GAS SENSING

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Redesign,Construction & Validation of a Sensor Testing Apparatus

Background & Importance

Chemical residence sensors are small, solid-state devices that can be used to detect gases in various environments. Today many researchers are focusing their attention on metal oxide chemical residence sensors in hopes of developing cost effective, efficient and highly sensitive models that will work in various environments; from common households to industrial plants. New chemical residence sensors and sensor materials must be tested and validated in a laboratory environment. This testing requires a special apparatus that can measure the response of the sensor as its environment is altered.

Chemical gas sensors

Solid-State Metal Oxide Semiconductor sensors are made up of layers of metal oxides evenly distributed on a ceramic substrate which has electrodes for making resistance measurements for testing purposes the sensor is kept at constant temperature by using a tubular ceramic furnace. When the metal oxide film is exposed to gas, the molecules are adsorbed along the surface, which alters the materials electrical resistance. Since electrical resistance of these materials is temperature dependent, the sensor must be maintained at constant temperature during operation. For most semi-conducting metal oxides, an operating temperature well above room temperature is necessary to the material to have a measurable resistance. For measurements, a baseline resistance is measured in background gas (such as Nitrogen or air), then the resistance in the presence of an analyte gas is measured and compared to the baseline response, Data is often reported as %Sensitivity versus gas concentration where:

$$\%S = \frac{Resistance_{Analyte} - Resistance_{Baseline}}{Resistance_{Baseline}}$$

Applications

- Semiconductor sensors are cost efficient, have a long life cycle and are sensitive yet stable. They are resistant to poisoning and can be used to detect a large range of gas molecules including all the CFC, HCFC, HFC refrigerants, ammonia and hydrocarbons.
- Mainly used to detect toxic gases, combustibles, and hazardous vapors in welding shops, mines, nuclear plants and wastewater treatment plants.

