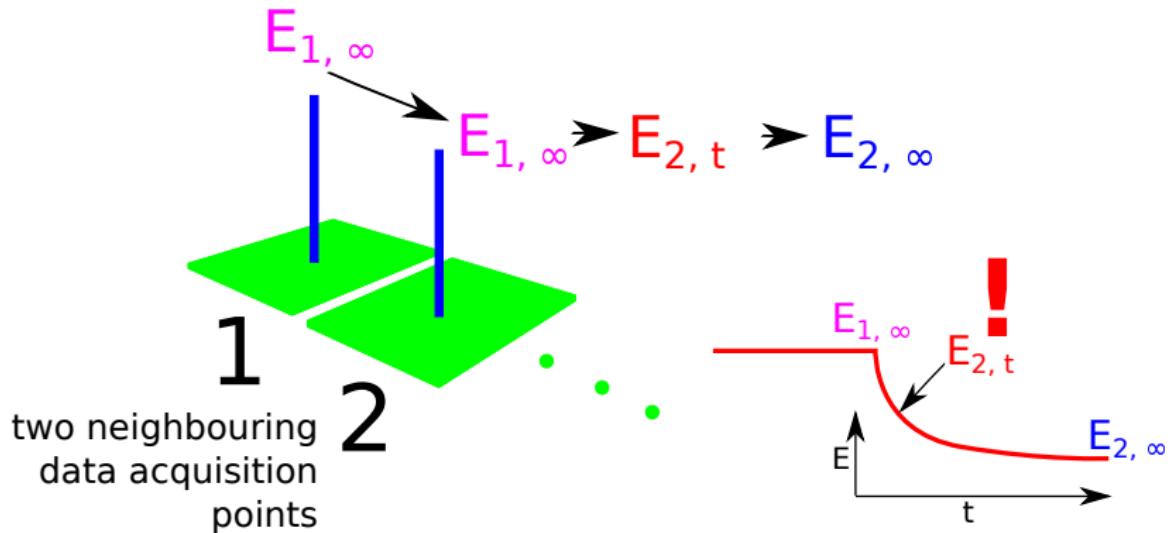


Trade-off triangle of potentiometric SECM

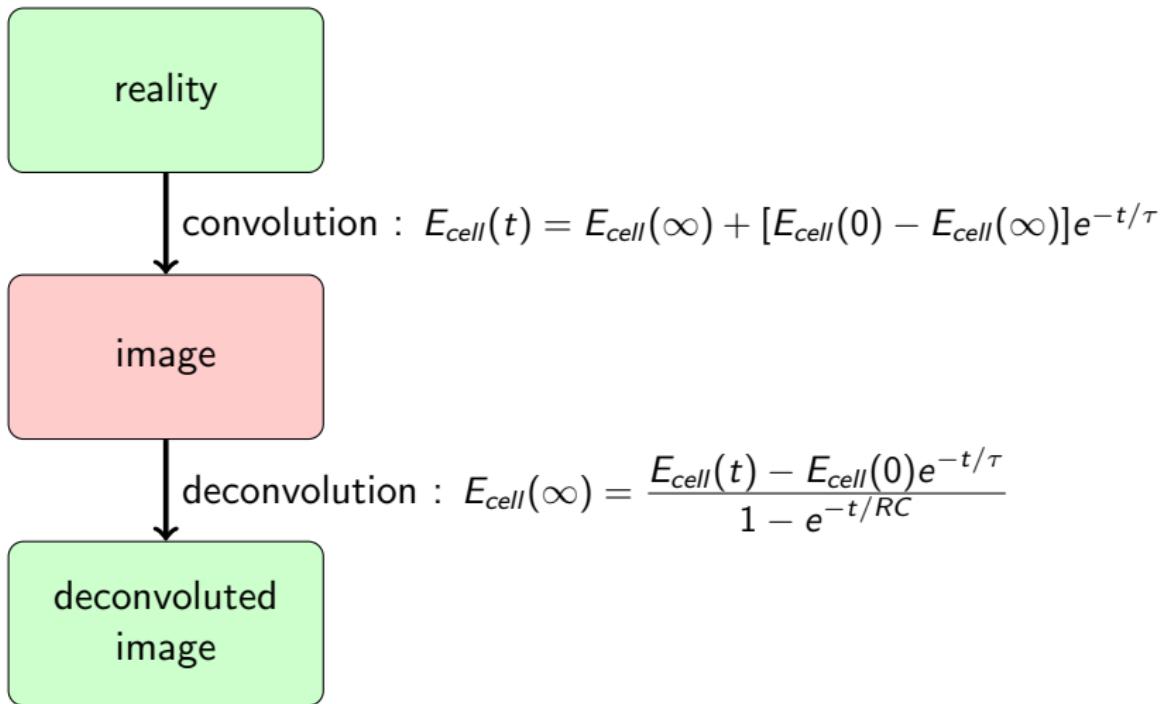
Compromise between the three desired competing properties



