Mercury Detection Using Gold Nanoparticles

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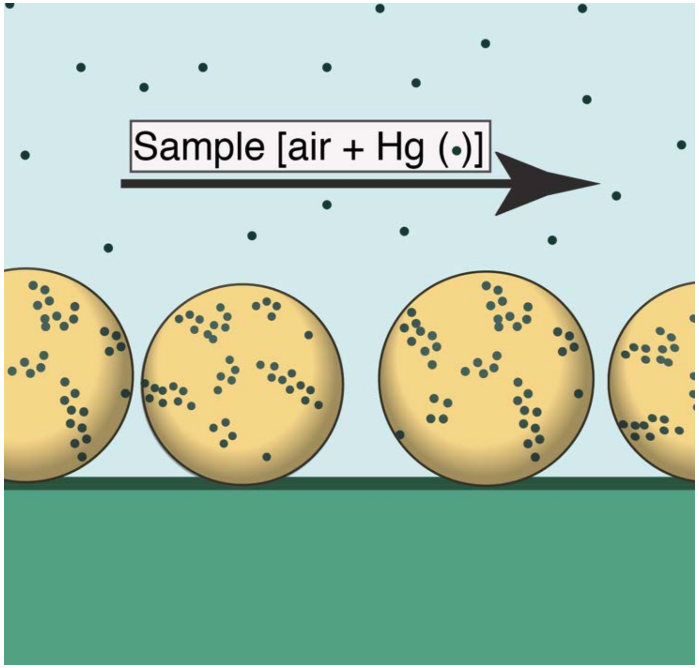
Jeffrey Crosby[1] Jay James[1]

Donald Lucas[2] Catherine Koshland[3]

1 Department of Mechanical Engineering, University of California Berkeley
2 Environment and Energy Technologies Division, Lawrence Berkeley National Lab
3 Department of Public Health, University of California Berkeley

Outline

- Introduction
- Fiber optic based sensor utilizing nanoparticles
- Sensor regeneration
- Optimizing response using mass flow results



Motivation/Mercury

Utah Department of Environmental Quality

Minamata Victim (Smith 1971)

Current Detection Methods

- Current detection methods
  - Occupational instruments
  - Environmental instruments
    - Costly
    - Require pre-concentration

Jerome 431X Arizona Instruments

Tekran-2537

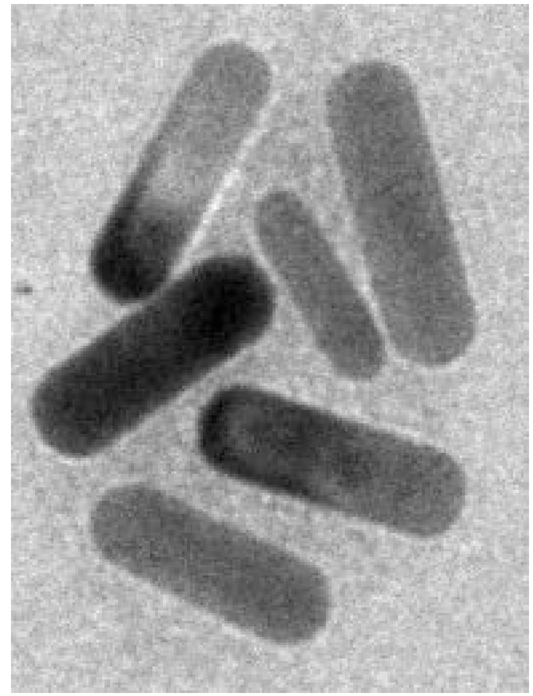
Localized Surface Plasmon Resonance

- Colloids long history of use
  - Roman Lycurgus cup, 400 AD
  - Stained glass windows
- Michael Faraday 1847