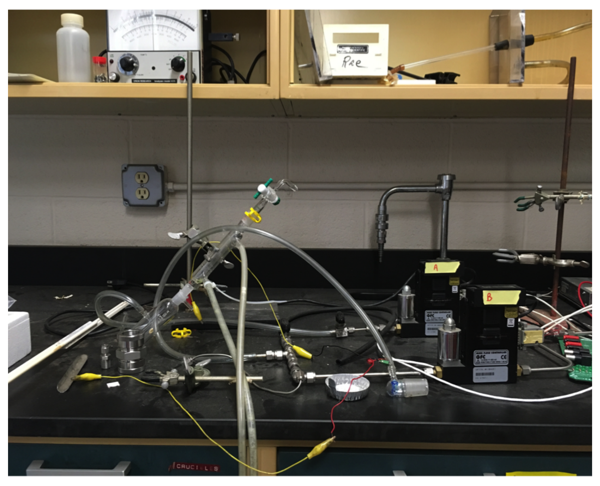
Original Design

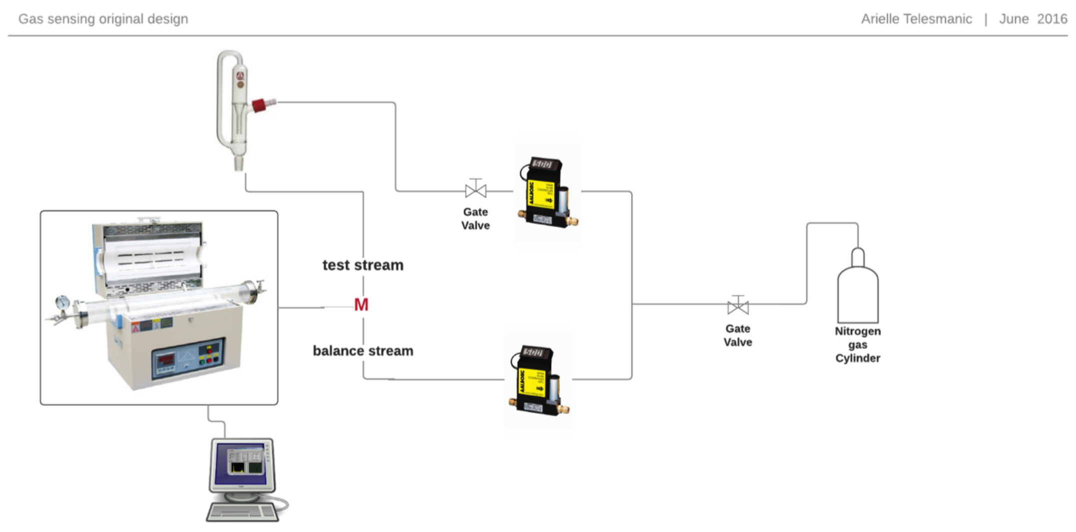
The project plan was to redesign the sensing apparatus built by a previous student. The apparatus consists of two main parts; a testing chamber housed within a high-temperature furnace, and a gas delivery system that consists of mass flow controllers monitored and controlled by a LabView generated software program. The testing chamber consists of an aluminum oxide platform that houses the sensor held within an aluminum oxide tube. Test-gas mixtures flow through the tube and over the sensor while the electrical response of the sensor is measured. To ensure that the sensor is only exposed to the test-gas mixture, the ends of the tube must be closed to the outside environment, yet have "ports" or "holes" through which the test-gas can be delivered and electrical connections to the sensor can be made.

In the original design, the end cap is a modified ground glass stopper.Four things to be considered in the cap design are that it:

I. can be easily removed and replaced so that at the sensor can be changed,
II. has a port for delivering the test gas to the sensor.
III. has a port for making electrical connections to the sensor
IV. Is able to hold the aluminum oxide platform in a stable position within the outer aluminum oxide tube.

The original gas delivery system is also flawed. The background, inert gas (air) did not mix well with the analyte gas. Without the proper mixing of the test stream and the balance stream the gas sensor was not exposed to the specified gas concentration.

