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Carbon Nanotube Based Aqueous Ion and pH Sensors

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Outline

- Introduction
- The Sensor System
- The Experiment Setup
- Results
- Conclusions
- Acknowledgements

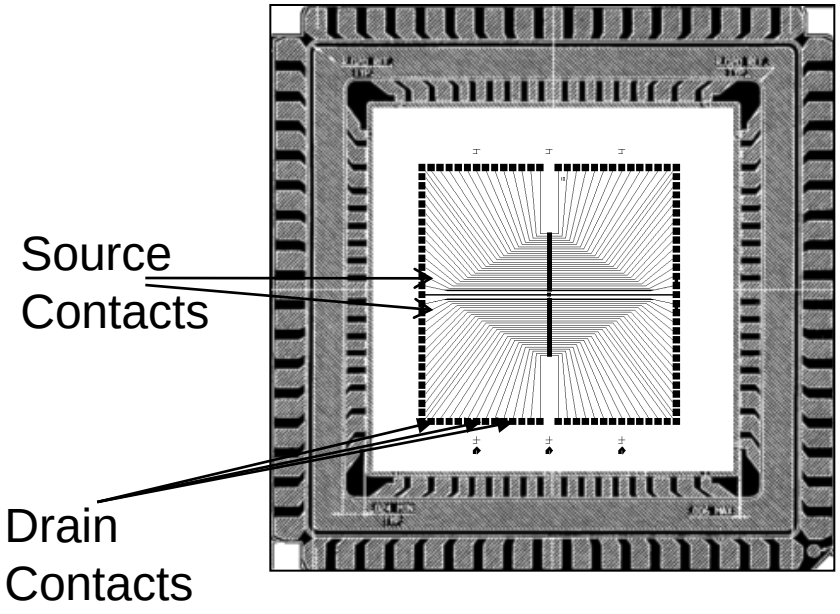
Introduction

- Carbon nanotube Field Effect Transistor (FET) based biosensors hav tile ns in detection of
  - Nucleic acid
  - Anti-body/ant
  - Peptides and p
  - Ionic concentration and pH of electrolytes

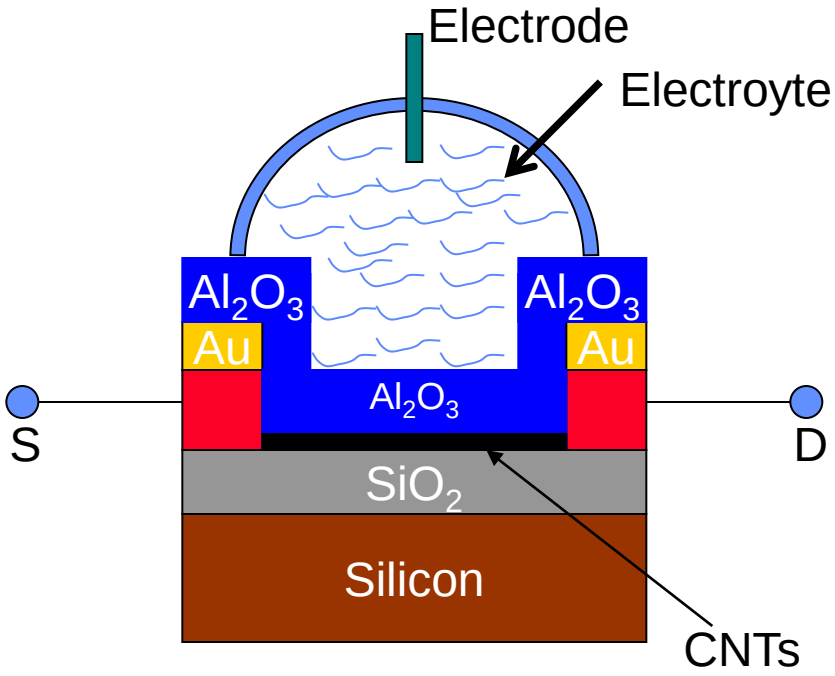
- Project Goals
  - Learn chip fabrication process and measurement system
  - Quantify biosensors' response to
    - Varying concentrations of sodium chloride (NaCl)
    - Varying pH of buffer solutions