The convolution function of the distortion

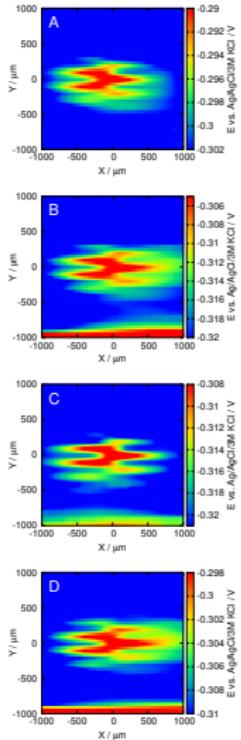


Convolution and deconvolution

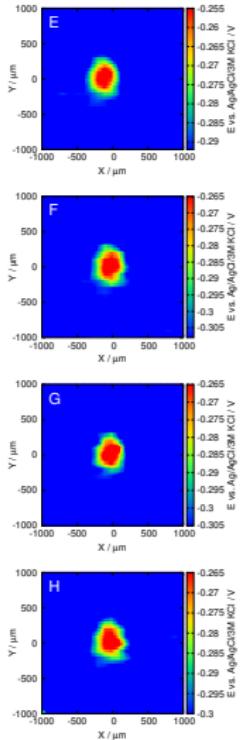


Deconvolution of potentiometric SECM images

Recorded using the antimony microelectrode following the meander algorithm

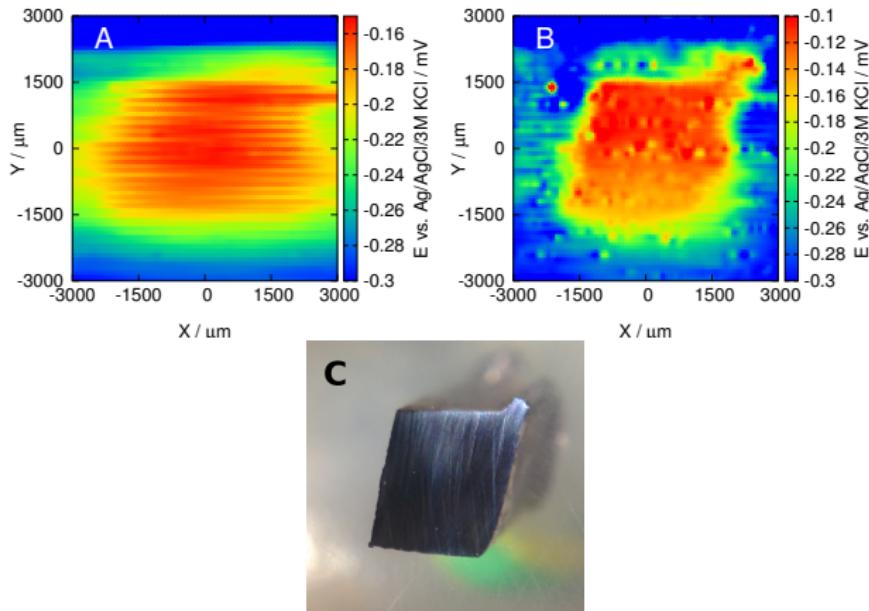


deconvolution
→



Practical example: corroding carbon steel sample

Scanned with an antimony microelectrode



9th Workshop on Scanning Electrochemical Microscopy and Related Techniques

Warsaw, Poland, August 13-17, 2017.



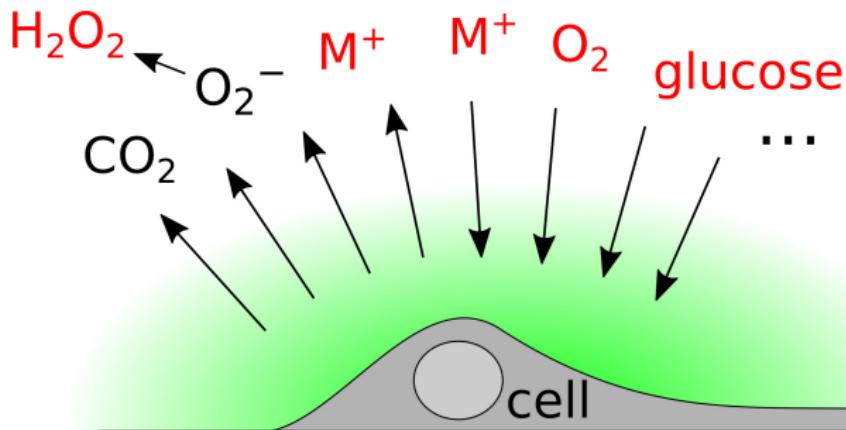
Can it be done with amperometric SECM images?