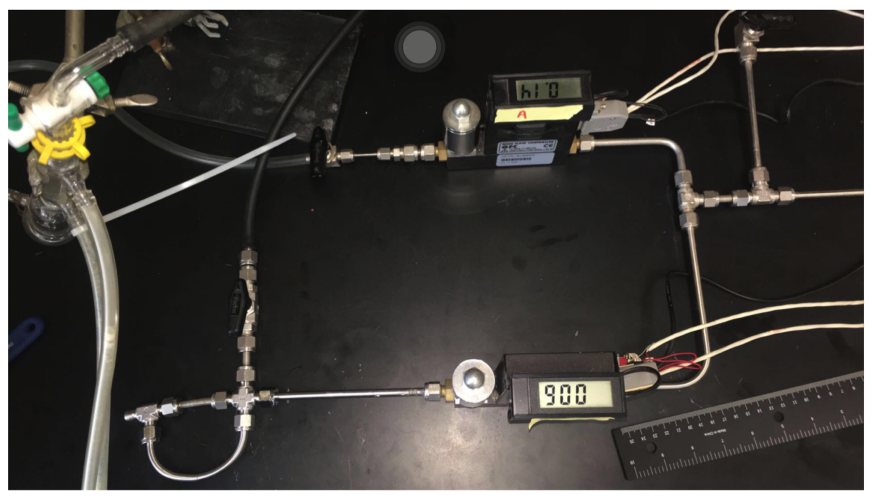


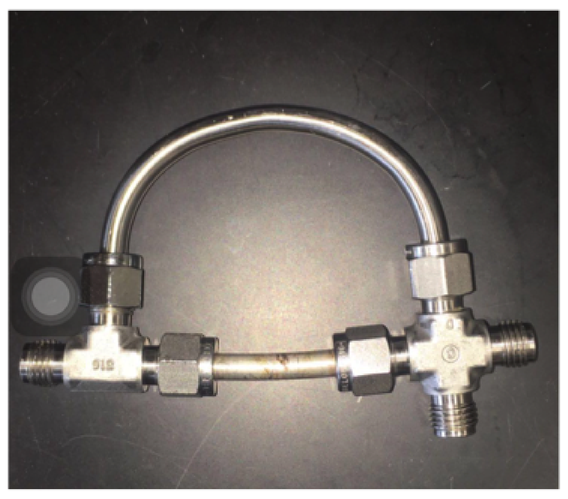


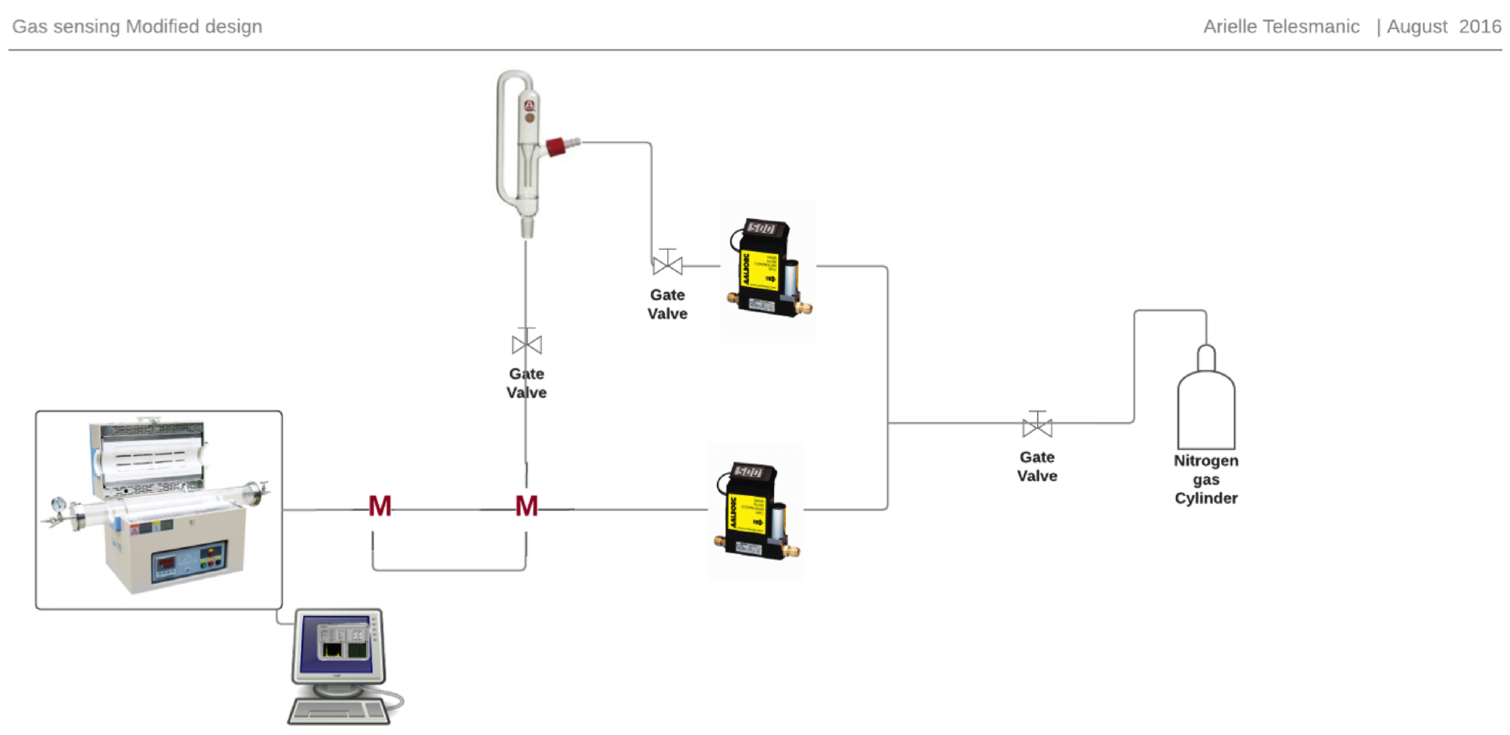
Redesign

In the original design, there was the issue of successfully mixing the balance stream and test stream together. This was due to the difference in pressure of the inert and test stream. The analyte gas was introduced at a a low flow rate and, due to the large pressure of the balance gas stream, would stop flowing and not mix with the balance gas.

