OPTICAL FIBER SENSOR ARRAY FOR DETECTION OF AQUEOUS-AMMONIA

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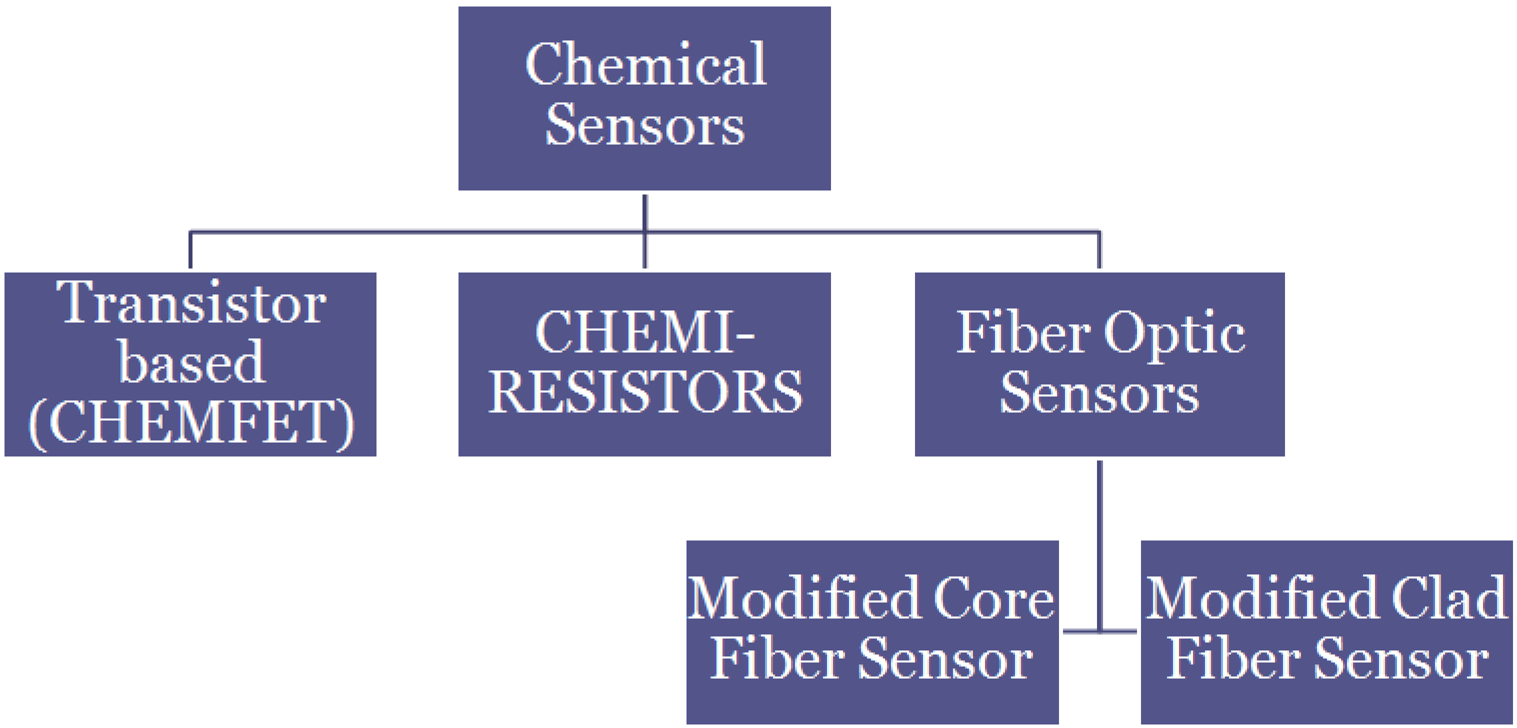
Background

- Motivation
  - Batch sampling of waterborne contaminants is inefficient
  - Quick response is required to safeguard lives in case of disasters or poisoning of the water supply
- Required
  - An on-line, continuous monitoring solution that can detect and quantify waterborne contaminants at many vital locations simultaneously