DAAD

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Why would you want to do SECM imaging of a cell?

It's an easy way to make real-time, selective, non-invasive, high resolution, single cell experiments



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Mary Ann Liebert, Inc.
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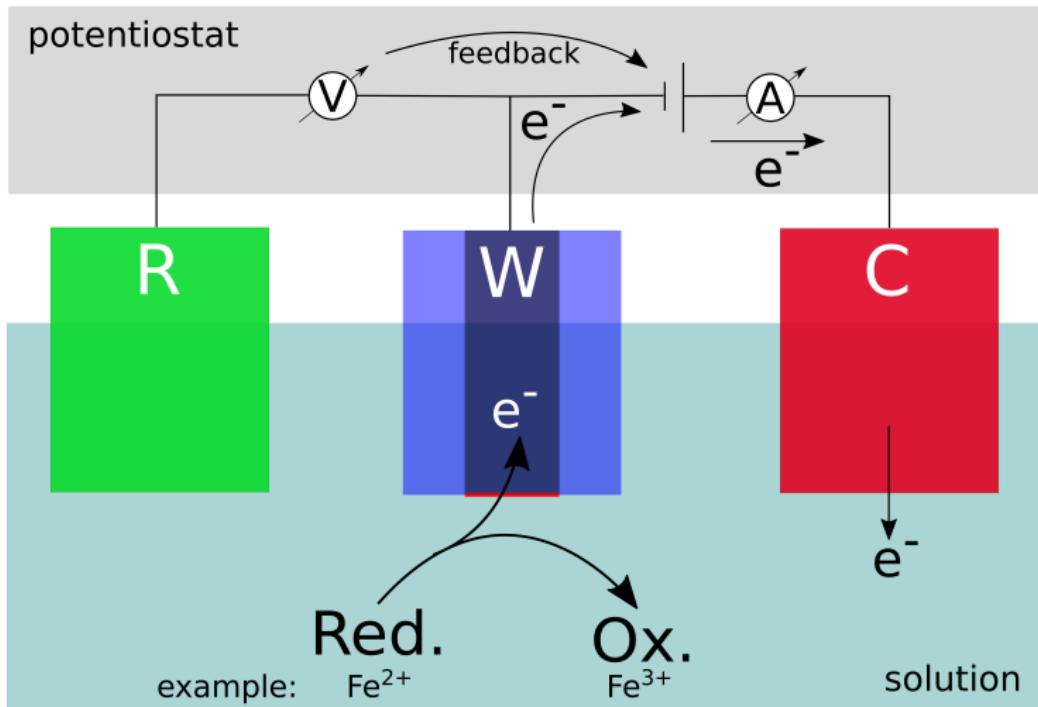


FORUM ORIGINAL RESEARCH COMMUNICATION

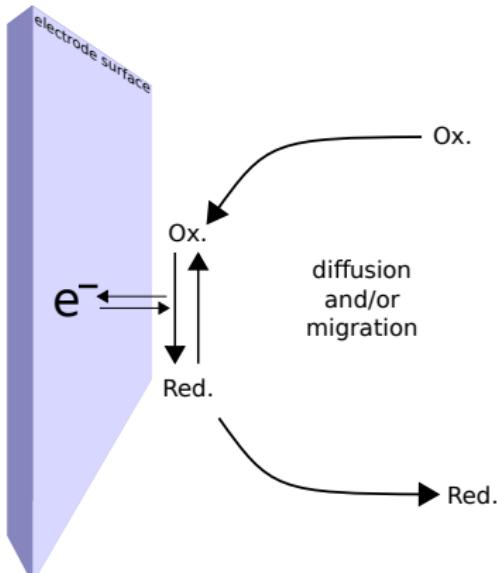
Electrochemical Quantification of Extracellular Local H_2O_2 Kinetics Originating from Single Cells

Monika Bozem,¹ Philip Knapp,¹ Valentin Mirčeski,² Ewa J. Słowiak,¹ Ivan Bogeski,^{1,3} Reinhard Kappi,¹ Christian Heinemann,⁴ and Markus Hoth¹

