THE APL VENUS ENVIRONMENT CHAMBER – SIMULATING VENUS SURFACE CONDITIONS. F. Lizano[1,2] and N.R. Izenberg[1], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD (noam.izenberg@jhuapl.edu) [2]Johns Hopkins University, Baltimore, MD (flizano1@jhu.edu).

Introduction: The APL Venus Environment Chamber (AVEC) is a reactor vessel designed to simulate surface temperature, pressure, and atmospheric composition conditions of the surface of Venus in the laboratory. AVEC is part of the Instrument, Concept, Evaluation Laboratory (ICELab) at the Johns Hopkins University Applied Physics Laboratory. It is designed to create a small volume of analog atmosphere at Venus surface temperature (465°C) and atmospheric pressure (92-95 bar) to enable testing of materials and simple sensors at ambient Venus surface conditions [1]. Tolerances of the chamber are designed to be ample (4000+ PSI and 500+°C). Temperature is monitored by a thermocouple located in a thermowell, and an additional thermocouple can be used inside the chamber itself. Pressure is monitored by an integrated transducer, limited to the nearest psi value (6894.76 Pa). The AVEC body is composed of Inconel with internal diameter of 6.35 cm and depth of 22.86 cm (thermowell depth of 15.24 cm), with a volume of ~700 ml. The chamber has a port for a feed-through for two wires to enable external monitoring of simple devices or prototype sensors inside the chamber.

AVEC is a static chamber that can be filled with custom gases to mimic the atmosphere of Venus at different altitudes, and temperature and pressure can be adjusted accordingly. The set temperature and pressure can be maintained for prolonged times (days to weeks). Samples for reaction experiments, and prototype simple instruments can be positioned in the chamber in a variety of appropriate holders (*e.g.,* ceramic), and instruments may be monitored in real time. AVEC is controlled by the Parker Autoclave "Universal Reactor Controller" (URC-II). The controller allows the user to adjust the temperature and pressure within the vessel tolerances. AVEC is a smaller, less capable, but easier to run experimental venue than the NASA Glenn Extreme Environment Rig (GEER) [2], which is used for more complex, large-scale experiments.

Past and Current Experiments: Temperature and pressure profiles returned from VEGA2 lander [3] and in *The Venus International Reference Atmosphere* [4] were used to create a model of the descent profile into Venus. It is important to note that the temperature – pressure profile of an AVEC experiment does not a mimic a descent through Venus atmosphere. The initial gas mixture is introduced at standard ambient temperature (21 – 23 °C) and filled to a pressure of ~ 553 psi (3.813 × 10^6 Pa). The chamber gets heated to Venus temperature, and we rely on the ideal gas law to achieve Venus pressure. We compare the temperature and pressure profiles for each experiment to the modeled descent profile, as well as an ideal gas law model (Fig 1). Using this, we look for pressure leaks, deviations from the linear ideal gas relation, and compare different experiment profiles to better understand chamber conditions.

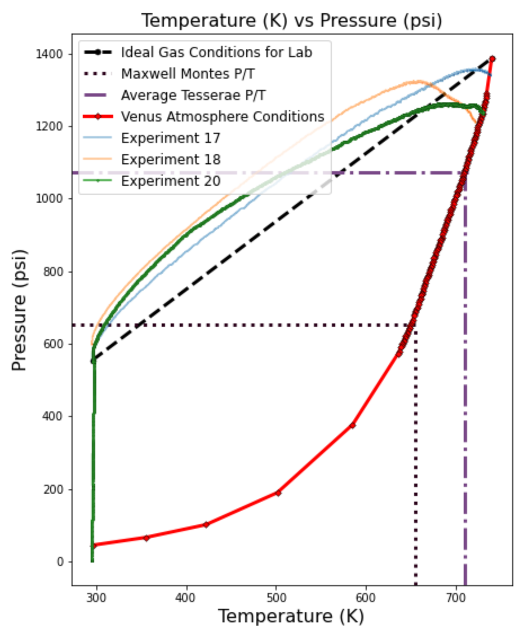

Fig 1. Pressure – temperature profiles of past experiments including the descent profile model, ideal gas model, and relevant Venus landforms

Currently, AVEC is working with four different investigations: Solid-state Electrochemical Micro-sensors for Atmospheric Nitrogen (SEMSAN); Venus In-Situ Mineralogy Reaction Array (VIMRA) (Fig 2); silicon-molybdenum alloy tests at Venus conditions for cooling and power systems; and an alloy exposure test for APL materials science. During pre- and post-experiment analysis, we use scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) to analyze samples and look for physical or chemical differences, namely changes in chemical composition, color, or mass. Below, we detail the results of a FeS (troilite) sensor from Makel Engineering before and after being placed in the chamber (Fig 3).

