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Underwater Ant House

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CAPSTONE DESIGN EXPO 2017

Project

Design and test a submersible superhydrophobic mesh enclosure intended to sustain small air-breathing animals via oxygen diffusion over a direct air-water interface.

Background

Hydrophobicity is a property that minimizes the interaction between water and a material's surface. This allow for behavior not typically possible such as self cleaning materials and enhanced bouyancy.
By coating a mesh with a superhydrophobic spray, it is possible to withstand moderate water pressures despite the holes in the surface. Because of these properties, a hydrophobic mesh structure to achieve high levels of water resistance with very little material.

As the mesh is not a solid surface, it leaves direct contact between the air and water on either side. Depending on the ratios of concentration in these two fluids, diffusion can transfer oxygen across this interface. If oxygen content on the air side of the barrier decreases, by respiration or some other process, it may be possible for that consumed oxygen to be resupplied by the water.

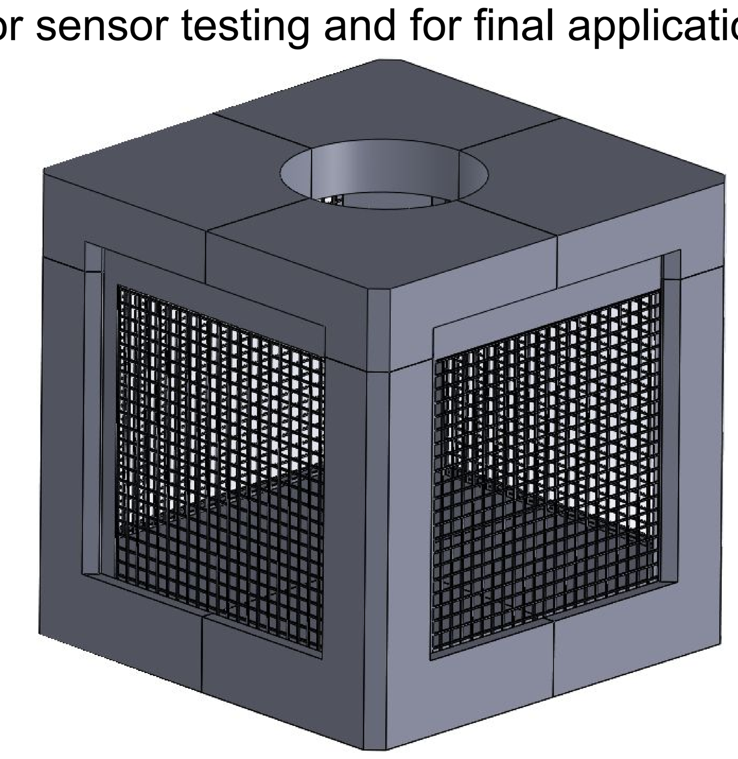
Design

Goal:
Utilize the possibility of a direct air-water interface by a superhydrophobic coated mesh to create an enclosure which can be fully submerged and maintain a breathable oxygen concentration.

Mesh:
As the primary component of the design, the mesh was chosen with a variety of considerations:

- Manufacturability
- Speed of Production
- Coating Quality
- Hydrophobicity
- Price
- Sizing
- Consistency
- Transparency

Enclosure:
The enclosure was designed to hold the mesh components and keep its contents from risking the integrity of the interface at the mesh's surface. It was important to ensure that it facilitated testing and minimized leaks. Separate versions were created both for sensor testing and for final application.



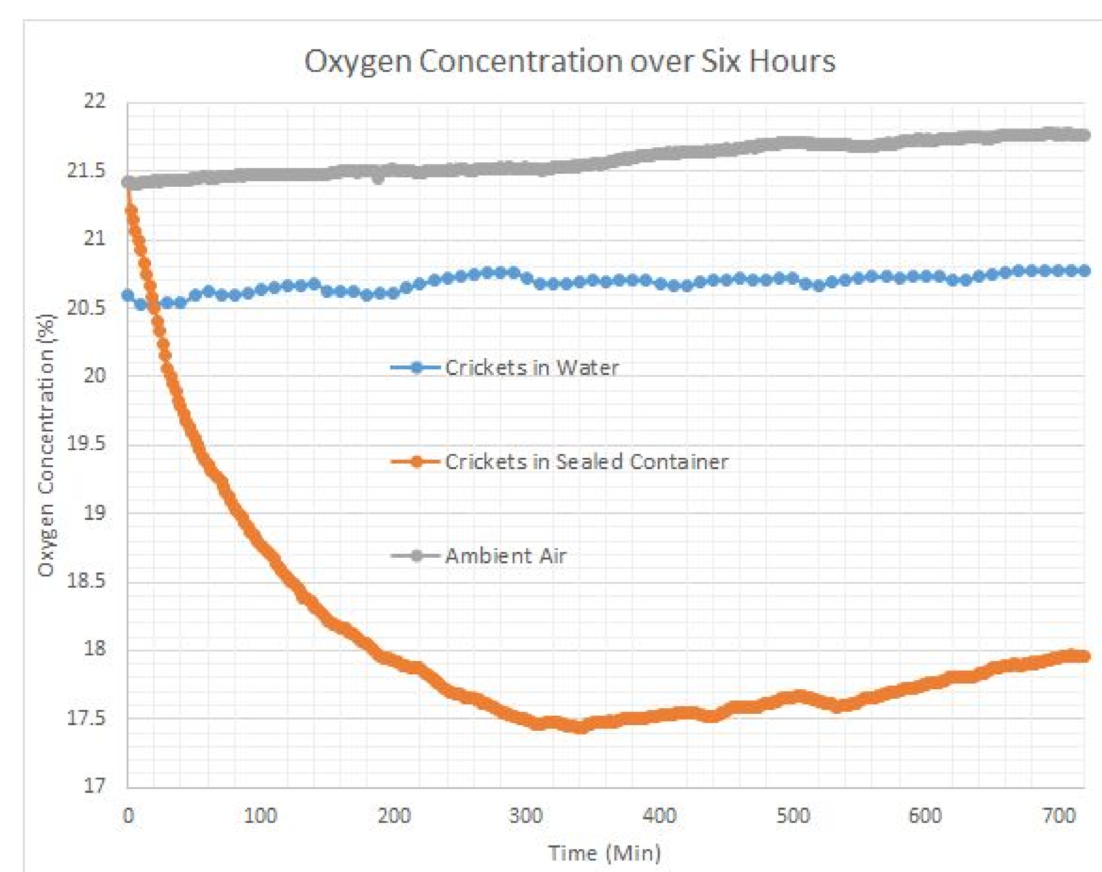
Analysis

Mesh Function:
In order to ensure consistent function, the mesh slides were tested extensively:

- Breakthrough Pressure
- Spray Quality and Contact Angle
- Influence of Gap size

Oxygen Transfer:
A specialized sensor was used to measure the concentration of oxygen under multiple conditions. These focused on testing of sustained life and oxygen diffusion.

- Extended Duration Trials
- Live Tests with Crickets
- Water Oxygen Concentration



Conclusion

- When submerged with live crickets, the oxygen levels reached a state of equilibrium approximately one percent less than ambient air. This is a significant improvement compared to a sealed container where the oxygen levels deplete rapidly. The collected data supports the original theory and demonstrates that the design functions as intended.
- A 3D printed design allows for greater ease of manufacture and diversity of designs but thin parts are prone to warping.
- Under normal conditions with good mesh quality the enclosure can be submerged to about three inches.

Future Improvements

- Larger and more detailed structure
- More detailed analysis of oxygen diffusion over complex geometries.
- Higher contact angle coating and more detailed mesh.