The Sensor System: Physical Layout

- 104 CNTFETs on a chip
- Analyte of interest serves as top gate
- Carrier transport through carbon nanotube (CNT) channels

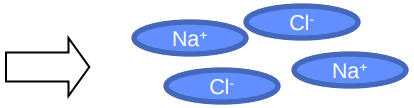


Packaged Chip Layout

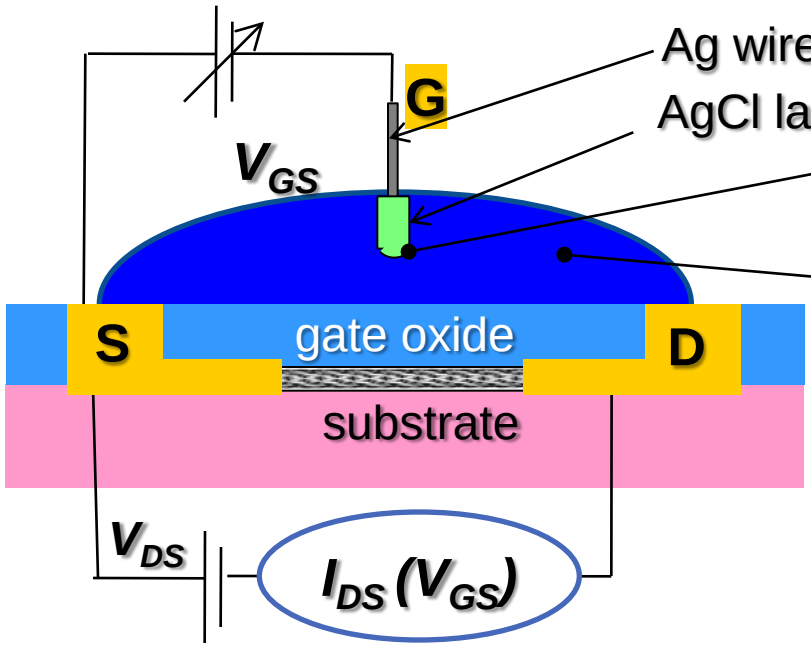


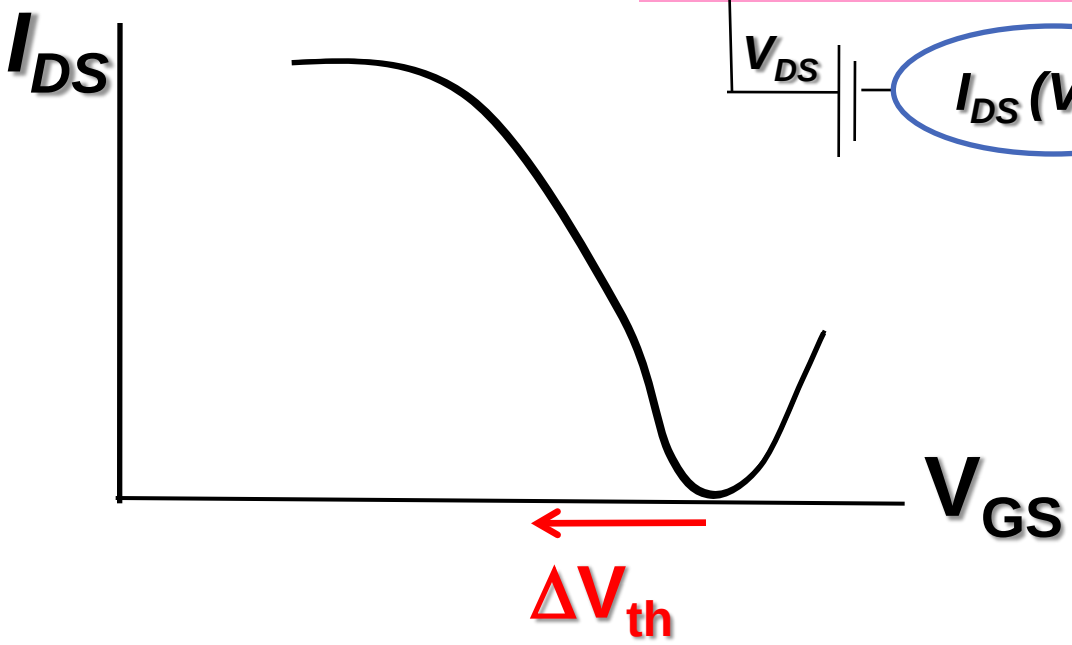
CNTFET

The Sensor System: NaCl Sensing Principle



Additional NaCl concentration





Applicable Nernst equation (at 25 ˚C):

$$E = \text{constant} - \left(59.16 \frac{\text{mV}}{\text{decade}}\right) * \log[Cl^-]$$