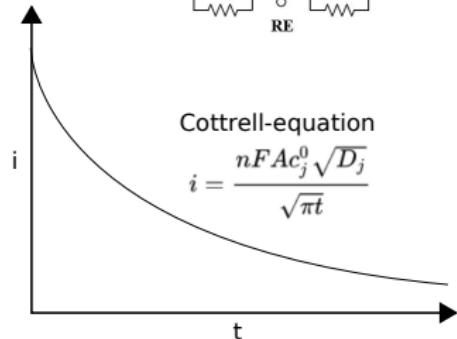
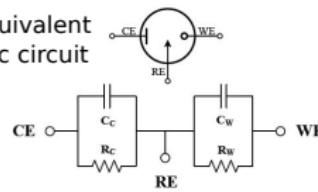
The amperometric measuring cell



Amperometric transient response

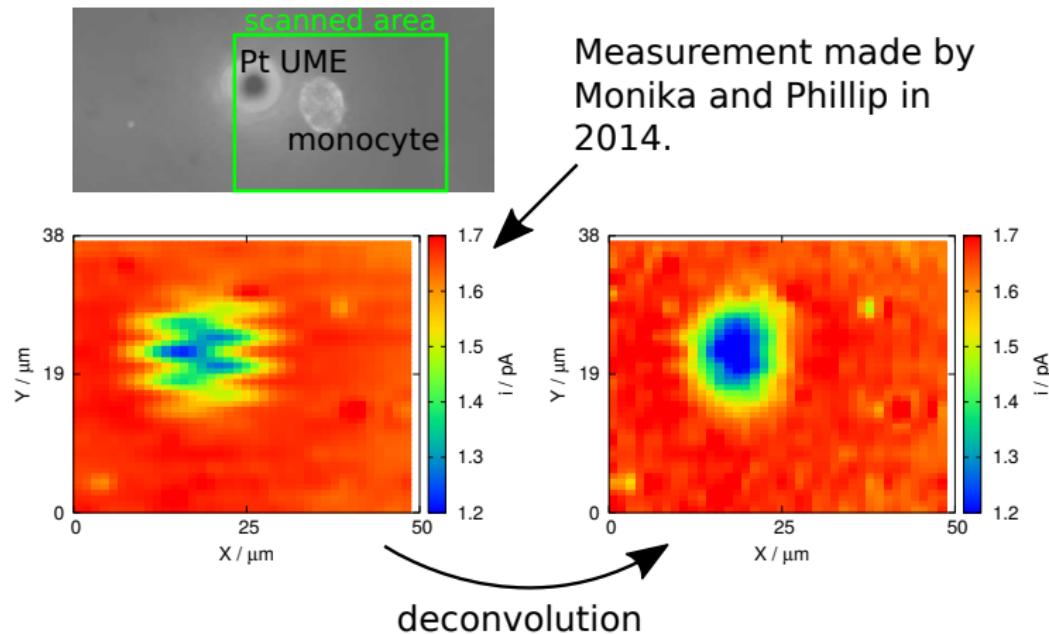


Simplified equivalent amperometric circuit

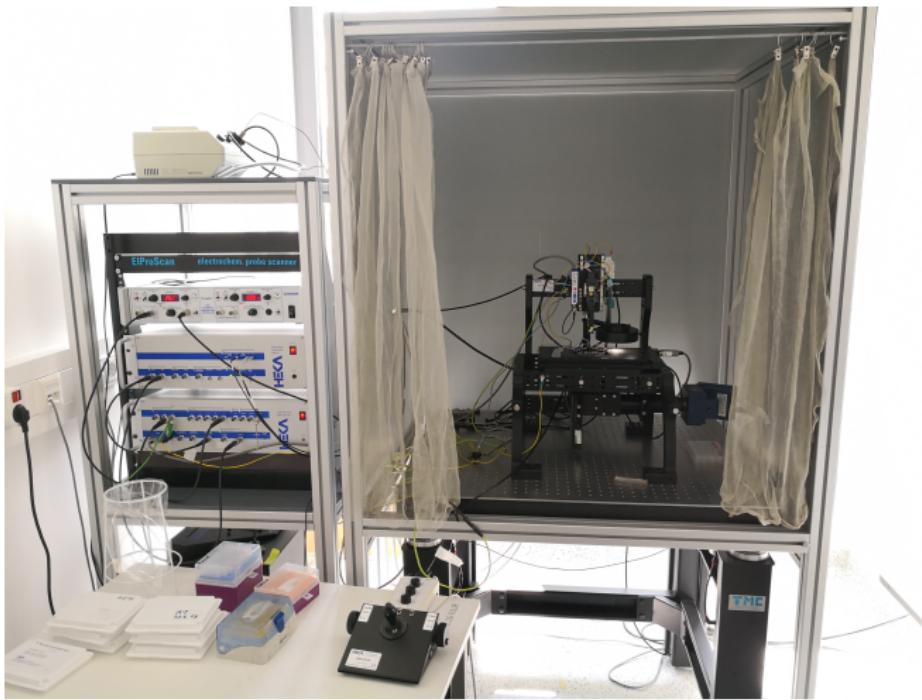


Deconvolution of an amperometric image.