Localized Surface Plasmon Resonance

- Nanoparticles widely used in sensors

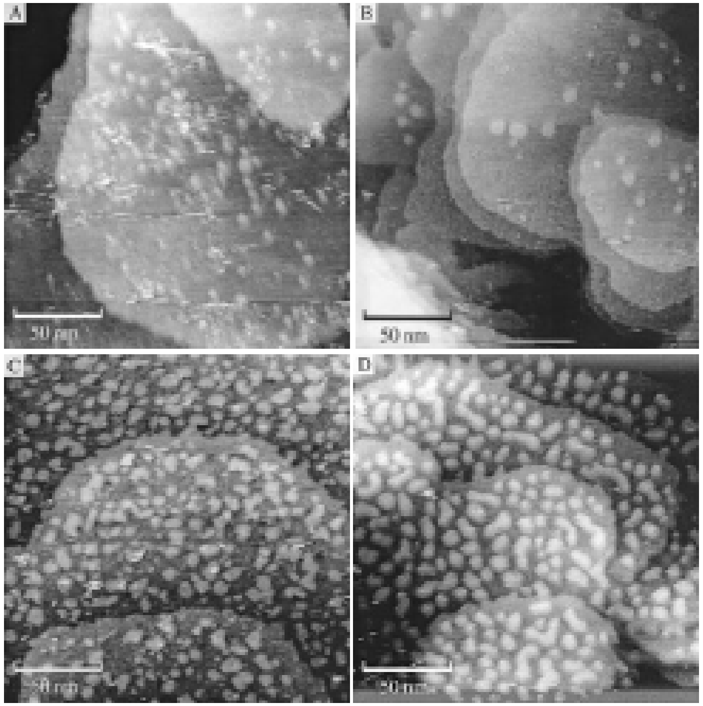
Nanopartz™ Nanorods



- Changing properties of NPs or medium can drastically change optical response

Mercury/Gold Interactions

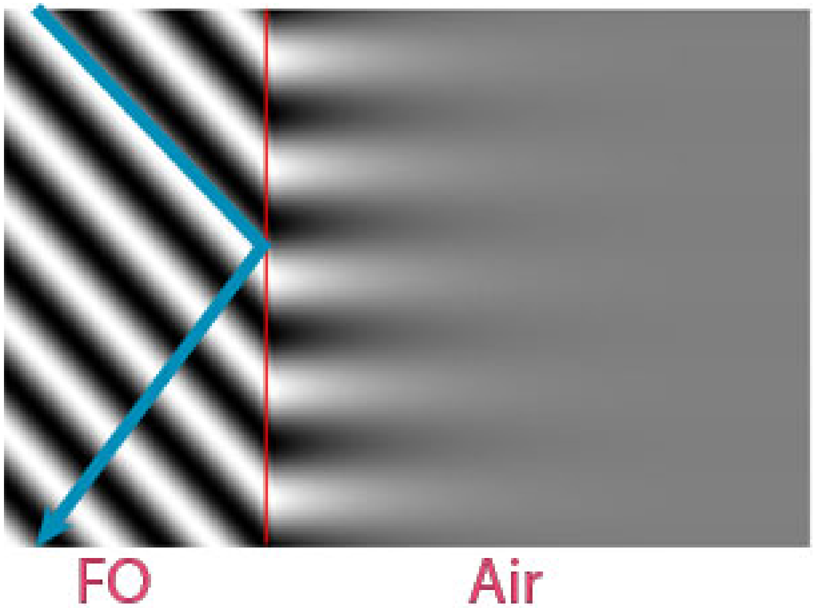
- Readily form an amalgam
- Levlin, Ikavalko, and Laitinen (1999) studied mercury adsorption onto gold and silver films
  - Initial fast adsorption followed by slower adsorption



M. Levlin, E. Ikävalko, and T. Laitinen, “Adsorption of mercury on gold and silver surfaces,” *Fresenius’ journal of analytical chemistry*, vol. 365, no. 7, pp. 577–586, 1999

Fiber Optic Sensors

- Based off evanescent wave at interface
- Have been used for chemical and biological sensors in a variety of media



- Penetration depth comparable to NP size:

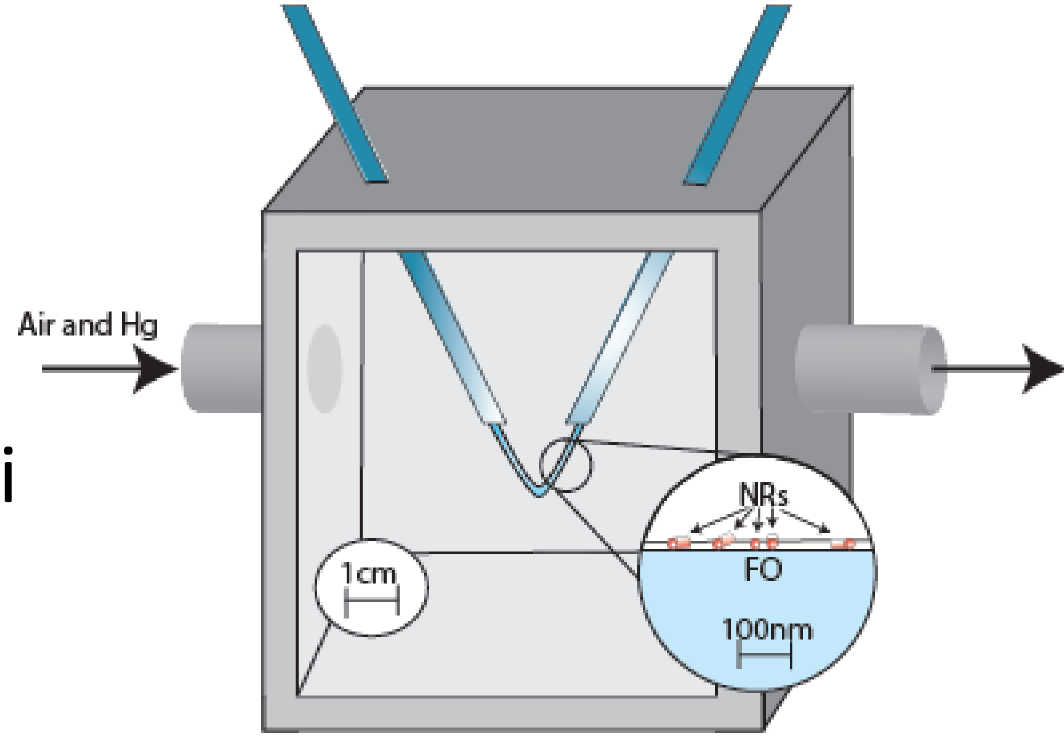
$$D_p = \frac{\lambda}{2\pi n_1 (sin^2\theta - sin^2\theta_c)^{0.5}}$$

D. Littlejohn, D. Lucas, and L. Han, “Bent silica fiber evanescent absorption sensors for near-infrared spectroscopy,” *Applied spectroscopy*, vol. 53, no. 7, pp. 845–849, 1999.

B. D. Gupta, H. Dodeja, and A. K. Tomar, “Fibre-optic evanescent field absorption sensor based on a U-shaped probe,” *Optical and quantum electronics*, vol. 28, no. 11, pp. 1629–1639, 1996

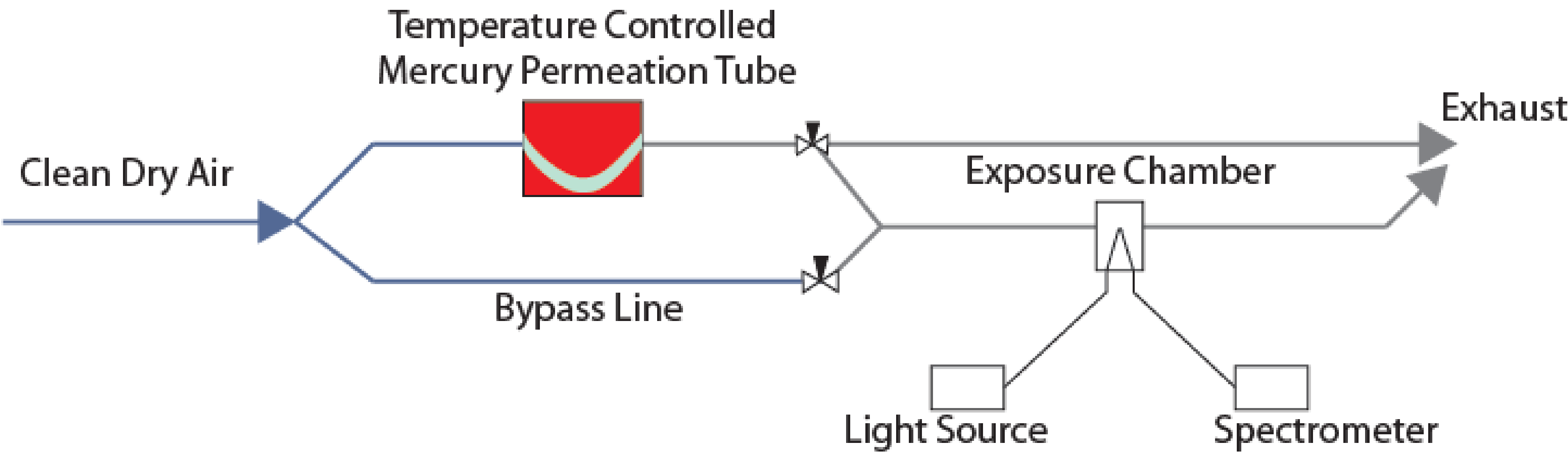
Experimental Set up

- Fiber optic cable de-clad and bent
- De-clad portion functionalized with MPTMS
- Gold nanorod soluti applied to fiber