Chemical Sensors



Why Fiber Optics sensor

- Simplicity
- Sensitivity
- Cost effective
- Large dynamic range
- Responsive to external physical, chemical and biological changes

Focus

- Objective
  - Develop novel interrogation routines for CMEOF sensor array
  - Characterize a two-element CMEOF ammonia sensor array
  - Establish relationship between the absorbance response of the CMEOF sensor array and concentration

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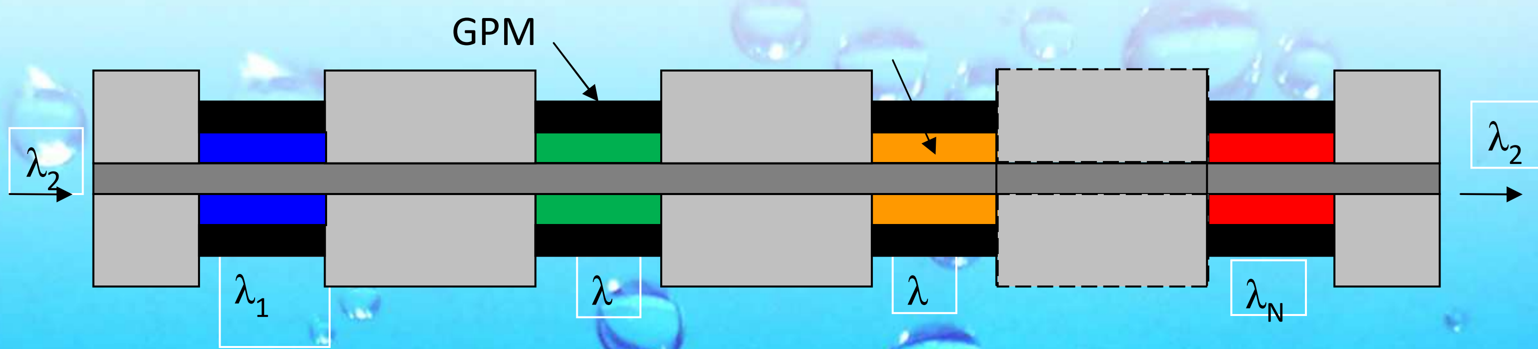
Concept

- Replace clad with sensing layer
- Gas permeable membrane that allows gas to pass through but blocks water
- Evanescent field will penetrate into the sensing layer
- Sensing layer absorbs part of the power in the optical beam and thereby reduce the overall power in the optical fiber