The solution was to change the geometry of the gas tubing.Ideally the balance gas and analyze gas lines would come together in an inverted "Y" shape to allow for better gas mixing, but "Y" shaped, gas-tight fittings in stainless steel was not commercially available. While these pieces could have been machined, this would have been time-sensitive and potentially expensive. An alternate design, which combined a cross-shaped fitting and a T-shaped fitting was proposed and built. This allowed two opportunities for the balance and analyte gas before flowing over the sensor. This design will allow the two streams to mix with less friction experienced due to the piping bends in the design. Measurement of the gas flow rates of the two streams before and after mixing along with analysis of the final gas stream by gas chromatography, will be used to validate the design in coming weeks.







Future Work

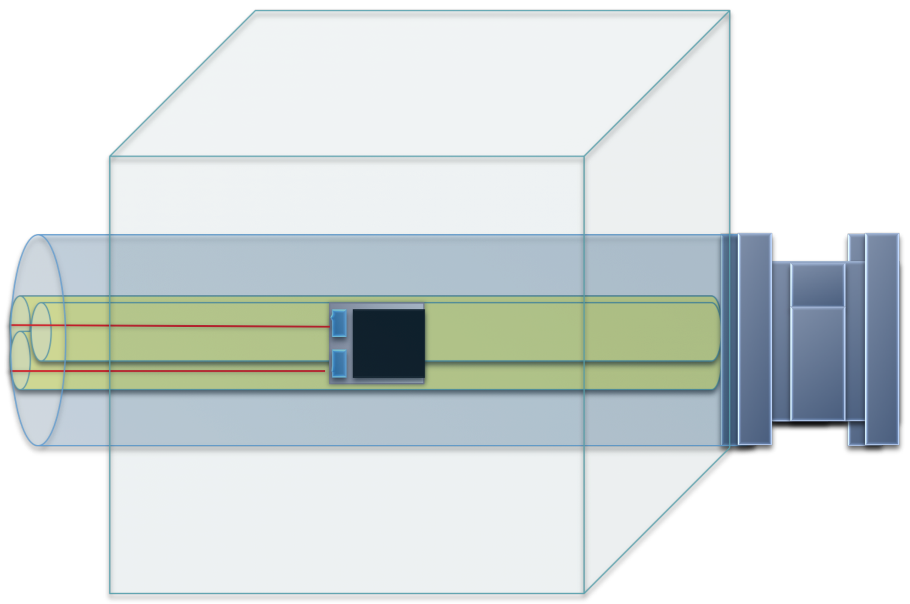
Additional modifications of the gas-sensing apparatus will be done during the fall semester. Two redesigned end caps will be constructed and installed on the test chamber.

One end cap will be installed at the outlet of the ceramic tube furnace utilizing a 1" to 1/4" reducer. This stainless steel reducer will vent the gas stream out of the test chamber.

The second end cap design is depicted in figure to the right. The design uses a stainless steel union fitting placed to make sure the instrument itself is user friendly when testing a sample. In order for the apparatus to be easy to use, the end cap will have ports for the gold electrical wiring, the sensor platform and the gas supply line. The fitting should be easily detached from the outer alumina tube so that the sensor can be accessed and changed. The design will allow ease of semiconductor replacement and rewiring.

Once both end caps are installed, the overall design will be tested using soap bubble leak test.

Additionally, the LabView software controlling the mass flow rates will be modified to incorporate feedback control loops for controlling the balance and analyte test gas streams.



Acknowledgement

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Sources:

OMEGA. (2015). *Sensor Theory of Operation What Makes Transducers and Load Cells Work?* (OMEGA) Retrieved from OMEGA.com: http://www.omega.com/technical-learning/pdfs/SensorTheoryofOperation_Article.pdf