E ⇒ electrode potential

$[Cl^-]$ ⇒ chloride concentration

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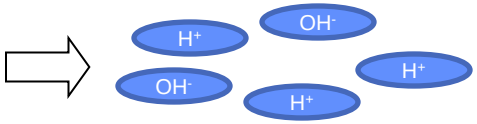
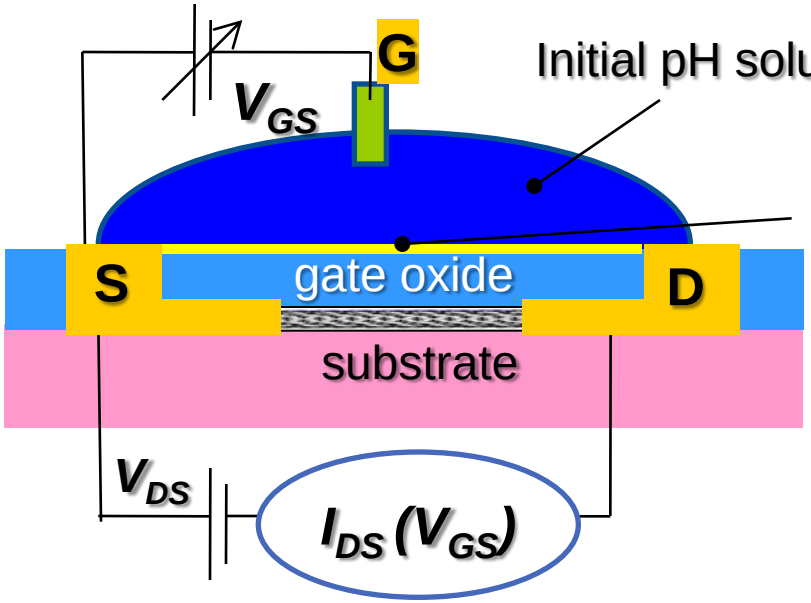
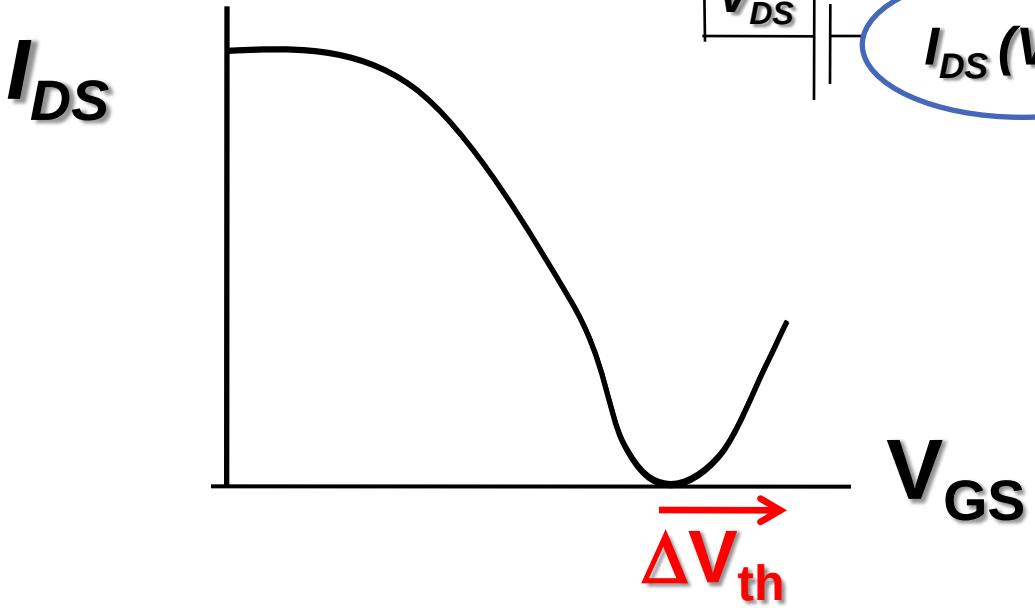
The Sensor System: pH Sensing Principle