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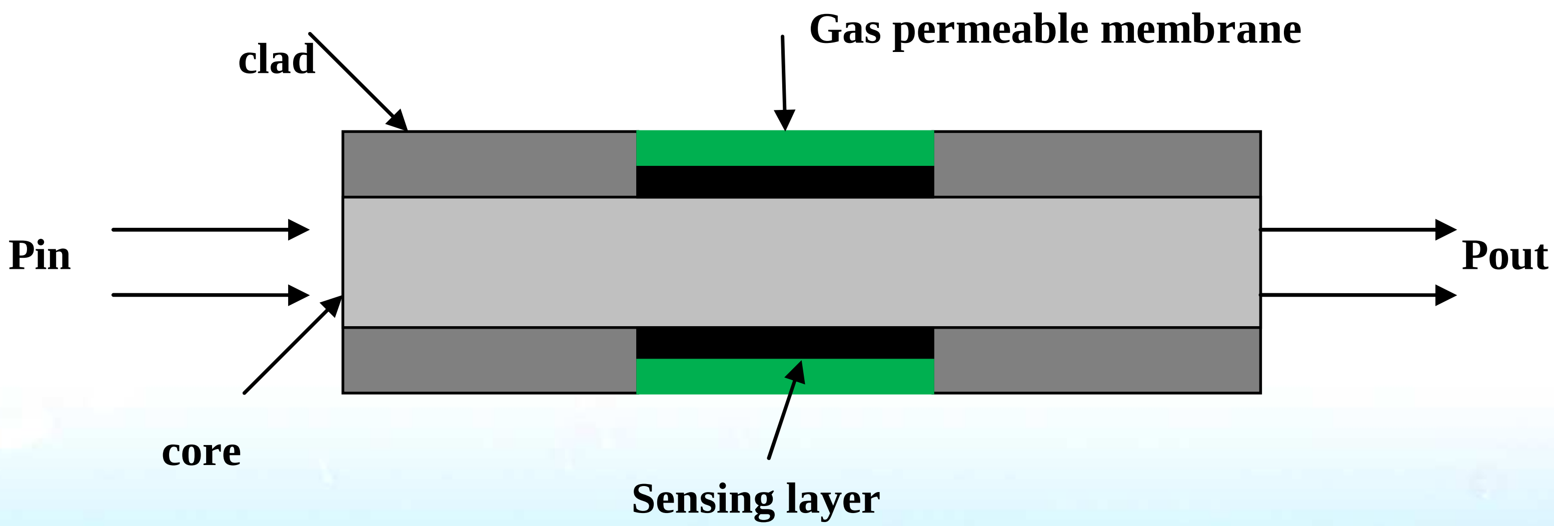
Ammonia Sensing principle



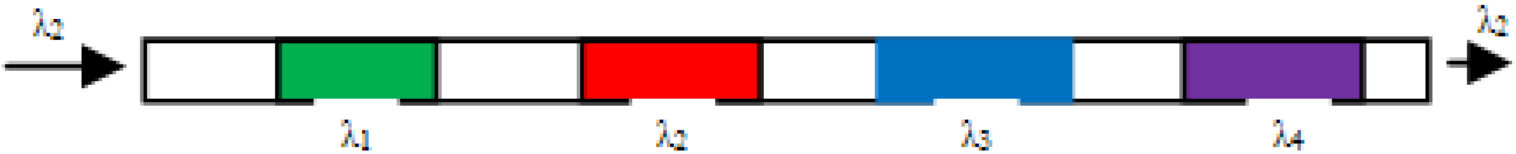
$$NH_3(vapor) + H_2O \Leftrightarrow NH_4^{\ +} + OH^-$$

$$H\_Dye(orange) + OH^- \Leftrightarrow Dye^-(blue) + H_2O$$

$$Dye^-(blue) + NH_4^{\ +} \Leftrightarrow H\_Dye(orange) + NH_3(vapor)$$

Analytical technique

Applying linear system of equations to:



$$A_{\lambda 1} = e^{1}{}_{\lambda 1} l C_1 + e^{2}{}_{\lambda 1} l C_2 + e^{3}{}_{\lambda 1} l C_3 + e^{4}{}_{\lambda 1} l C_4$$