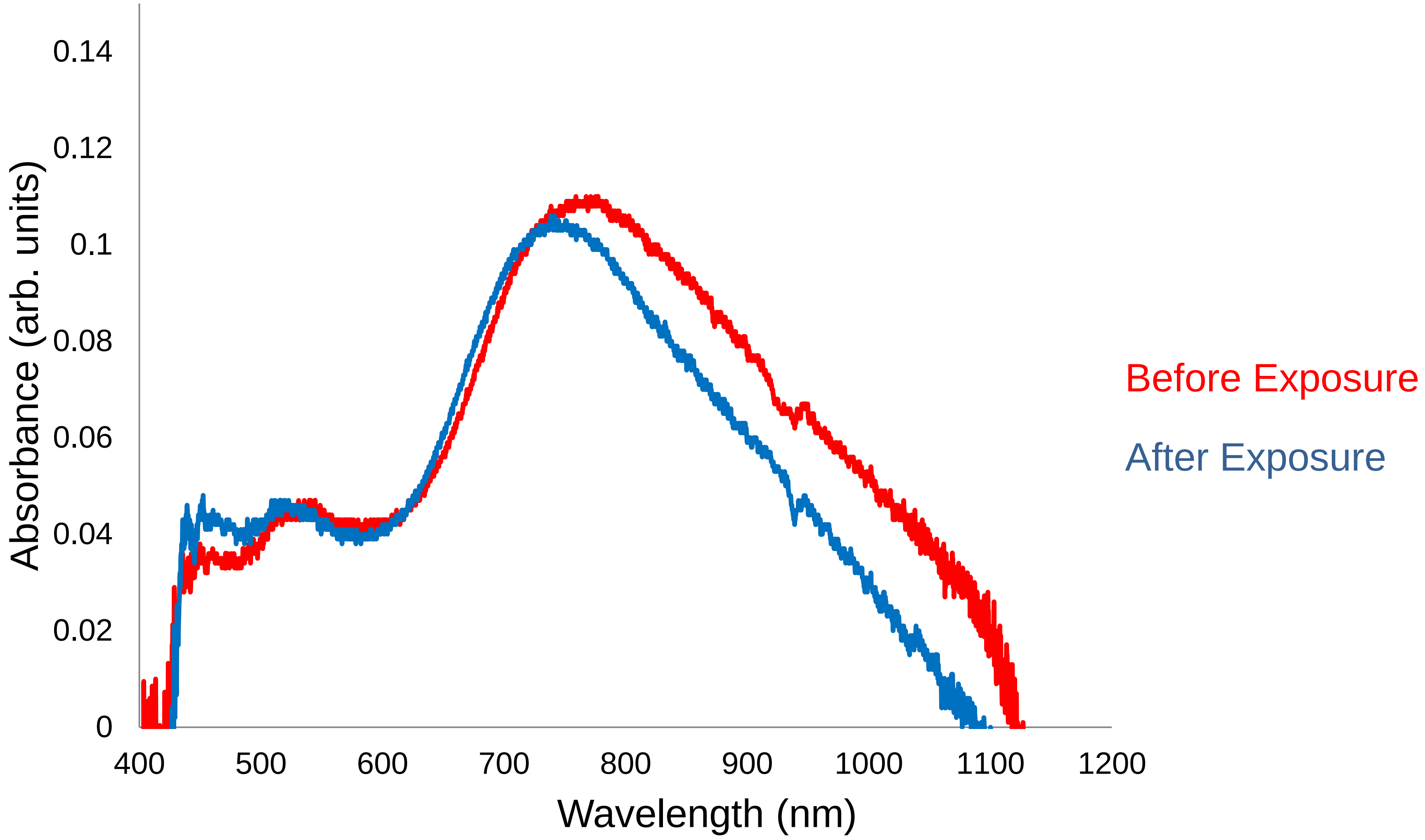


Experimental Set-Up

- Vital to control flow and Hg concentration
- Achieved with permeation tube



Results



.015 mg/m³ for 90min.