H_2O_2 oxidation current above a monocyte exposed to extracellular H_2O_2 (10 μM).

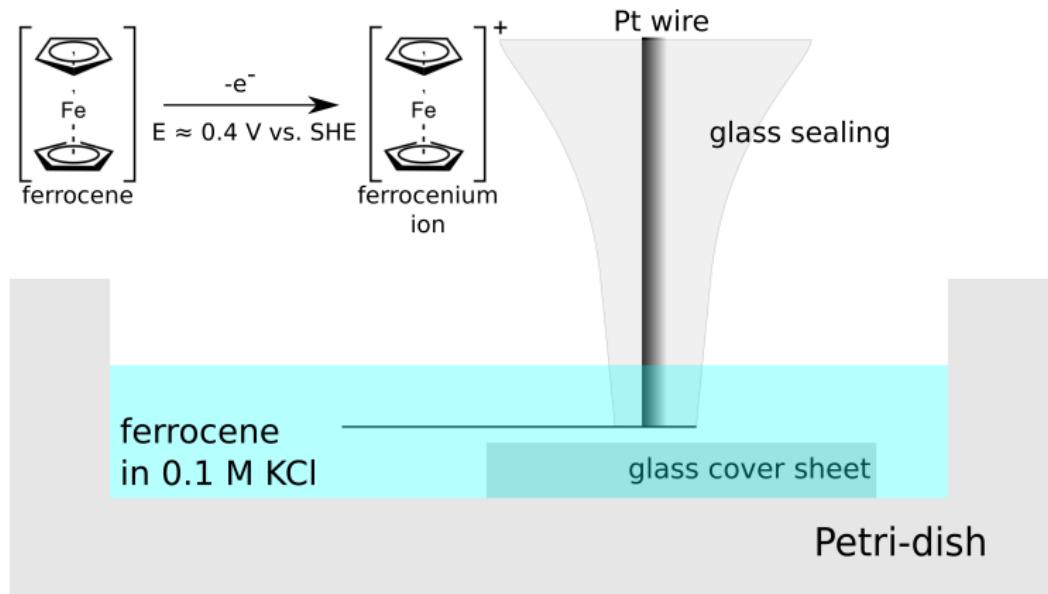


The HEKA ElProScan.



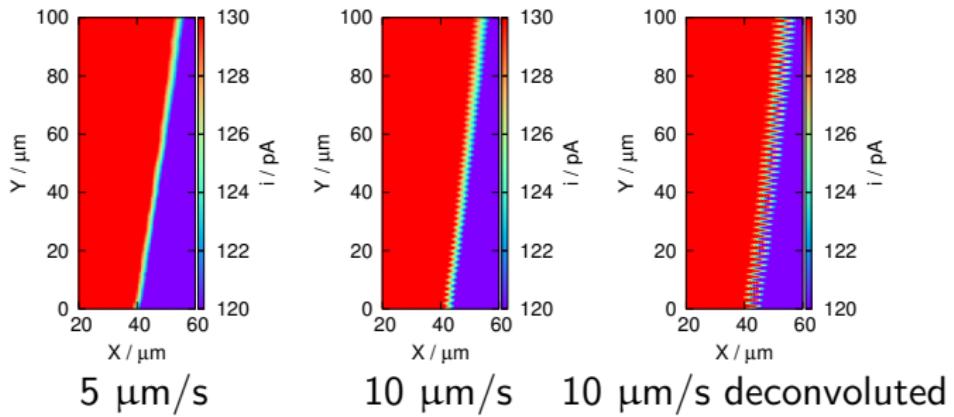
Investigating a step response over a glass sheet edge.

With the ferrocene/ferrocenium system.



