College of Engineering - School of Chemical, Biological, and Enviromental Engineering

COvered - Carbon Monoxide Sensor and Mask

Bioengineering Capstone Design, Winter 2022, Group 7 - Jordan Oliver, Thomas Close, Lucas Lundy, Sam Melvin, Christopher Clairmont

BIOE.07

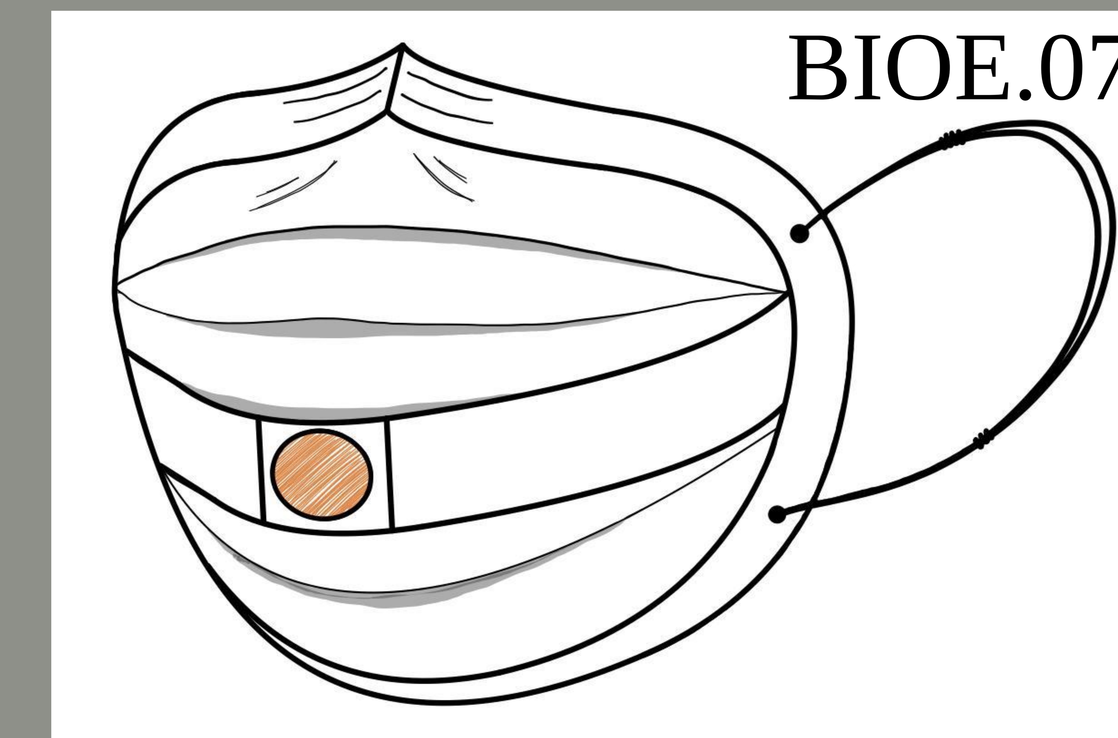

Figure 8: An illustration representing our final mask design incorporating the sensor that utilizes the ruthenium complex for CO detection.

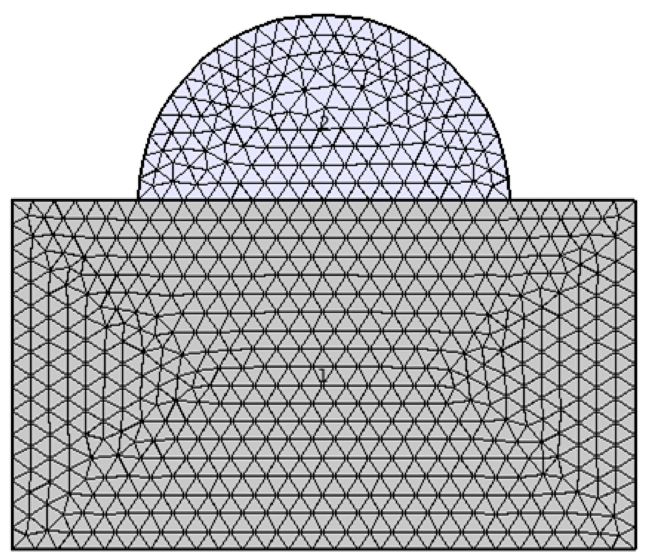

Figure 1: 2D COMSOL Analytical mesh. 56 µm membrane made to represent mask layer, with a liquid droplet/gas pocket found at the surface of the mask to simulate liquid penetration resistance/gas fluid flow through mask layers.

Figure 3: The Medline analogous carbon dioxide sensor used in modeling. The purple shows the base state, and the yellow represents increased concentration of carbon dioxide.