Target pH solution

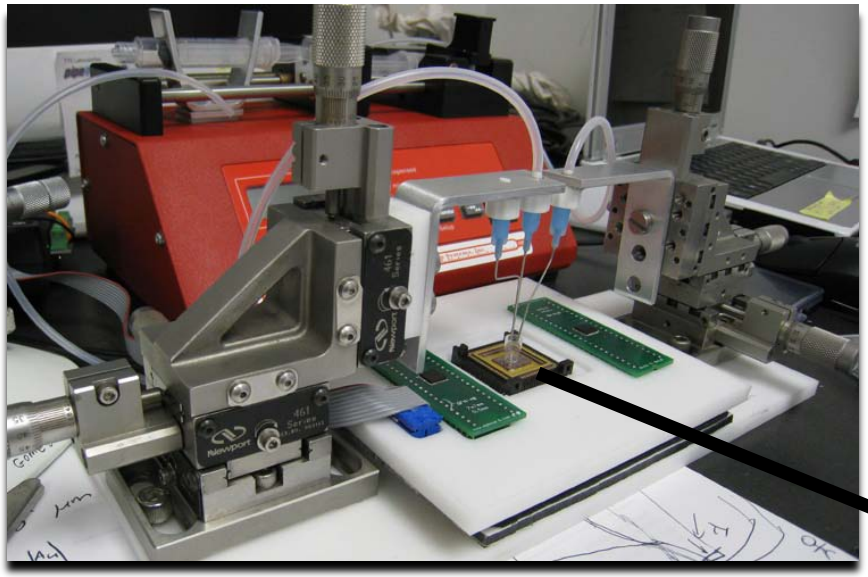


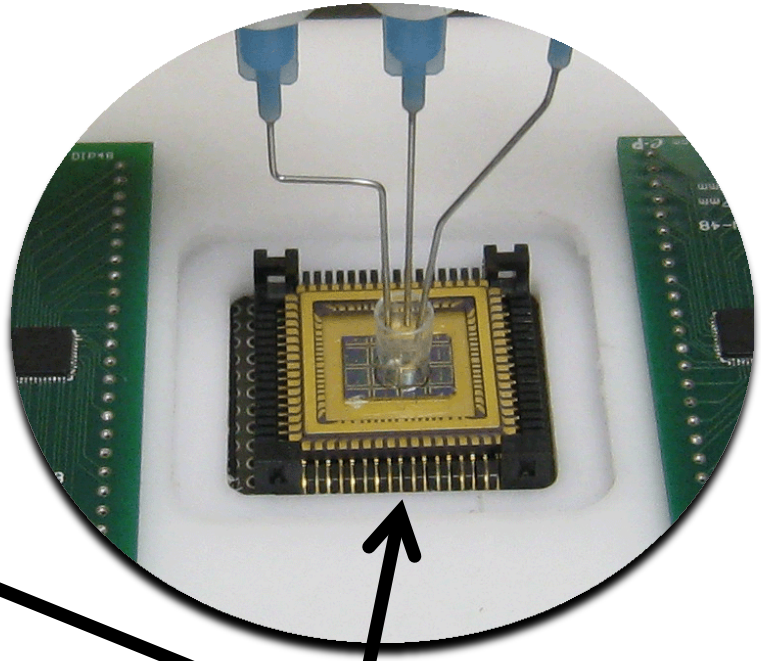


- Amphoteric sites of oxide layer get protonized or deprotonized depending upon pH
- Such surface charge fluctuations modulate electrode potential

The Experiment Setup

- Drain-source bias V_{ds} = 0.1 V constant
- Drain current (I_d) vs. V_{gs} data saved autonomously as Excel file