Peak Response and Concentration

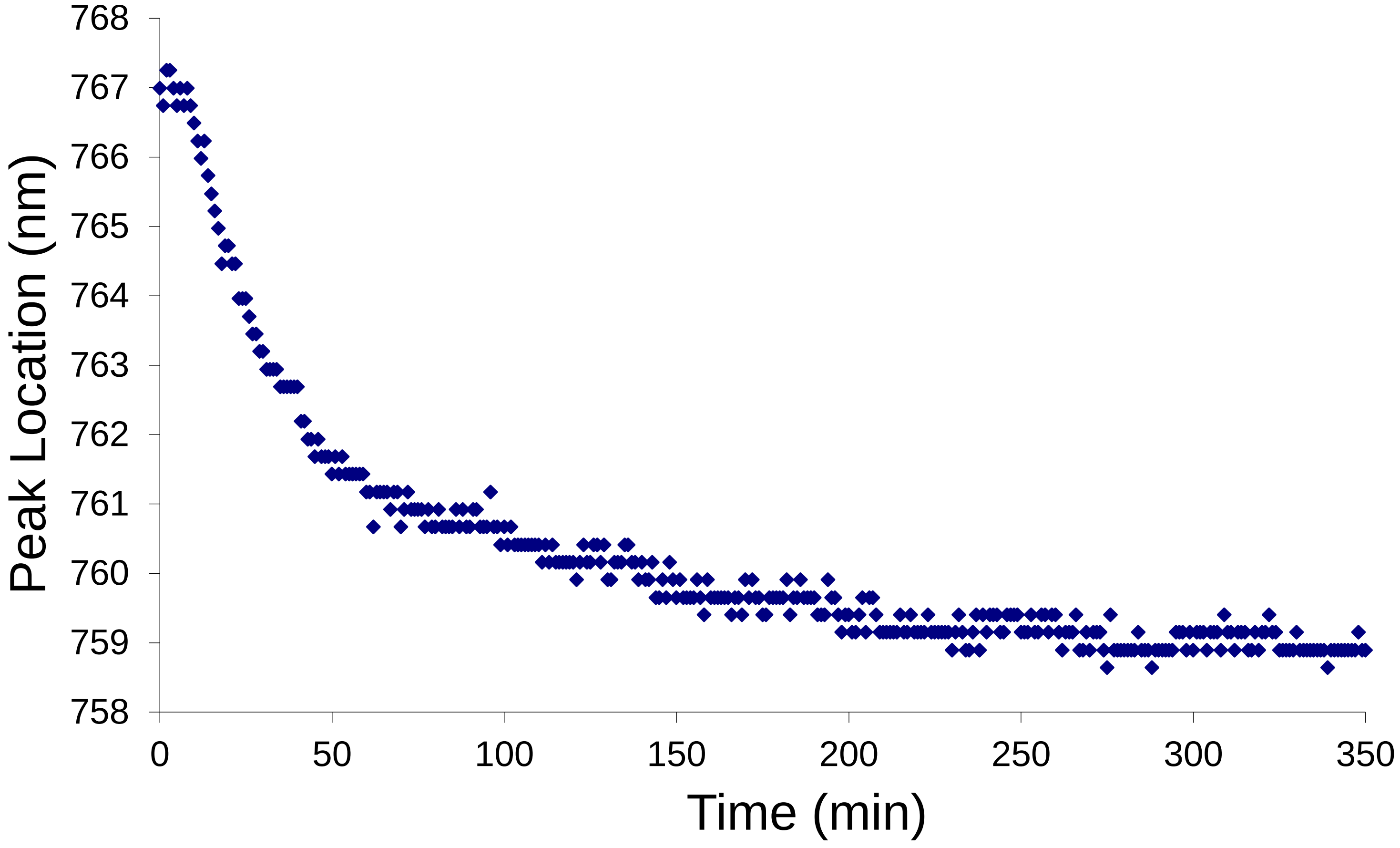
- Concentration gradient drives response:

$$\alpha(\lambda) \sim \dot{m}_{hg}$$

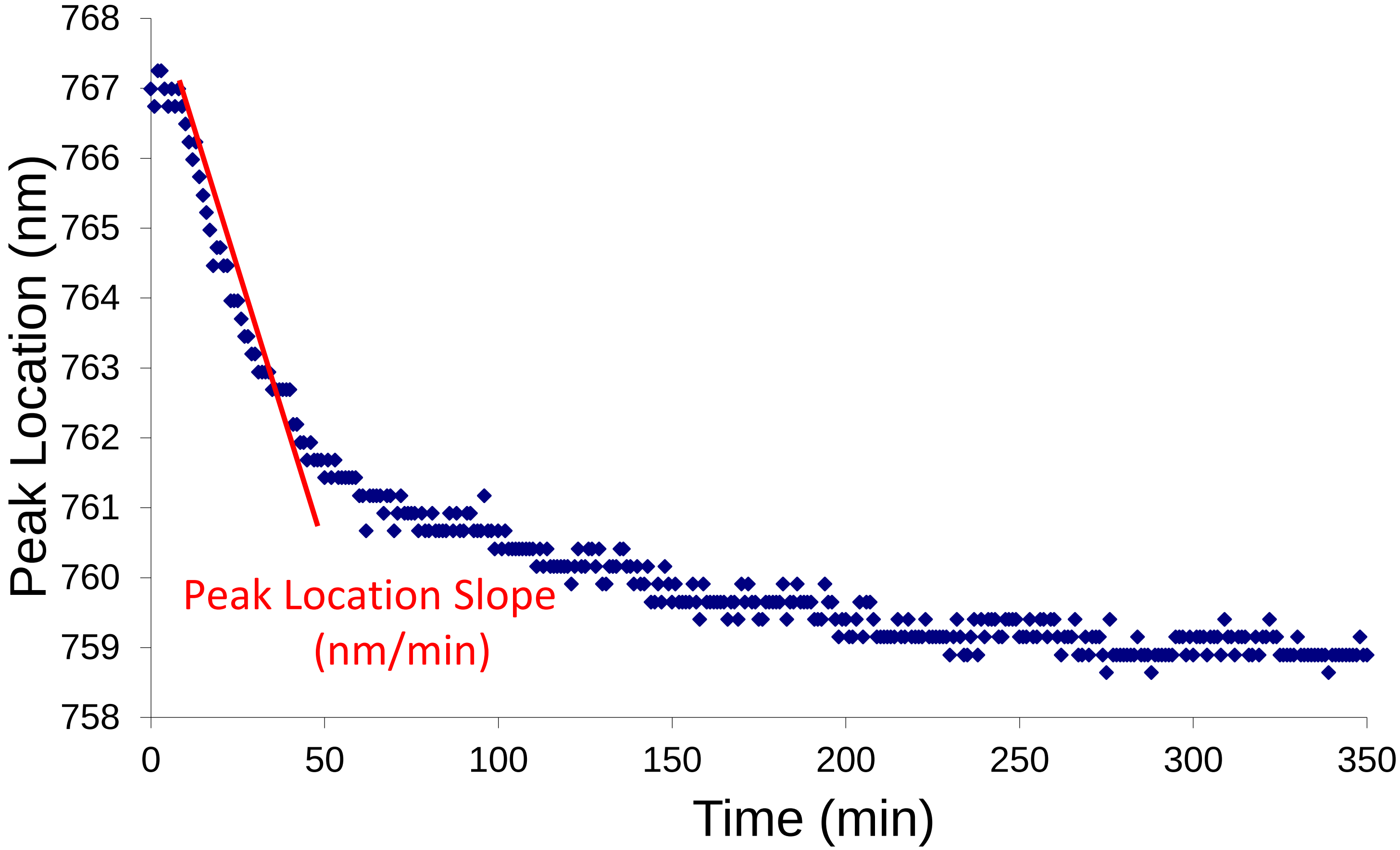
$$\dot{m}_{Hg} \sim C D_{air-Hg} \frac{dC_{Hg}}{dx}$$