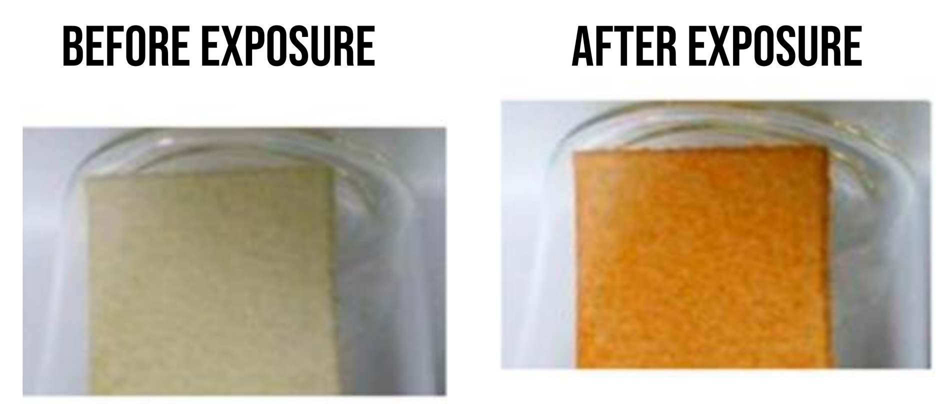

Figure 5: The color change for the ruthenium(II) complex (source). The yellow on the left shows the complex before exposure to CO, and the orange on the right shows the complex after exposure to CO. This is the color change we can expect on the COvered mask.

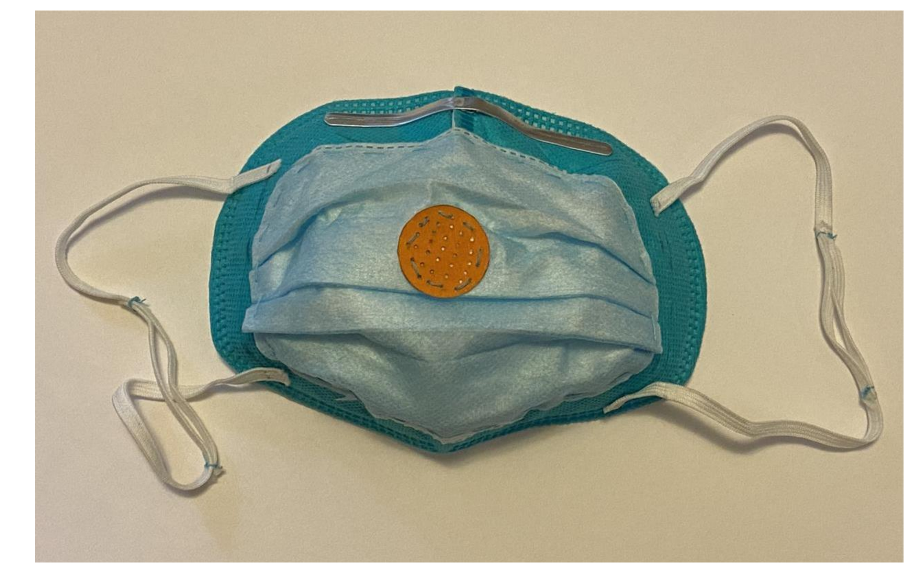

Figure 7: A physical prototype of our final design using N95 and surgical mask components, adjustable straps, and a paper substitute for the ruthenium complex.

Opportunity

- 430 people die each year in the U.S. due to carbon monoxide (CO) poisoning and 50,000 are hospitalized.
- CO is colorless, odorless, tasteless, and non-irritating making it difficult to assess the danger it poses when in an environment with a high CO concentration.
- Symptoms include headache, dizziness, weakness, upset stomach, vomiting, chest pain, and confusion.
- CO poisoning can lead to loss of consciousness and even death.
- Current solutions include CO sensors and face masks, but neither meet both criteria of protecting against respiratory hazards in the environment and alerting the user to dangerous levels of CO.

Ruthenium II Complex

- A coordination complex that emits a visible colorimetric change when it binds to Carbon Monoxide.
- It can detect carbon monoxide from one part per billion up to 100 parts per million, well within the range of use for our product.
- Testing shows a very small amount of the complex would be needed to make a visible reaction at this level, offsetting the cost of using the complex.

Final Prototype

- The final device is portable and hands-free as well as easy to operate.
- Color change occurs over an 8-10 hour period within the OSHA permitted range of exposure.
- Comfort, fit, and aesthetic were at the forefront of mask design.
- The device tracks ambient carbon monoxide exposure and notifies the user via an easily detectable color change from orange to yellow.
- Device cost makes it accessible.