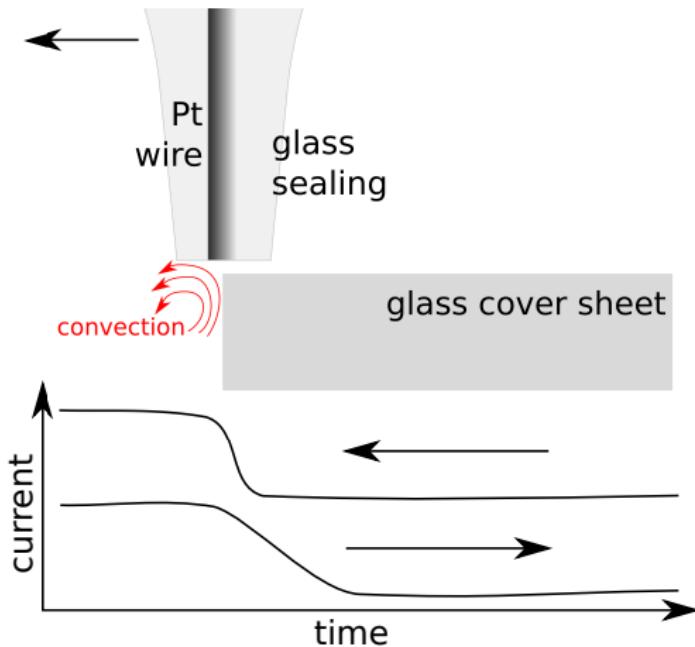
Investigating a step response over a glass sheet edge.

Results.



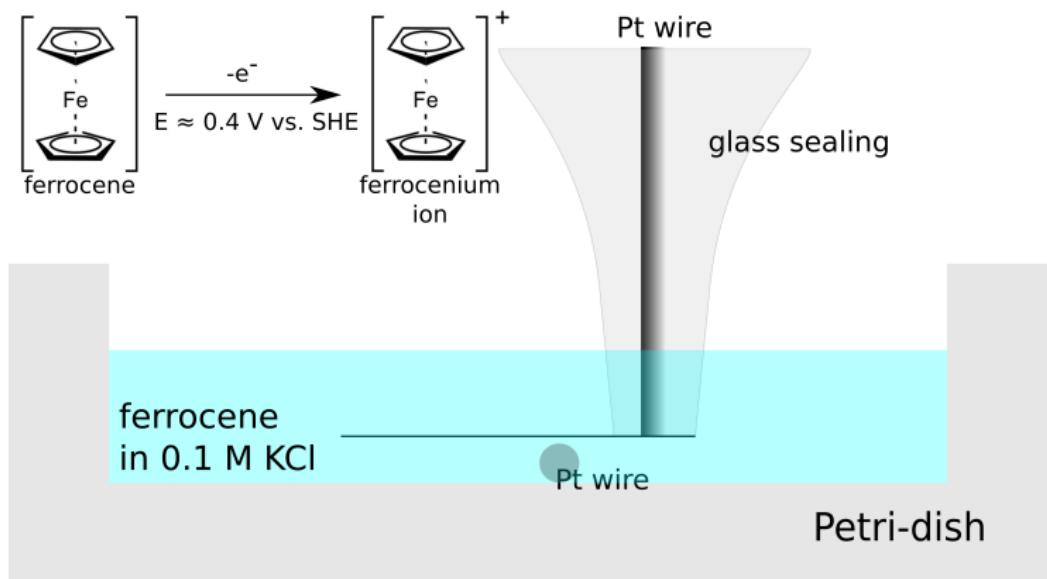
Investigating a step response over a glass sheet edge.

Discrepancy caused by convection.



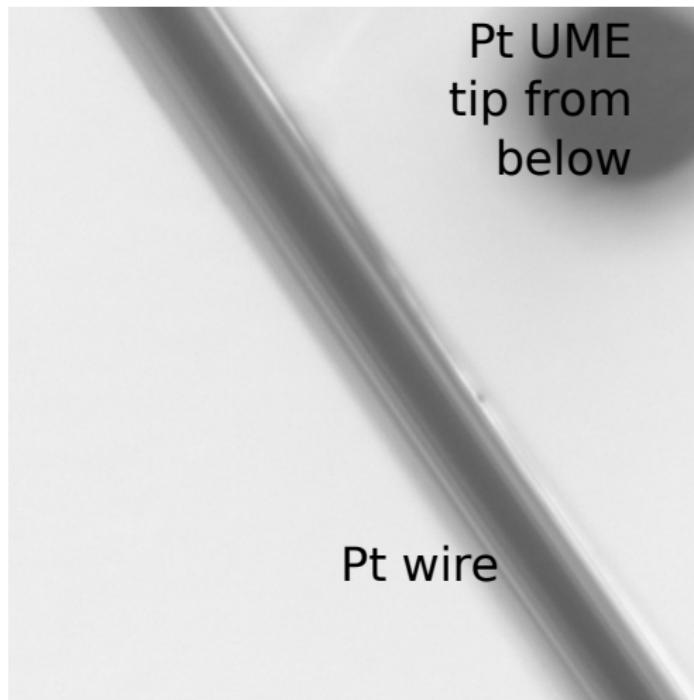
Investigating a step response over a $d = 10 \mu\text{m}$ Pt wire.