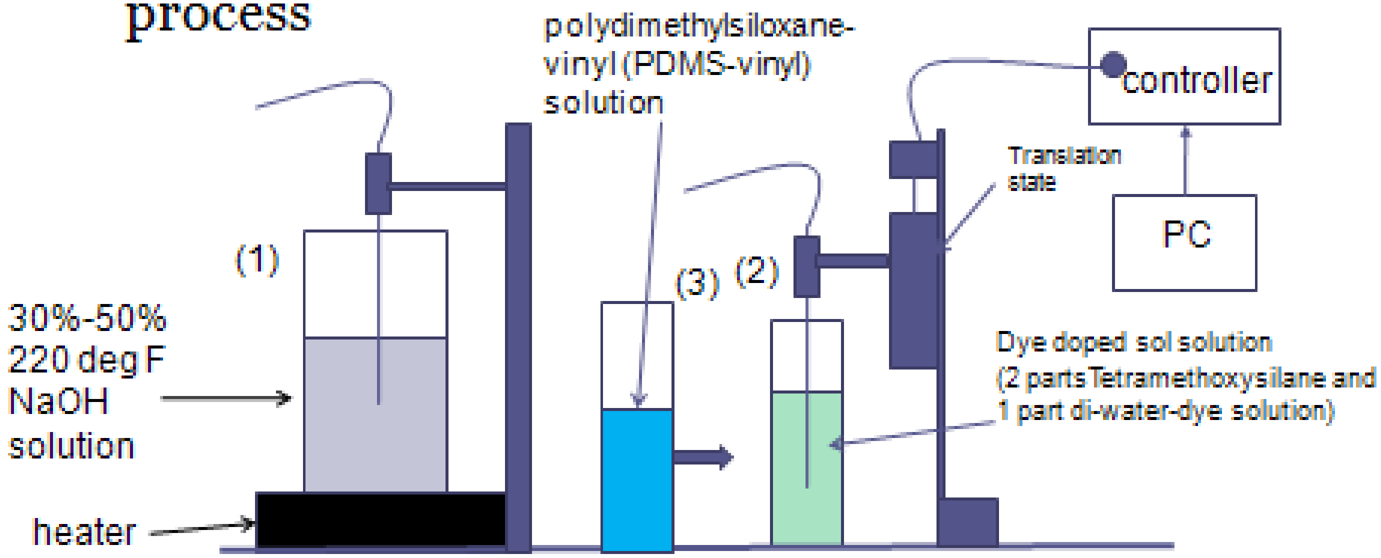
......

$$A_{\lambda N} = e^{1}{}_{\lambda N} l C_1 + e^{2}{}_{\lambda N} l C_2 + e^{3}{}_{\lambda N} l C_3 + e^{4}{}_{\lambda N} l C_4$$

$$[e][C] = A / l$$

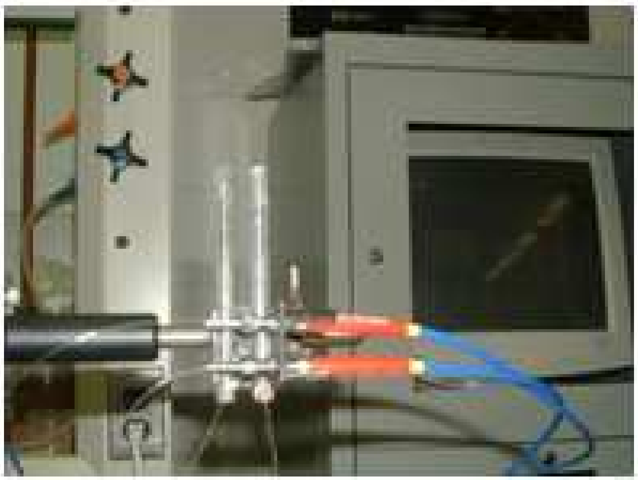
CMEOF Fabrication

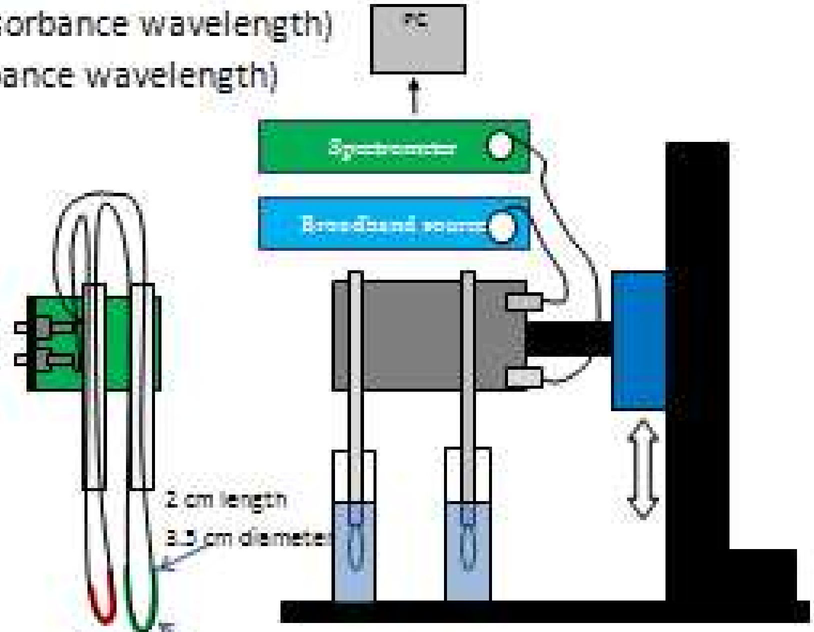
- Three step glass etching dip coating process