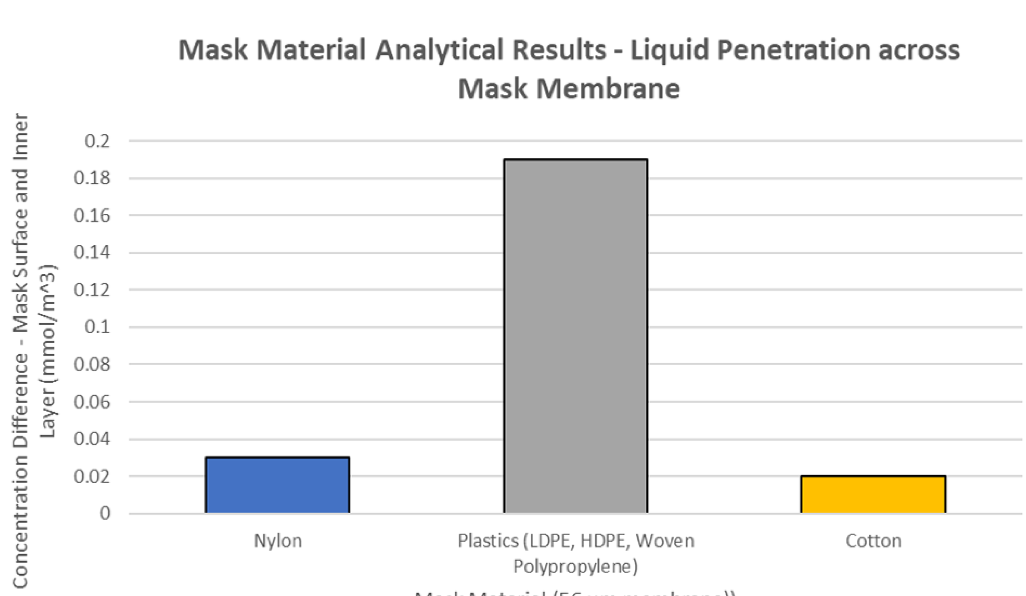

Figure 2: Displays the results of a COMSOL model addressing different material properties and concentration difference across the mask. Results indicate plastics are the best material for the outer layer of the mask for droplet protection.

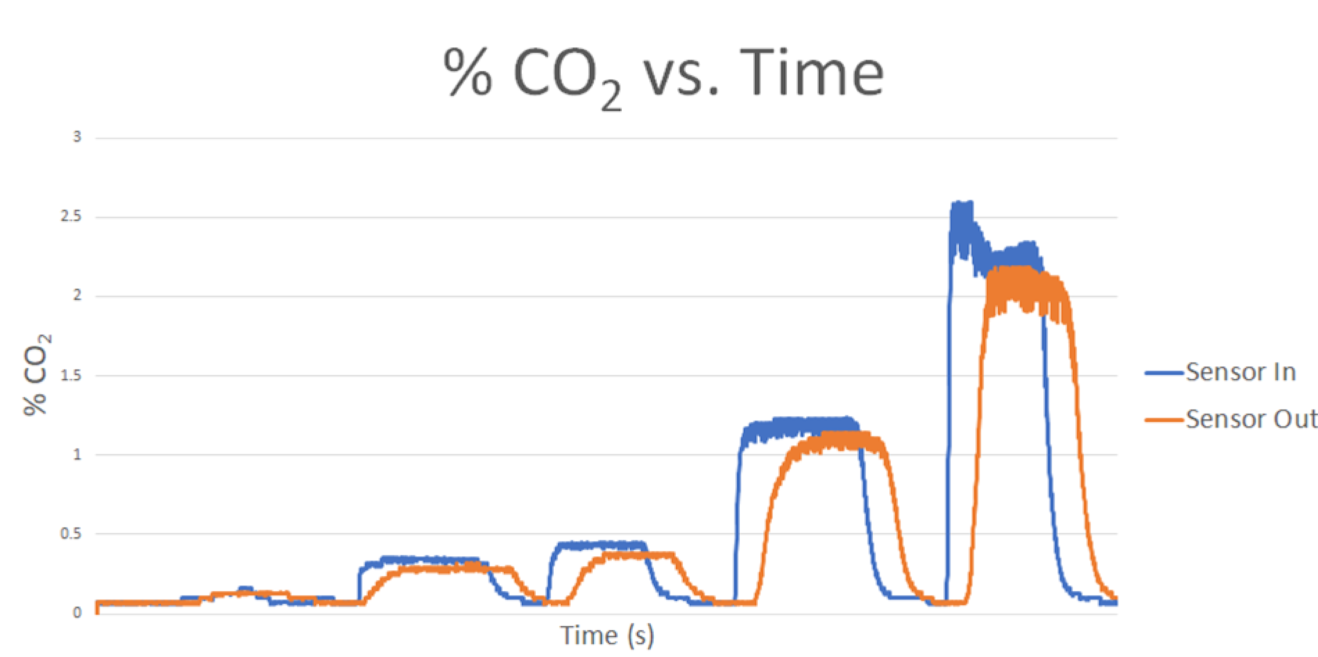

Figure 4: A visual representation of the concentration of CO_2 that was achieved to test the colorimetric portion of COvered.