With the ferrocene/ferrocenium system.



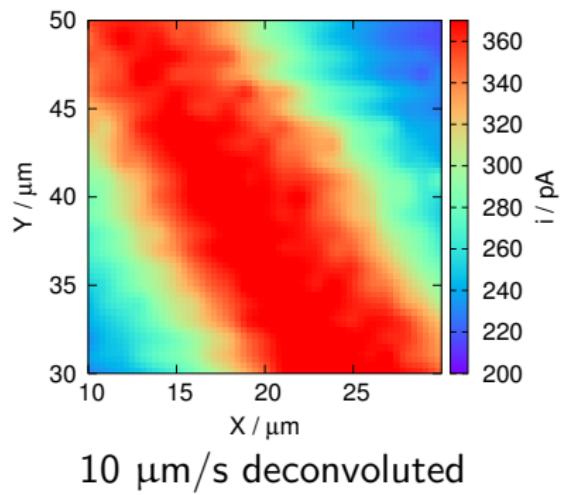
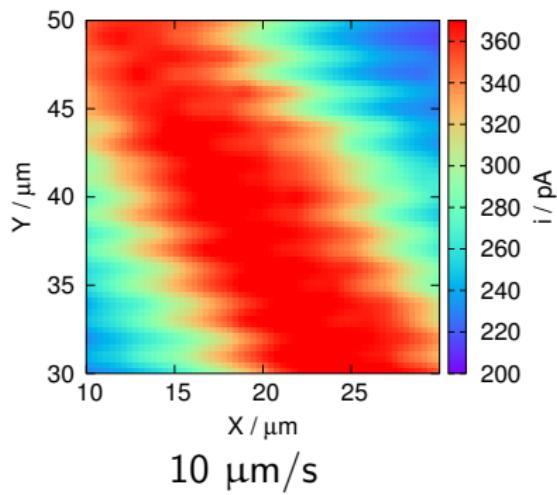
Investigating a step response over a $d = 10 \mu\text{m}$ Pt wire.

Microphoto of the model system from below.



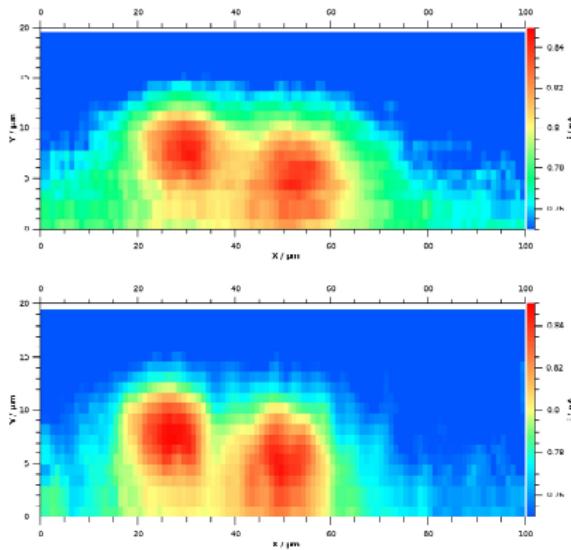
Investigating a step response over a $d = 10 \mu\text{m}$ Pt wire.

Results.



H_2O_2 measurement over TPA stimulated monocytes.