- Once the nanorod saturates the process is no longer diffusion limited

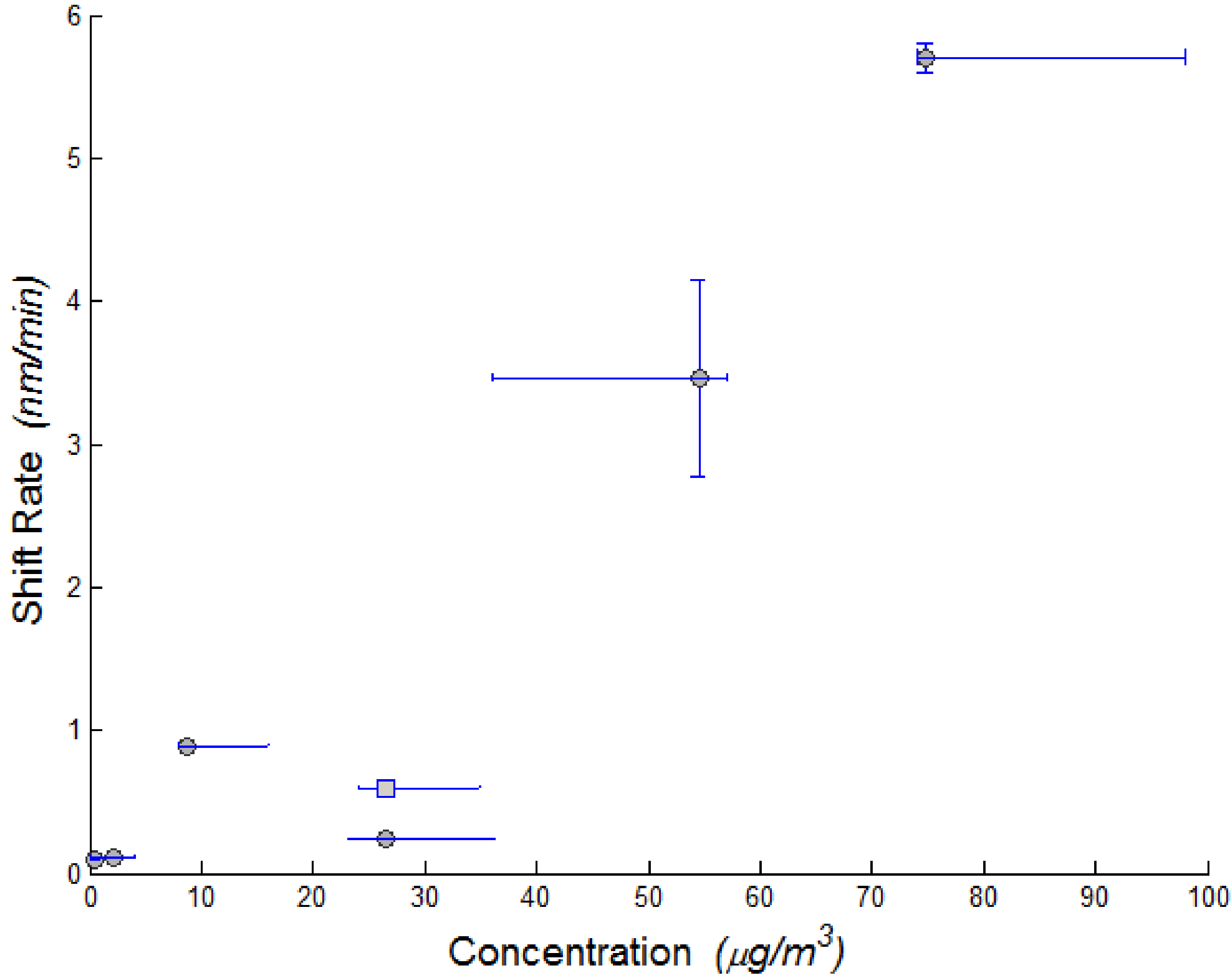
LSPR Peak after Exposure



LSPR Peak after Exposure

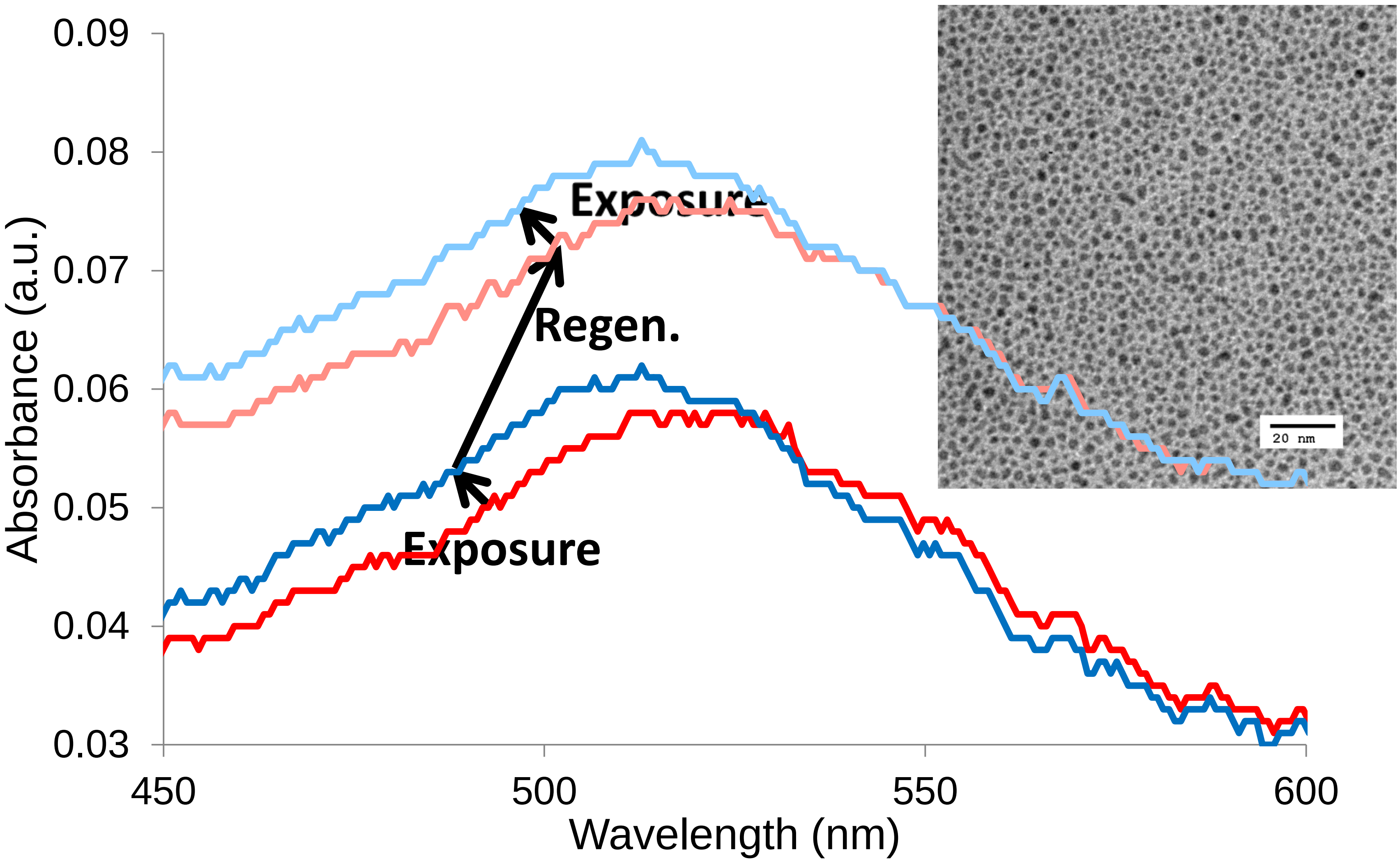


Blue Shift due to Concentration



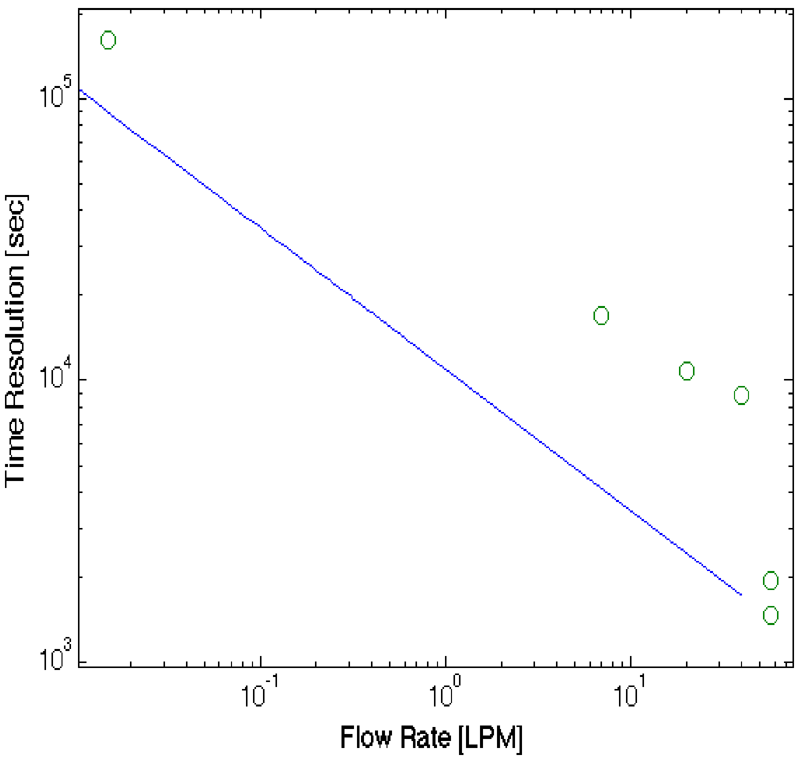
Regeneration of Sensors