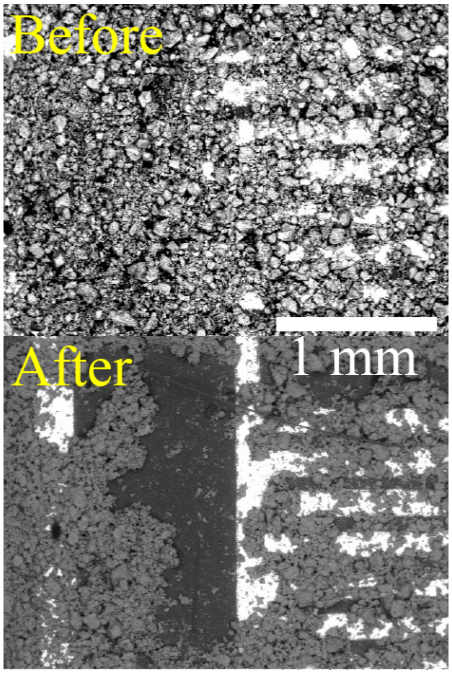

Fig 2. SEM images of a Makel Engineering sensor VIMRA project FeS pre- and post-experiment.

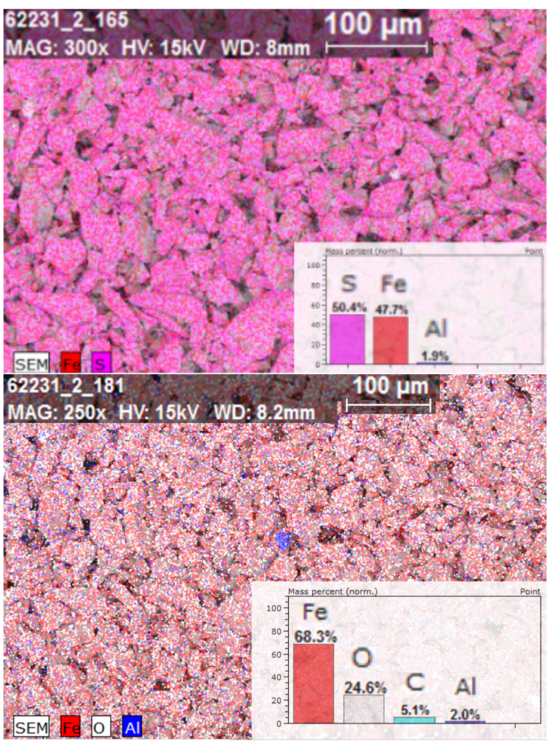

Fig 3. EDS maps and mass graphs of a Makel Engineering sensor pre- (above) and post- (below) experimentation.

It is known that the sulfur on Venus exists in equilibrium with troilite and pyrite [5]. FeS is oxidizable under the reaction:

$$FeS\ (s) + \frac{9}{4}O_2\ (g) \rightarrow \frac{1}{2}Fe_2O_3\ (s) + SO_3\ (g). \quad [1]$$

Iron can also undergo oxidation under the reaction:

$$3FeS\ (s) + 3CO_2\ (g) + \frac{1}{2}O_2\ (g) \rightarrow Fe_3O_4\ (s) + 3COS\ (g). \quad [2]$$

This experiment is the first conducted with a CO_2, N_2, SO_2 gas mixture that mimics the Venus environment more accurately.

Analysis of the EDS and SEM data shows a distinction in the chemical composition of the sensor. The sulfur present before experimentation has completely dissipated in post-experiment images, most likely due to the lack of equilibria with the environment. During this experiment, we filled the chamber with a gas mixture composed of ~19 psi house N_2, 206 psi of a CO_2/SO_2 mixture (125 ppm SO_2), and 356 psi of pure CO_2 to mimic the lower Venus atmosphere. The sulfur present on the sensor fails to stabilize with the minimal amount of SO_2 in the environment, causing for the elimination of all sulfur atoms from the sensor. It is most likely that there would need to be more sulfur in the environment for stability to reached; thusly, the sensors developed with sulfur present would not be suitable for prolonged exposure to the Venus environment. We observed physical changes as well – the top layer mineral was noticeably eliminated, exposing the underlying sensor.

Future Experiments: AVEC will continue to be utilized as a device for experimentally expanding the knowledge of Venus. Simulating the Venusian environment conditions and experiment with materials will lead to new or aid in in current scientific research regarding the planet. Current plans involve further testing of all three sample subgroups, as well as incorporating testing of the VfOx prototype for Goddard's DAVINCI+ mission.

The goal for AVEC is to be open to the community for scientists as an experimental tool for planetary research.

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