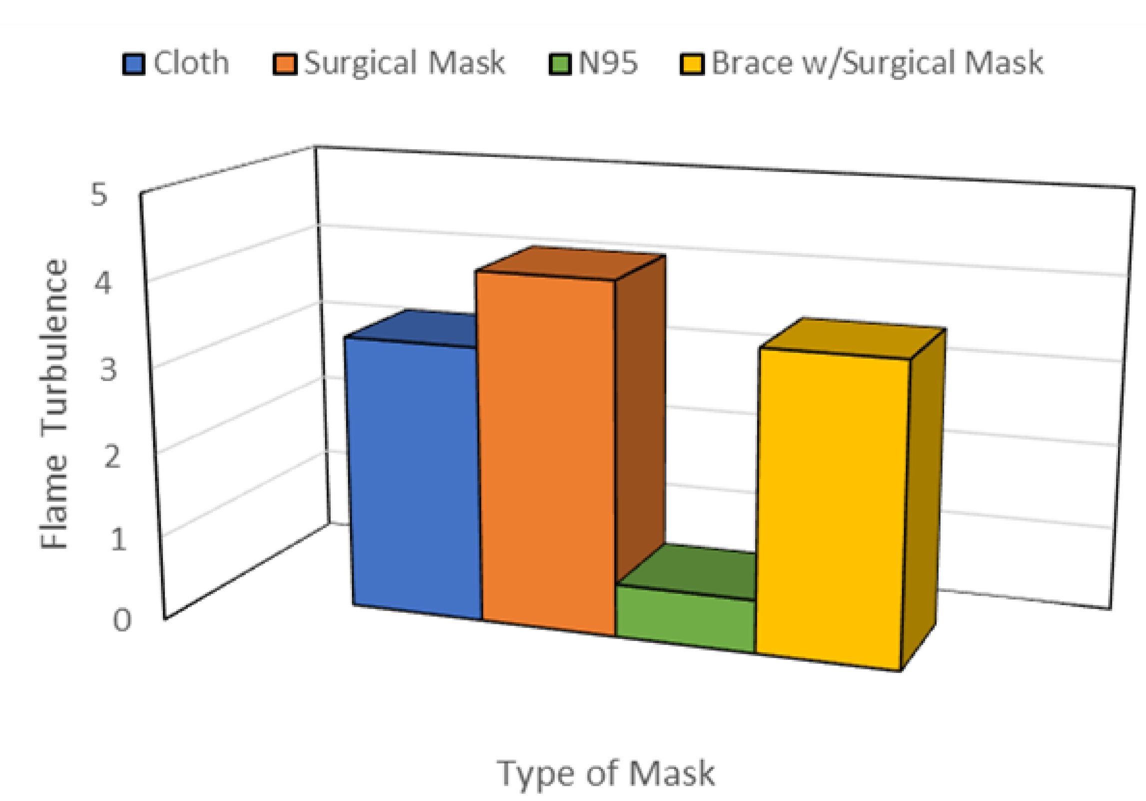

Figure 6: Shows results of the flame-mask resistance test. Low flame turbulence corresponds to increased mask resistance and protection. Results indicate the N95 offered the most protection based on the test.

Discussion

Experimental procedures for all three models were comprehensive, though difficulties did arise in several models, including:

Model #1: COMSOL fluid-flow analysis software inadequate for mass transfer and heat transfer across our reactive surface

Solution: Utilize the more modern COMSOL V6

Model #2: CO2 gas clinging in the gas flow experiment

Solution: Utilized a sequential Purge/Flush process in prototype experimental SOP

Conclusion

Through the use of our analogous carbon dioxide adsorption experiment, and our realistic reaction-rate analysis for Ru(II), the initial model of the COvered mask is validated, and we are able to proceed with more costly platinum-group metalloid canary indicators for final model experimentation

Future Work

- DFM: Design for manufacture
- Parameterization of color change with ruthenium-based compound
- Alternative chemiluminescence sensor testing

Acknowledgments

We would like to acknowledge John Cochran for providing lab space and consultation with the analogous sensor experiment. We would also like to thank Dr. Baio for continuous support and consultation on different product design concepts and features, Dr. Rorrer for assistance in initial conceptualization, and Dr. Geoghegan for help troubleshooting Solidworks and COMSOL.

Finally, our team would like to recognize all survey and interview participants, who were instrumental in the design process.

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