DEVELOPMENT OF THE VENUS IN-SITU MINERALOGY REACTION ARRAY (VIMRA) D. B. Makel, M. S. Gilmore, N. Izenberg, S. Carranza, and E. Kuang. Makel Engineering, Inc., 1585 Marauder St., Chico, CA, 95973 USA dmakel@makeengineering.com, Wesleyan University, Middletown CT, Applied Physics Lab, Laurel, MD.

Introduction. A high temperature sensor array to measure reaction chemistry of minerals with the gases in the Venus atmosphere is under development. The Venus In-Situ Mineralogy Reaction Array (VIMRA) Sensor Platform is a harsh environment sensor array suitable for measuring reactions of Venus gases with surface minerals using a platform which could ultimately be part of the science instrument payload for planetary landers such as the Long Lived In-Situ Solar System Explorer (LLISSE)[1]. The VIMRA sensor platform is being developed to accommodate a variety of minerals of interest on the surface of Venus. The current phase of work is developing and demonstrating the VIMRA sensor platform in Venus simulated surface environments using the Johns Hopkins University Applied Physics Laboratory (JH/APL) Venus Environment Chamber (AVEC)[2]. The objective is to demonstrate the capability of VIMRA as a sensing platform to measure the type and rate of gas-solid reactions by monitoring electrical properties of thick films of an array of known and well-characterized minerals under controlled Venus-relevant atmospheres and thus constrain type and rate of atmospheric gas interactions with selected minerals.

Concept Overview: The VIMRA sensor platform is a potential component of the Venus Surface Mineralogy In-Situ Instrument System (V-Lab). V-Lab is a proposed in-situ reaction chemistry experiment where known geological materials will be placed on a microsensor platform. Changes in each geological material are monitored through electrical measurements of redox solid-gas reaction(s) in the Venus environment. Oxidation and sulfidation are the major likely reaction pathways of solid materials with the Venusian atmosphere[3]. These processes are related to key components of the Venusian atmosphere and can provide information about many important aspects of the solid surface (e.g., oxidation state of iron and other multivalent cations, mineral stability, etc.). This information is important to understanding the Venusian crust and its evolution. The VIMRA sensor platform is intended to ultimately be used in combination with chemical microsensors used to measure trace atmospheric gases[4] and SiC electronics under development by NASA to provide a high temperature capable payload suitable for extended operation on the surface of Venus[5].

VIMRA Development Progress: The initial phase of work is focusing on the design and demonstration of the mineral sensor platform which features high purity mineral samples deposited over sensing electrodes to facilitate real time measurement of changes in electrical and chemical properties as the mineral samples interact with simulated Venus atmospheric gases. The high surface area mineral layers derived from pure powder forms of the minerals of interest are deposited with thick film printing process over precisely formed gold electrodes on the sensor substrate as shown in Figure 1. The intent is to design a high sensitivity platform for mineral/gas interaction measurements so rates can be determined within expected lander operational time frames (up to 120 days). Initial proof of concept testing of the VIMRA platform was conducted in 2018 at the NASA GEER facility for 30 days at Venus surface conditions[6]. Pre and post-test measurement of both pure mineral samples and the FeO sensors showed measurable changes in electrical properties which correlate to chemical changes in the minerals.

![Prototype VIMRA Sensor Element Combines Mineral Sample with Precision Electrodes.](image1)

Prototype mineral sensors have been fabricated with powdered (5-50µm) forms of hematite (Fe₂O₃), magnetite (Fe₃O₄), troilite (FeS), pyrite (FeS₂), hydroxyapatite (Ca₅(PO₄)₃(OH)), pyroxene ((Ca,Na)(Mg,Fe,Al,Ti)₃(Si,Al)₂O₆) and olivine ((Mg, Fe)₂SiO₄). All mineral powder samples and fabricated mineral sensor platforms are measured with an ASD FieldSpecFR spectroradiometer operating over the visible/near-infrared (VNIR, 350-2600 nm) at Wesleyan University. VNIR spectra of the samples show that the fabrication process causes some dehydration of the samples, but that other major spectral features are preserved (Figure 2).

Sensor platforms are currently being tested at the AVEC facility at simulated Venus surface conditions. Post-test analysis of samples including VNIR, SEM/EDX and electrical measurements is ongoing and will be reported. Figure 3 shows photographs, and
scanning electron microscope (SEM) images of three VIMRA test chips before heating in AVEC, and SEM images post heating. The ~4 hour experiment experiment achieved a maximum temperature of 465°C with a pressure of 356 psia (2.54 MPa) of laboratory grade CO₂ gas. While the Magnetite and Troilite samples were largely unaffected, the Pyrite sample clearly experience gas-solid reactions resulting in loss of most of the chip coating. Current testing is proceeding at full Venus surface temperature and pressure conditions with real-time electrical measurements of conductivity and impedance.

Figure 2. VNIR spectra of hematite (Fe₂O₃) powder, both unprepared and applied to circuits using two different fabrication methods

Figure 3. Pilot VINRA samples in AVEC test.

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