Measurement Setup

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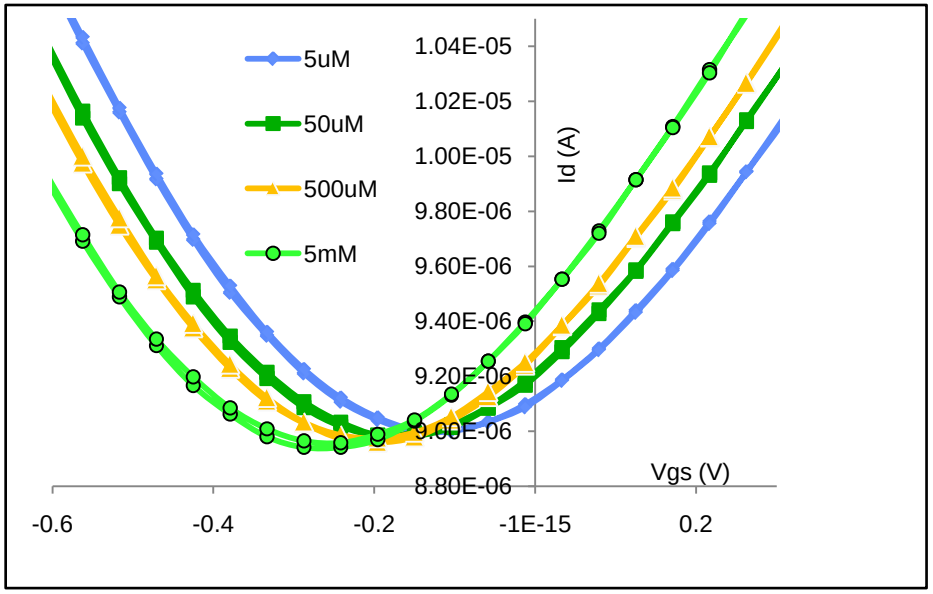
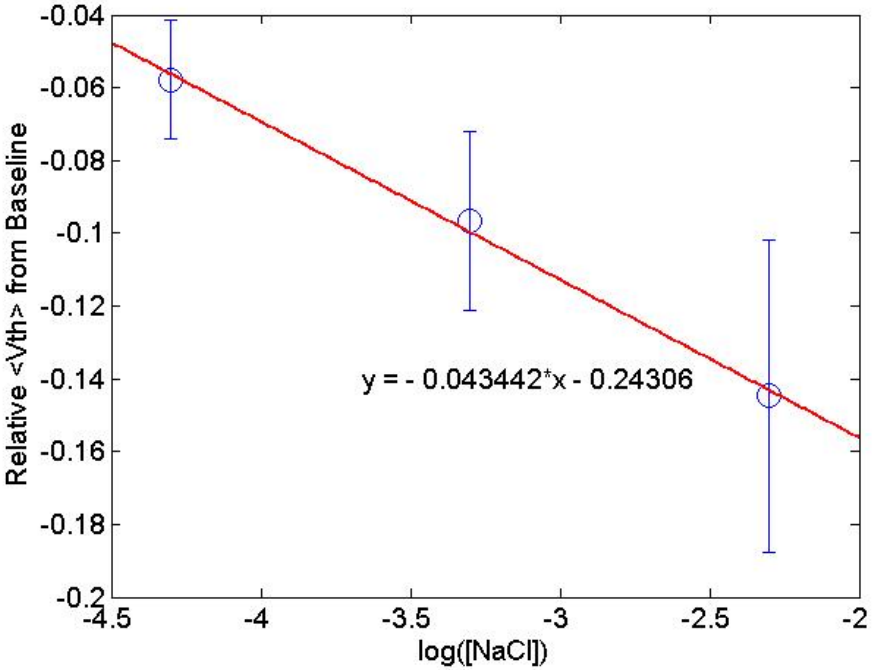
Results: Sensor Response to NaCl