- Can restore peak and reuse with clean hot air.

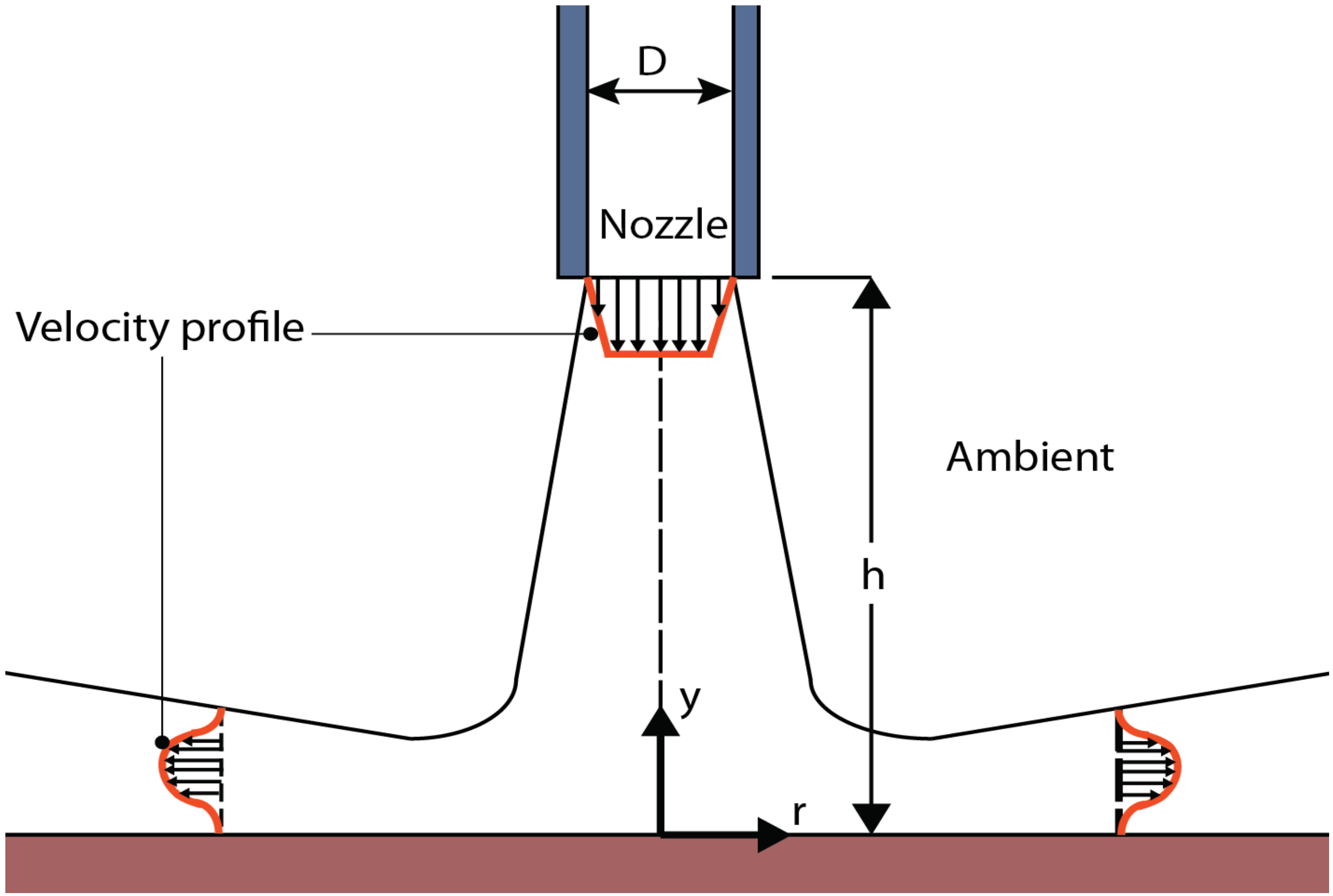


Mass Transfer and Hg Sensors

- Sensor performance is driven by Hg deposition on surface
- Totally quiescent medium would take about 3 years to respond to 1µg/m^3
- Our increased response is due to the flow enhancing mass transfer