2-element CMEOF Ammonia Sensor Array

- Sensing materials: pH sensitive dyes immobilized in sol-gel
  - Bromocresol green (618 nm peak absorbance wavelength)
  - Phenol Red dye (550 nm peak absorbance wavelength)



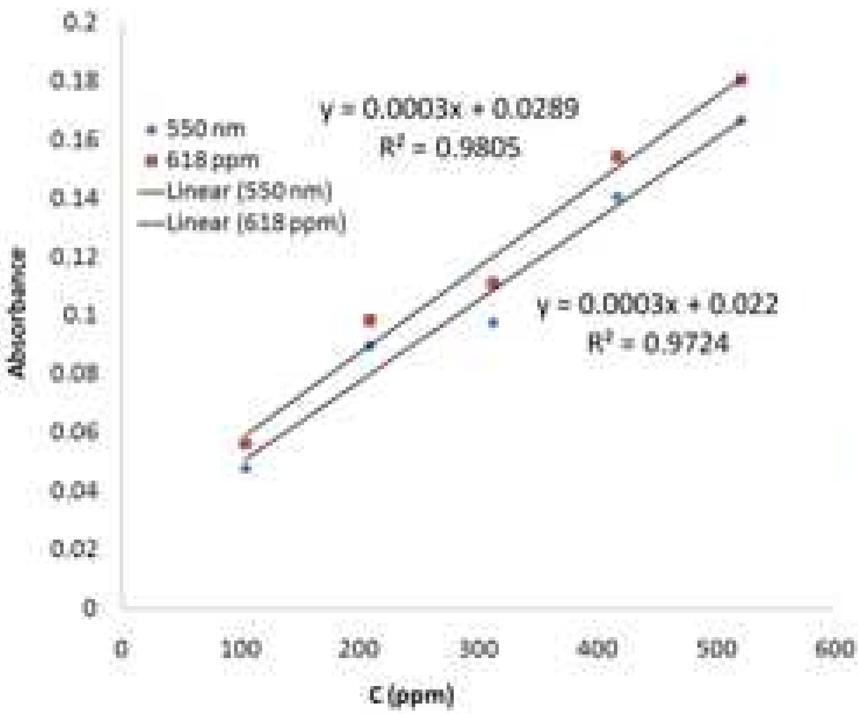


