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Measuring Zeolite Thermal Conductivity for Carbon Dioxide Adsorption Systems

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Background

The Carbon Dioxide Removal Assembly (CDRA) currently aboard the International Space Station (ISS) is a critical component of the air revitalization system in the Environmental Control and Life Support System (ECLSS). The CDRA operates by employing a zeolite material that adsorbs carbon dioxide (CO_2) from the cabin air and desorbs it downstream from the cabin for further processing, ensuring CO_2 levels at 2 mmHg[1]. The low thermal conductivity of zeolite reduces the heating rate of the temperature swing cycle and increases power requirements.

Table. 1 (Left to right) Thermal Conductivity of Common Materials

Material	Thermal Conductivity
Zeolite[2] (Grace Davidson 554)	0.1 W/mK
Fiberglass[3]	0.04 W/mK
Copper[3]	401 W/mK

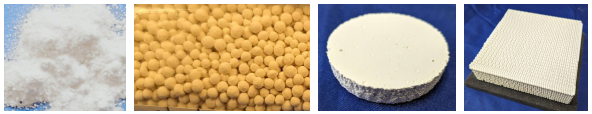

Fig. 1 (Left to right) Zeolite powder, Zeolite pellets, Zeolite solid, Zeolite 3D Printed Lattice

Objective

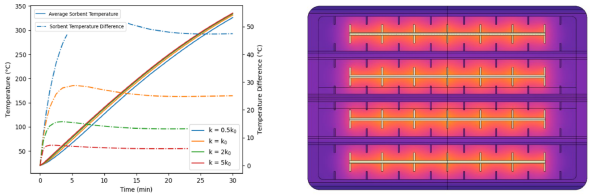

Fig. 2 (Left) Simulated temperature differential in a Zeolite Chamber per thermal conductivity. (Right) Temperature differential within a Zeolite Chamber. The far edges of the Zeolite are unable to get hot enough for rapid desorption.

- Establish methods for testing of Zeolite formulations and set up for future work to increase the thermal conductivity of the Zeolite.
- Measure the thermal conductivity of various Zeolite 13X formulations.
- Study formulations that will increase temperature uniformity of air revitalization systems, allowing for fewer heaters and thus a reduction in mass and volume.

Testing Methodology

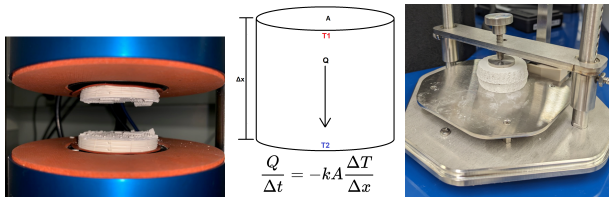

Fig. 3 (Left) Hot Plate thermal conductivity testing on a TA Fox 50. The top plate heats samples while the bottom cools creating a gradient. (Middle) Heat flows through a material based on thermal conductivity. (Right) Transient Plane Source testing apparatus on the Thermtest MP-1. A sensor placed between two samples pulses heat to measure conductivity.

- The flow of thermal energy through any material is governed by the thermal conductivity *k*, seen in Fig. 3.
- There are two commonly used classes of methodology for thermal conductivity measurement: Steady State Analysis and Time-Domain (Transient) Analysis:
  - Steady State Heat Flow meters such as the Fox 50 from TA Instruments measure thermal conductivity by creating a constant temperature gradient over a sample and measuring the thermal energy needed to sustain the gradient[4].
  - The Transient Plane Source method utilized by Thermtest's MP-1 measures conductivity by applying heat to a material and studying the temperature as a function of time[5].
- These methodologies are the most capable of measuring thermal conductivity in the range of Zeolite (approximately 0.1 W/mK) through the span of temperatures used in an air revitalization system (0 - 200°C)[6].

Results & Discussion

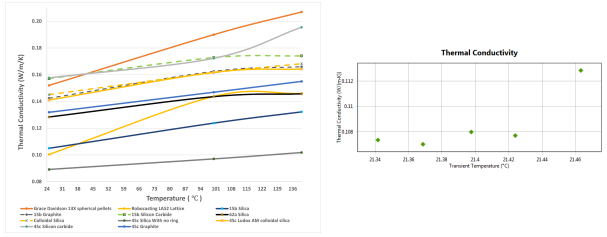

Fig. 4 (Left) Thermal conductivity recorded on the Fox 50 of a variety of Zeolite formulations. (Right) Thermal conductivity of Zeolite LA52 formulation on the Thermtest MP-1.

- Testing with the Hot Plate reveals thermal conductivity for most formulations of Zeolite in the 0.1 - 0.2 W/mK range. The pressure applied during these tests typically destroys the sample due to its brittle nature.
- Utilizing the Transient Plane Source method averages results at 0.108 W/mK at room temperatures. This method provides higher precision with capabilities for a wider range of temperatures.
- Currently, the MP-1 is being set up to provide thermal conductivity measurements varying from room temperature up to 200°C on a multitude of formulations. This data allows for mathematical models to accurately simulate the CO_2 capture process.

Conclusions & Future Work

The Thermal Conductivity measured by both the MP-1 and Fox 50 align with previous measurements from Honeywell[2]. Due to the thermal conductivity of zeolite being much lower than many other materials there is a lot of potential for future formulations / configurations to greatly increase the overall conductivity.

- Additives such as graphite, copper, and others will be tested with these methods seeking to improve the thermal conductivity of future sorbents.
- New zeolite configurations such as 3D printed lattices and embedded heater wire will be tested to increase the thermal conductivity of the overall system and reduce equivalent system mass.

References

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