Improved Method for Iron Detection with Colorimetric Sensor

Ngan Anh Nguyen
Advisor: Erica Forzani & Gregory Raupp & Margaret McCaul & Aoife Morrin
Program: IRES
Date: August 1\textsuperscript{st}, 2022
Location: ASU/DCU
Agenda

- Introduction & Background
- Development of Iron Sensor
- Results: Improved Approach for Color Detection
- Platform Based On Microfluidics For Potential Iron Detection
- Conclusion
Introduction & Background
Physiology of Iron Metabolism

Maintain iron stores

Iron metabolism proteins

Iron Stores
- Males: 600-1000 mg
- Females: 200-300 mg

Abnormal iron metabolism

Iron Deficiency
Iron Overload
Iron deficiency & iron overload

- **Iron deficiency** leads to **anemia**
  Iron deficiency is the number one nutritional disorder in the world

- **Iron overload** is closely related to **hemochromatosis**

  Hemochromatosis is mostly prevalent in European Countries and US
Current diagnostics

- Expensive
- Time-consuming
Need for Point-of-care screening device

Iron Deficiency

50 ug/dl

POC screening device

Iron Overload

150 ug/dl

Iron deficiency

Iron overload

Early screening $\rightarrow$ Intervention $\rightarrow$ Prevention
Development of Iron Sensor
Developed sensor

Layer 1: Nylon

Layer 2: Fiberglass

Layer 3: Asymmetric Polysulfone

Layer 4: Hydrophilic nylon

50 uL sample

Reference

Layer 1
Layer 2
Layer 3
Layer 4

Colorimetric reaction for iron detection

$\text{Fe}^{3+} \xrightarrow{pH<5} \text{Ascorbic Acid} \xrightarrow{} \text{Fe}^{2+}$

Chelating agent ferene

Ferene-iron complex

Visible spectrum
UV-Vis spectrophotometry
Golden standard method

Wavelength (lambda) vs. Corrected Absorbance

$\lambda_{\text{max}} = 590 \text{ nm}$
Limitations of previous work

- Required a sensing chamber
- Required consistency of light
- Required same phone model
Preparation

3D printed sensors

Cut membranes using laser cutter
Improved Approach for Color Detection
Approach for color normalization under effect of different lighting

\[ \text{Corrected abs} = \frac{\text{Abs}_{\text{sensing area}}}{a} \]

Controlled light

Uncontrolled light

1

2
Method to validate sensor measurements

Agreement on iron concentrations?
Absorbance from Spectrophotometer

Absolute calibration curve

CV=1.6% (N=3)

Spectrophotometry calibration curve

Absorbance at Wavelength 590nm

\[ y = 0.0013898x \]

\[ R^2 = 0.9999827 \]
Tested sensors with different color scale

Iron concentrations from left to right: 0 50 100 150 300 500 ug/dL

- **BLUE**
- **RED**
- **GRAY**
- **GREEN**

Compare the correlation plot with spectrophotometry

Sensor with **Blue** reference areas shows most accurate results
Correlation Plot for Blue Reference

Correlation Plot for C = 0 ug/dL

Correlation Plot for C = 50 ug/dL

Correlation Plot for C = 100 ug/dL

Correlation Plot for C = 150 ug/dL

Correlation Plot for C = 300 ug/dL

Correlation Plot for C = 500 ug/dL
Absorbance for Blue Reference

Sensor calibration curve (controlled light)

\[ y = 0.0003631145x + 0.0278063686 \]
\[ R^2 = 0.998895536 \]

Correlation plot of sensor vs. spectrophotometer

Normal clinical range
Implement 5 Blue Reference Areas

- Controlled light (Anh)
- Uncontrolled light, uncontrolled distance
  - Emily
  - Anh
  - Amber
Correlation plot - For 5 Blue Reference Areas

Correlation Plot for C = 0 ug/dL

Correlation Plot for C = 50 ug/dL

Correlation Plot for C = 100 ug/dL

Correlation Plot for C = 150 ug/dL

Correlation Plot for C = 300 ug/dL

Correlation Plot for C = 500 ug/dL
Absorbance if having **5 Blue Reference Areas**

Controlled picture taken with Anh’s phone
Emily: Iphone
Anh: Samsung galaxy
Amber: Samsung Note

Suggested that, any uncontrolled sensor should be taken along with a blank sensor to correct.
After intercept correction

Controlled picture taken with Anh’s phone
Emily: Iphone
Anh: Samsung galaxy
Amber: Samsung Note

Concentration correlation plot

\[ y = 1.1922x + 50.1642 \]
\[ R^2 = 0.99588 \]

Normal clinical range

Concentration correlation plot after intercept correction

\[ y = 0.95385x + 4.25073 \]
\[ R^2 = 0.99888 \]

Normal clinical range
Platform Based On Microfluidics For Potential Iron Detection
Figure 1: Fluidic chip

Figure 3. (A) Exploded render of the microfluidic chip showing (1) the clear PMMA optical windows at each side of the optical channel; and (2) the top PMMA layer with the milled reagent/sample inlet and waste outlet. (B) Render of the microfluidic chip custom 3D printed alignment rail and sliders with detector components. (1) 375 nm UV LED; (2) photodiode; (3) LED slider; (4) photodiode slider; (5) microfluidic chip mount and alignment rail; and (6) microfluidic chip. (C) Image of the fluidic chip integrated into the alignment rail.

Getting Started with Fluidic System via Ocean Optics

- Light source
- Sampler holder
- 3D printed cover for cuvette
- Spectrophotometer
Projected Results from Ocean Optics

Spectrophotometer

Spectrum Scan for C = 100 ug/dL

Absorbed at 594 nm

Ocean Optics

Spectrum View

Absorbed at 594 nm

Choose LED with dominant wavelength
Conclusion

- This work built on previous work and developed an improved approach to accurately detect iron levels regardless of lighting and distance conditions.

- Developed a method for sensitively sensing color of any colorimetric reaction involving different analytes.

- Discovered a platform based on microfluidics for potential iron detection in water.
Overall Experience & Future Research
Questions?

My work email: annguye6@asu.edu
Thank You!