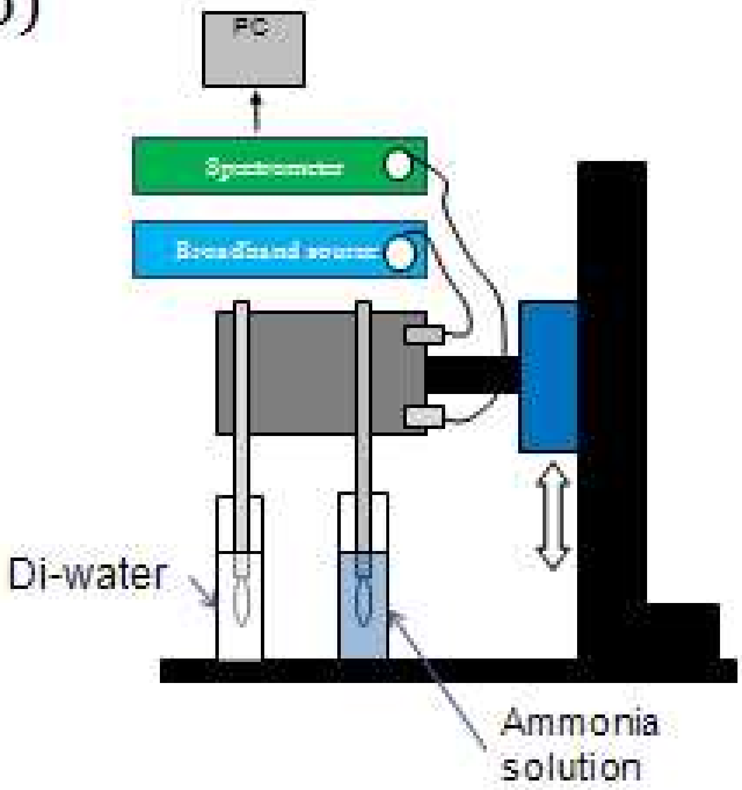
Phenol Red (PR)
550 nm

Bromocresol Green (BG)
618 nm (peak absorbance)

CMEOF Ammonia Sensor Array (Calibrating results)

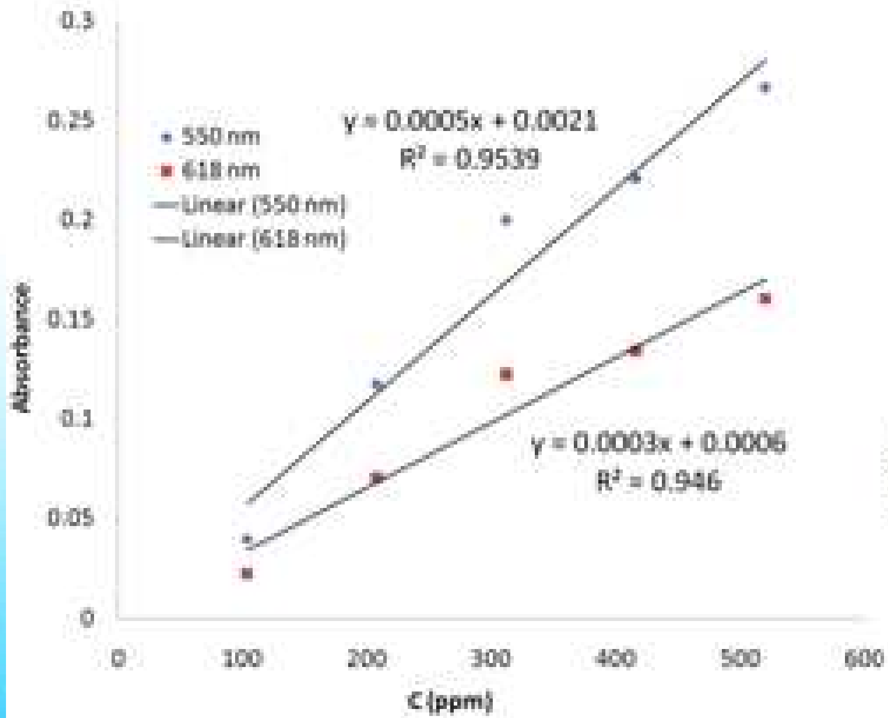
- BG response (C1=C,C2=0)