Drain current curve shifts

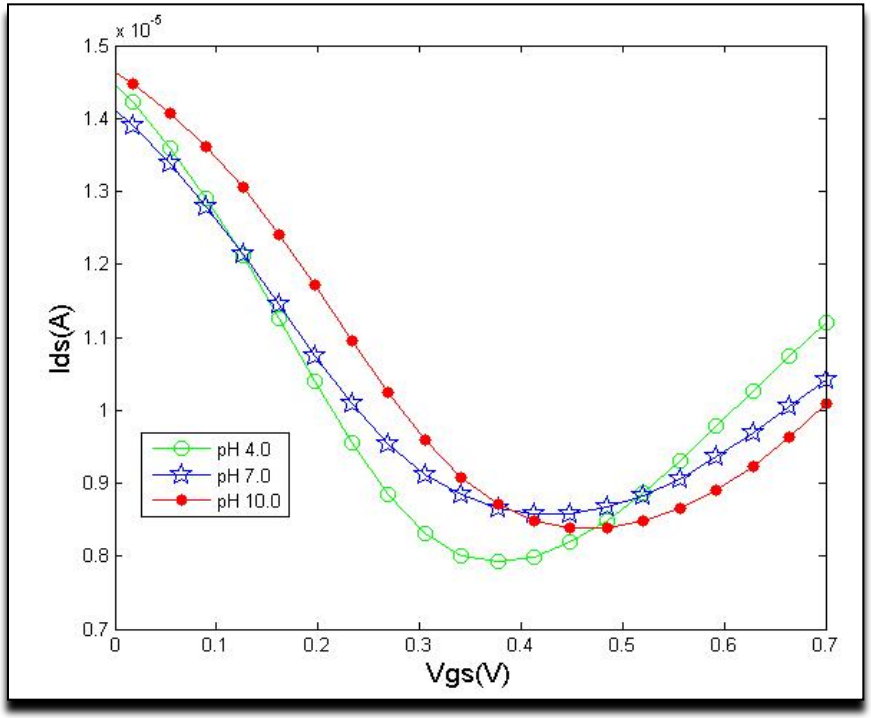


NaCl sensitivity

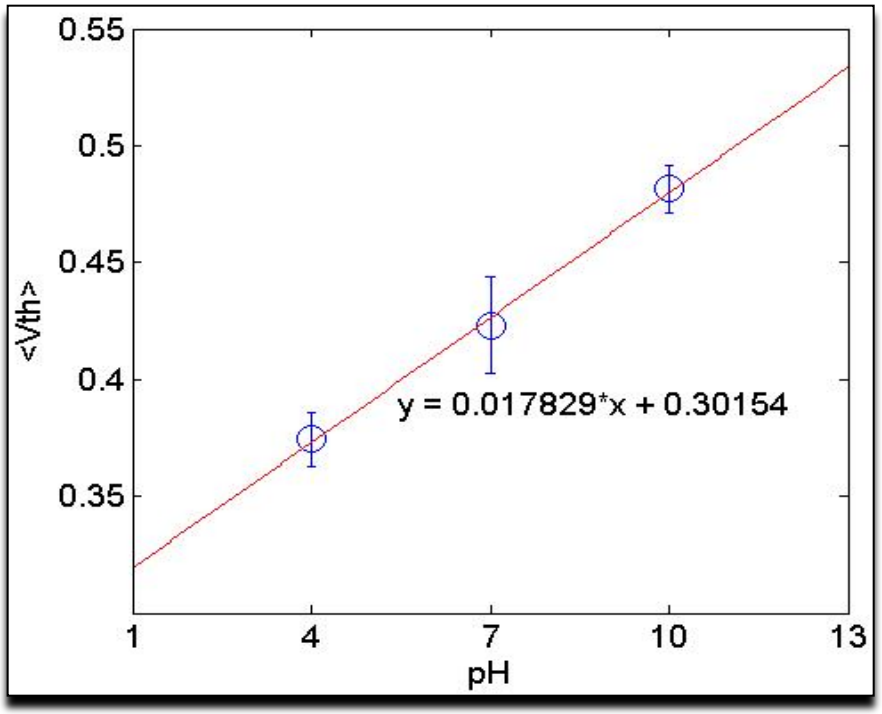
NaCl sensitivity details

- $\langle V_{th} \rangle$ from 64 FETs;
- -43.44 mV/decade
- Baseline [NaCl] = 5 µM

Results: Sensor Response to pH



Drain current curve Shifts



pH sensitivity

pH sensitivity details

- 1 FET
- +17.83 mV/pH

Conclusions

- Learned chip fabrication process and measurement techniques
- Determined sensitivity to NaCl concentrations:

  -43.44 mV/decade
- Determined sensitivity to pH:

  +17.83 mV/pH
- Future directions
  - pH measurements on multiple FETs on chip
  - Larger sample of pH both on acidic and basic side
  - Rigorous error analysis of the obtained results

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