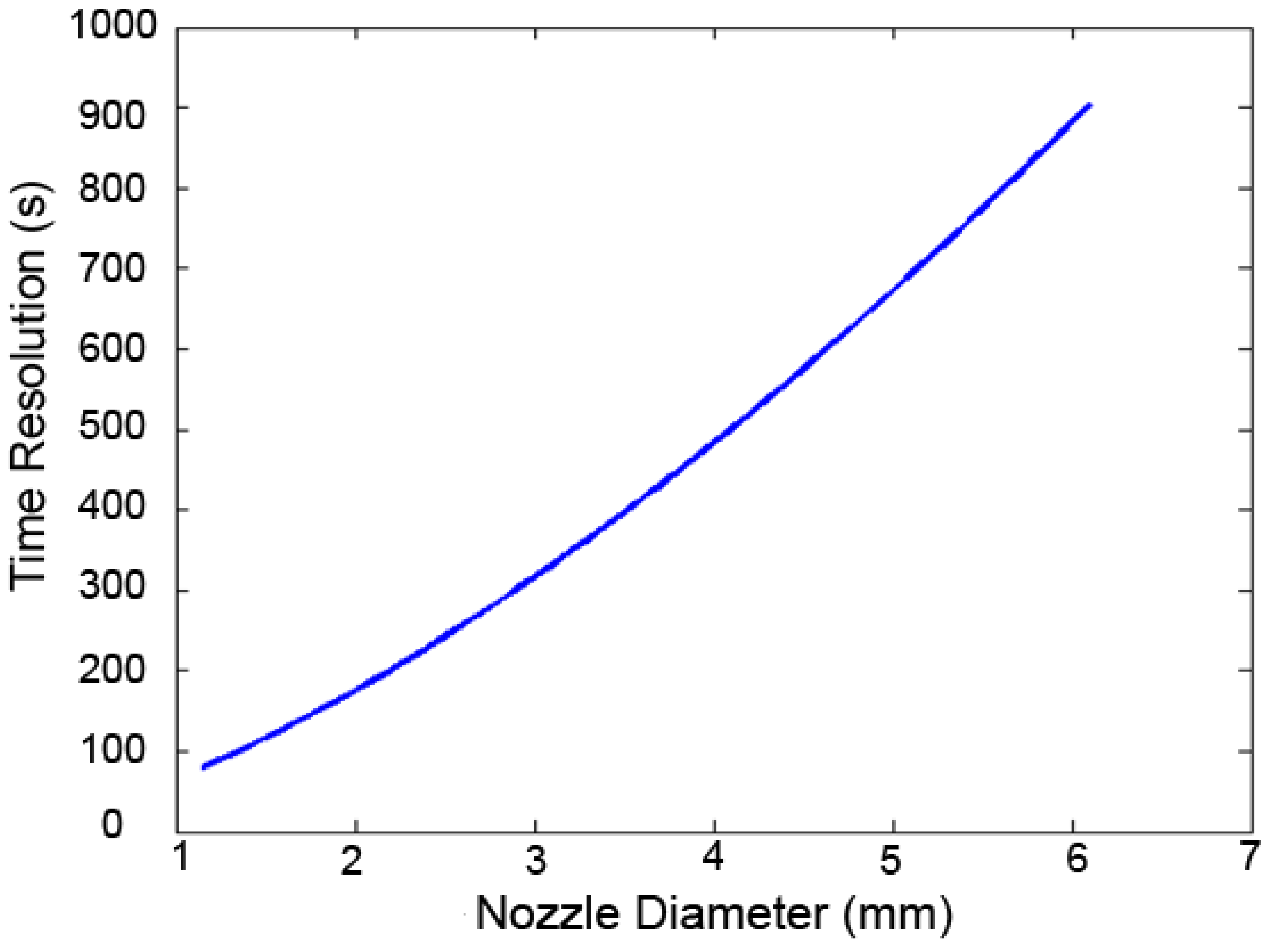


Mass Transfer and Hg Sensors

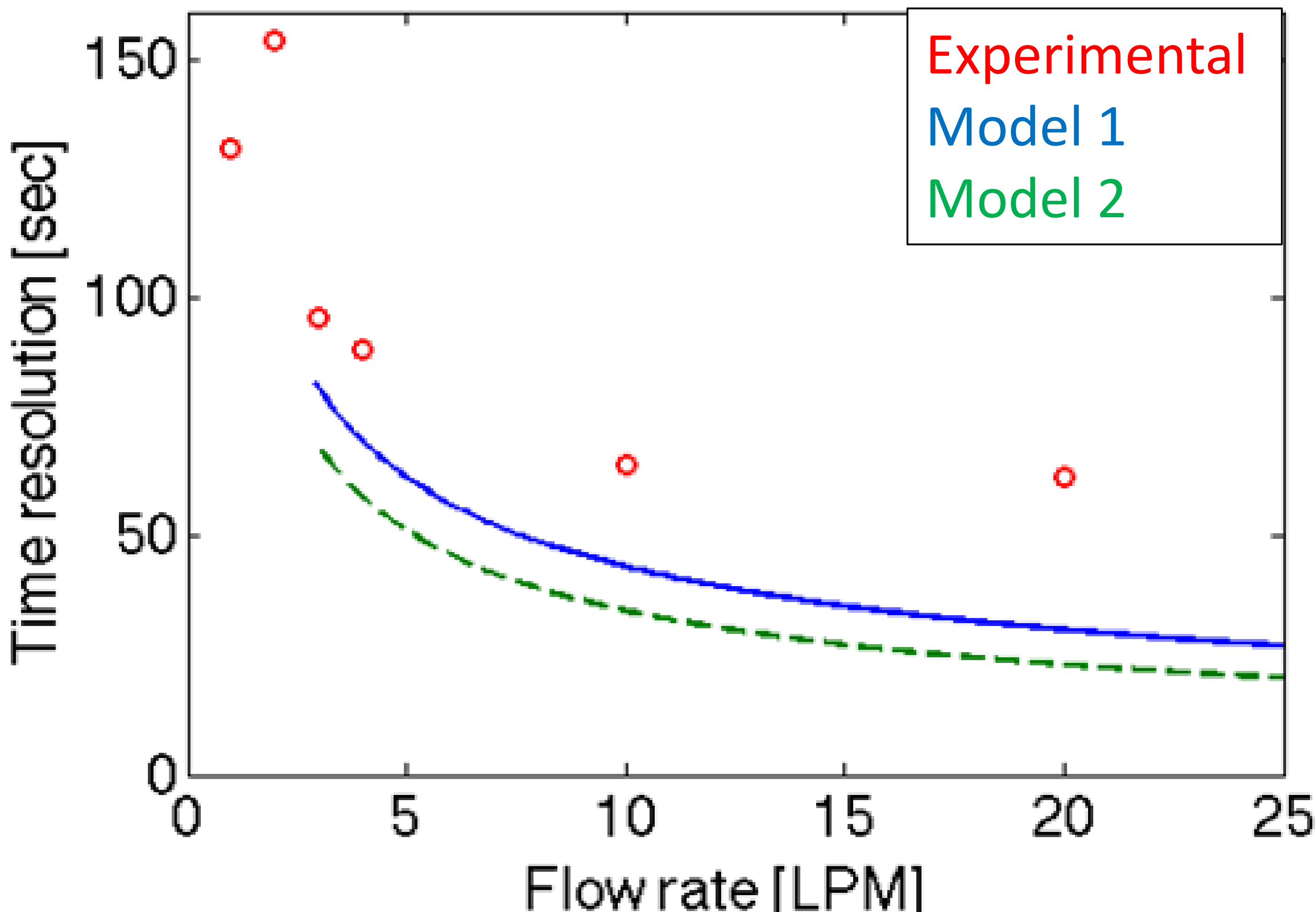


Mass Transfer and Hg Sensors

Faster response and additional parameter of nozzle diameter