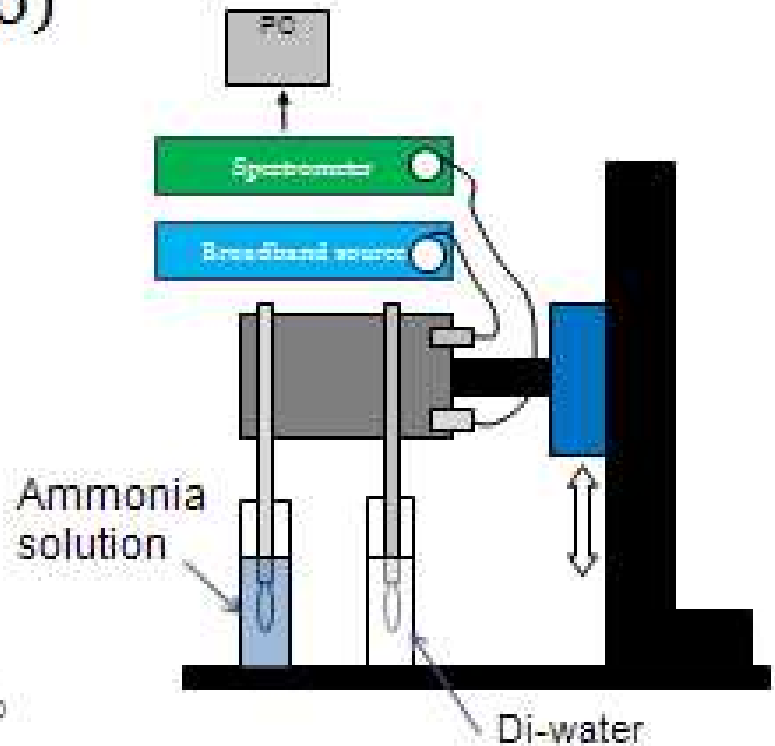




CMEOF Ammonia Sensor Array (Calibrating results) cont.

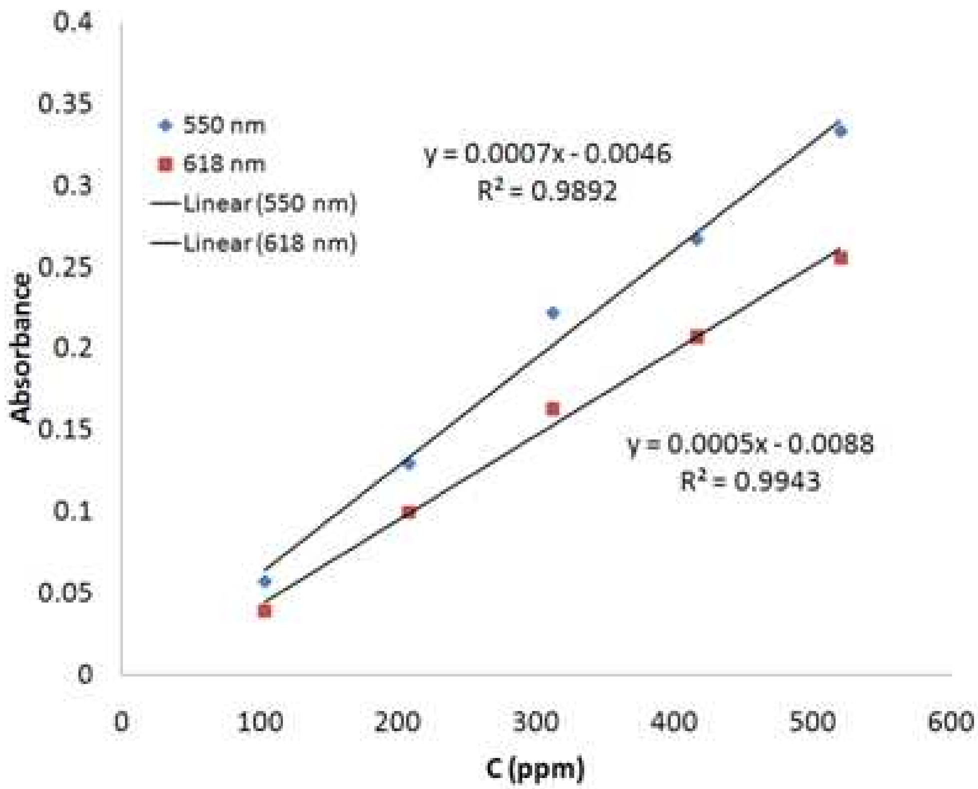
- PR response (C2=C, C1=0)