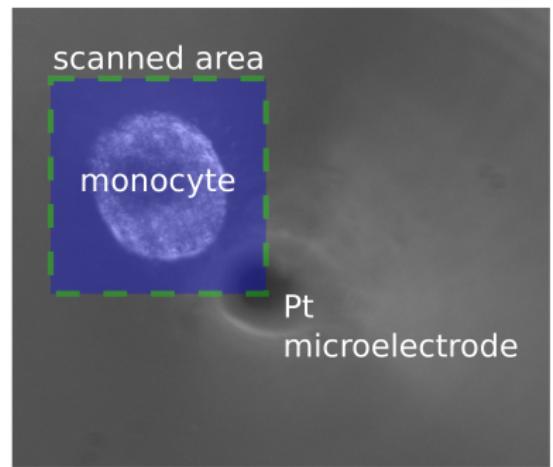
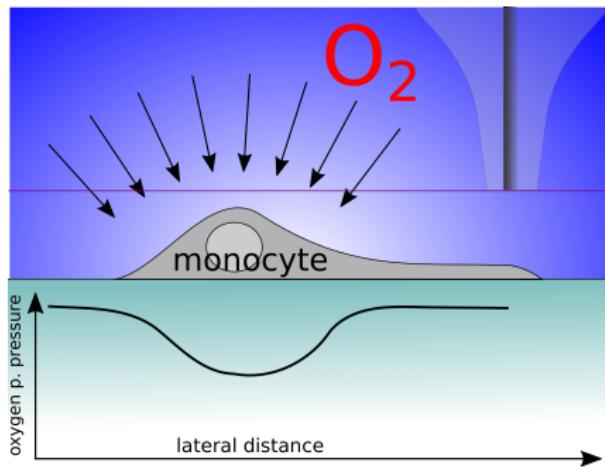
Results.



Top image: original measurement, made by Monika in 2014.
Scanning speed was 2 $\mu\text{m}/\text{s}$. Bottom image: deconvoluted image.

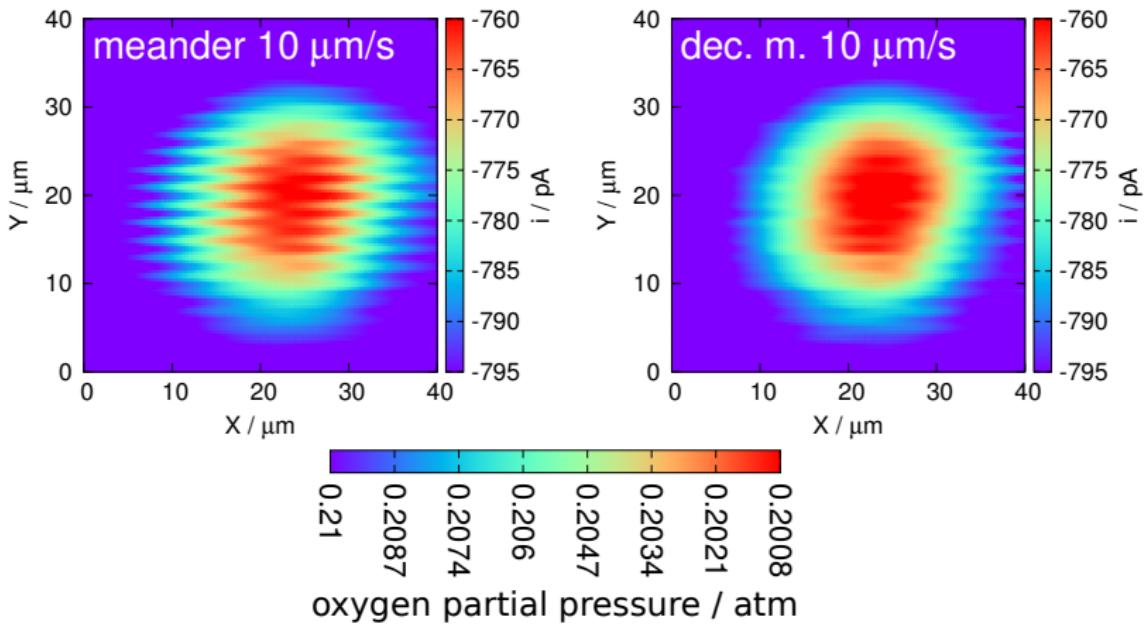
Oxygen reduction current above a monocyte.

Experimental setup.



Oxygen reduction current above a monocyte.

Results.



Conclusion

1. SECM is a powerful tool. Many systems can be studied best with this technique.
2. However, it suffers from low scan speeds and high distortion.
3. Previously I have worked out a deconvolution technique to solve this problem for potentiometric SECM.
4. During my stay here I have worked out a similar method for amperometric SECM.
5. I have used the technique to restore images recorded by Monika and Phillip previously.
6. I have introduced single cell oxygen measurements here with the SECM, and successfully applied the deconvolution to those images as well.

Thank you!

Dr. Monika Bozem
Prof. Dr. Markus Hoth
Phillip Knapp
Katerina Stankoska
Rüdiger Stumpf
Staff of CIPMM

DAAD

Thank you for your kind attention!