Mass Transfer and Hg Sensors



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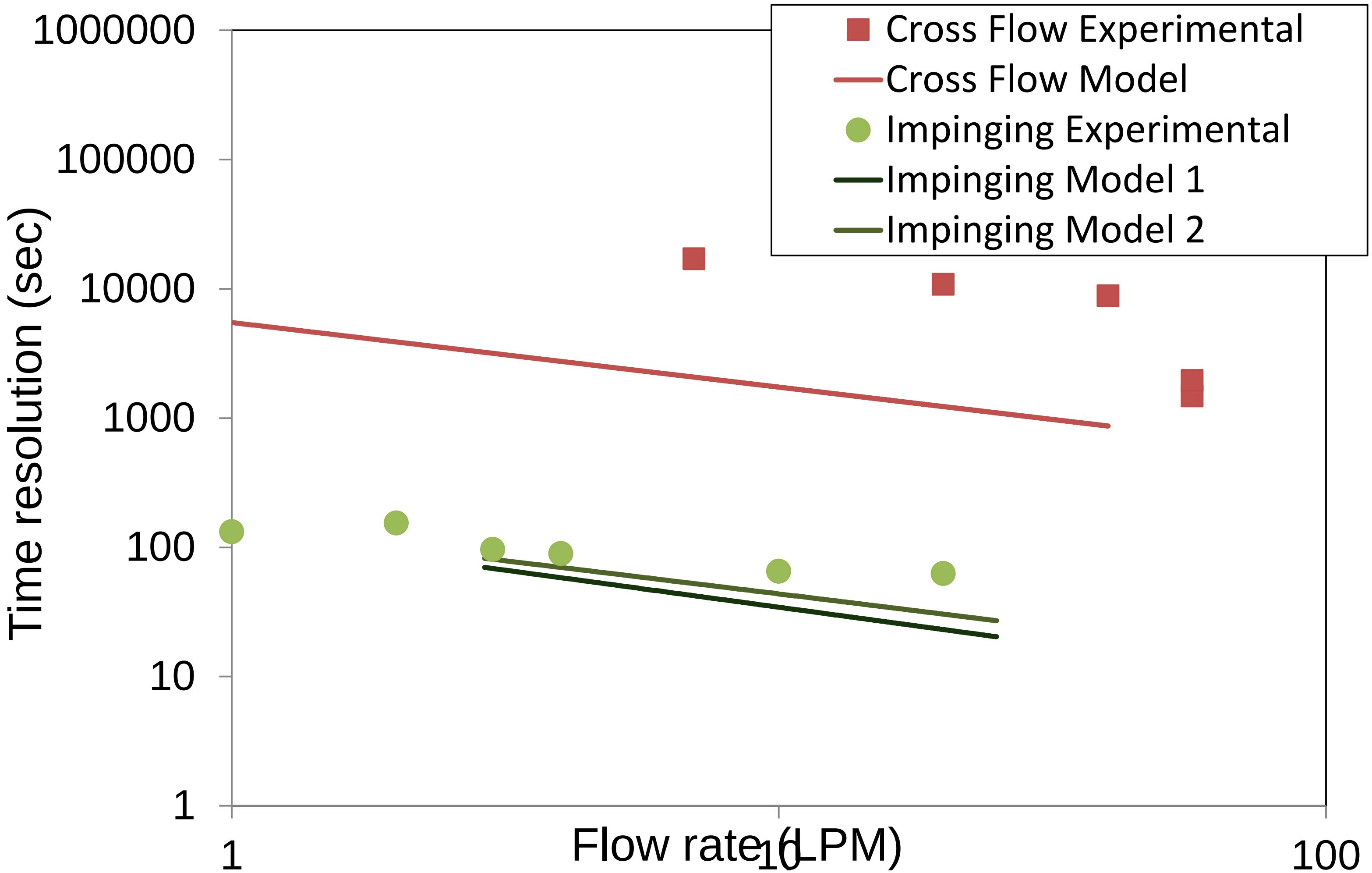

Acknowledgements

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- **Thank you for your time and attention**