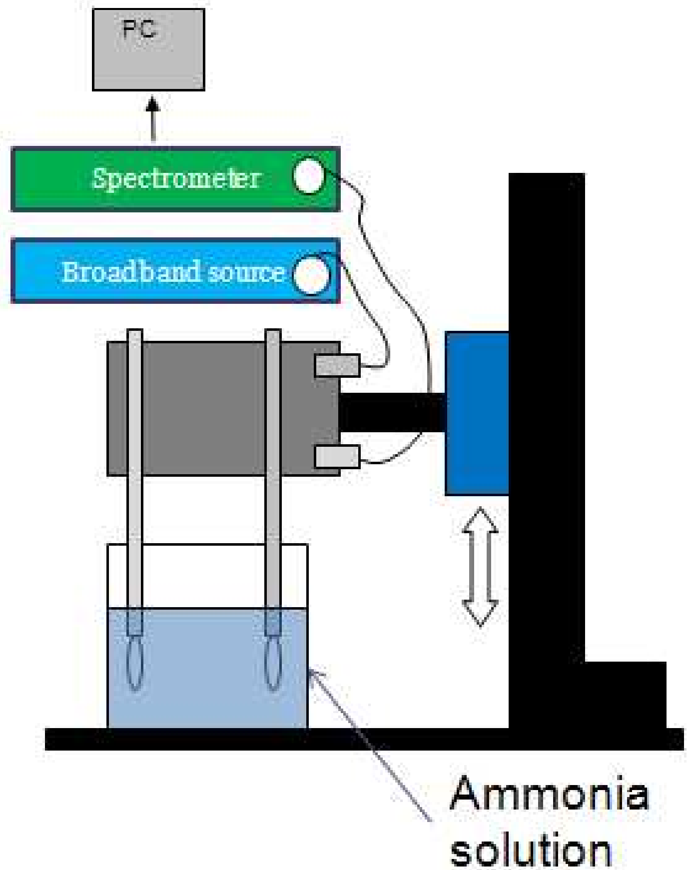




CMEOF Ammonia Sensor Array (Testing results)

- PR +BG (C1=C2=C)





CMEOF Ammonia Sensor Array (WDM-LSE results)

- PR + BG (C1=C2=C)
- WDM-LSE:

$$A_{618\,nm} = 0.0006C + 0.0295$$

$$A_{550\,nm} = 0.0008C + 0.0241$$

- Actual :

$$A_{618\,nm} = 0.0005C + 0.009$$

$$A_{550\,nm} = 0.0007C + 0.005$$

- 17% maximum error between experimental WDM-LSE results

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Sources of error

- Hysteresis
  - residual ammonia gas trapped behind gas-permeable membrane (GPM) layer
- Variability of GPM layer
  - Currently air dried
  - Curing oven should increase the stability
- Variability in ammonia concentration
- Small number of sensor elements in LSE
  - Increase the number of sensor elements

Conclusions

- On-line monitoring of water borne containments utilizing CMEOF chemical sensor array is feasible
- Demonstrated that a 2-element CMEOF ammonia sensor array is able to detect dissolved ammonia gas at two locations along the length of an optical fiber
- The WDM-LSE interrogation and signal processing routine quantified dissolved ammonia gas to within 17% of actual concentration values.

Conclusions

- The accuracy of WDM-LSE routine can be increased by adding more sensor elements and improving the GPM layer
- Further work is required to characterized the dynamic response of CMEOF sensor array in water piping network

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