FIREFOX – AN OXYGEN FUGACITY SENSOR FOR VENUS. Noam R. Izenberg, Stergios J. Papadakis, Andrew H. Monica, and David M. Deglau, Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723, USA. Noam.izenberg@jhuapl.edu #4008

Introduction: FirefOx is a Metal/Metal Oxide oxygen fugacity sensor to be mounted on the outside of a Venus descent probe or lander, with electronics to be housed inside a thermally controlled environment. It is a simple, low power and cost sensor derived from common industrial and off-the-shelf ceramic oxygen sensors, with the express purpose of determining the partial pressure of oxygen in the lowest scale heights of the Venus atmosphere, and especially the lowest hundreds of meters and the surface-atmosphere interface, where the atmosphere and surface move to thermodynamic equilibrium.

The primary sensor capability is the detection of the partial pressure of oxygen gas (fO_2) in the near-surface environment of Venus, so the sensor must operate in the 710-740K temperature range and at up to 95-bar pressure (predominantly CO_2) for sufficient time to obtain a precise, accurate measurement. The baseline sensor objective is survival for at least two hours at Venus surface conditions, and produce accurate measurements (fO_2 to 0.5 +/- 0.5×10^{-24} within the range of 10^{-18} to 10^{-24}) at a temperature range between 710 and 740K. Mean planetary elevation has a temperature near 735 K, and the operational temperature range covers a range of potential landing elevations. FirefOx requirements are low (~100-200 grams, milliwatt power, several kilobytes total sicence data), while its potential science return is high.

Importance of Oxygen Fugacity Knowledge: Oxygen is a trace gas in the lower atmosphere of Venus, controlled by the CO-CO_2 chemical equilibrium. At mean planetary radius and temperature of ~740 K, fO_2 is calculated to be ~ $10^{-21.5}$ bars [1,2]. Lower actual CO values at the surface (i.e. below the 20 ppm measured at 22 km), oxygen fugacity would be higher. Observational and theoretical constraints suggest a CO abundance of 3-20 ppm at the surface of Venus [1], thus a plausible range of oxygen fugacity would be ~ 10^{-20} bars to ~10^{-24} bars.

Direct measurement of fO_2 would both improve understanding of the carbon gas chemistry in the lower atmosphere of Venus. This might change predicted mineral stability regimes, and thus mineral phases present presented at the surface of Venus [2]. Direct measurement of the partial pressure of oxygen would provide robust constraints on gas chemistry and surface mineral stability, and confirmation of carbon gas measurements obtained by other methods.

Principles of Technique: The oxygen sensor is a solid-state, solid electrolyte oxygen concentration cell (henceforth called a ceramic oxygen sensor). Ceramic oxygen sensors have been used to measure oxygen fugacity in hot gases for nearly 50 years [3]. The basic principle relies on a reference material of a known fO_2, a solid electrolyte, and a sample atmosphere or material. The fO_2 differential between the known and unknown materials causes a diffusion of oxygen through the electrolyte, resulting in a small, measurable voltage. A prototype schematic is shown in Figure 1.

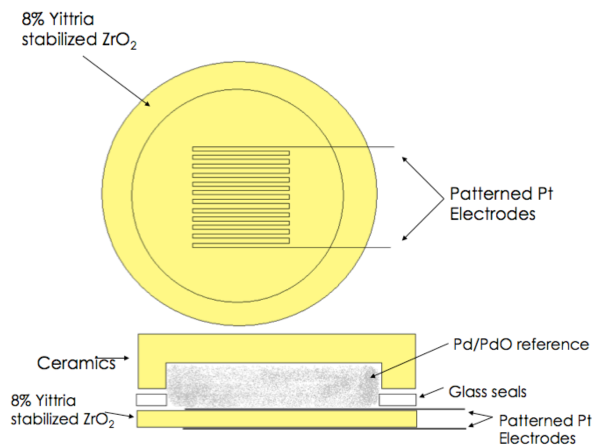

Figure 1. Prototype schematic of FirefOx sensor

A simple COS fO_2 sensor should follow the Nernst equation [cf. 4-5], and is thus a primary sensor (in other words, one that should not actually need calibration, but whose output is fundamentally related to the inputs). The Nernst equation directly relates the potential generated by the diffusing oxygen atoms through the sensor to the fO_2 via a relationship similar to

$$E = RT/4F \ln(P_{O2}/P_{refO2}) \qquad (1)$$

Where E is the open circuit potential across the sensor electrolyte (directly measured by the sensor), R is the universal gas constant, T is the temperature, F is the Faraday constant, P_{refO2} is the reference oxygen pressure on one side of the electrolyte (metal oxide), and P_{O2} is the unknown oxygen pressure of the outside environment [5].

References: [1] Fegley, B. Jr. et al., (1997), *Icarus*, *125*(2), 416-439. [2] Fegley, B. Jr. and Trieman, A. H. (1992), *Venus and Mars: AGU Monogrpah 66*, 7-71. [3] Nenov, T., and Yordanov, S. P., (1996), CRC Press. [4] Arculus, R. J., and Delano, J. W., (1981), *Geo. et Cosmo. Acta* 45, 899-913. [5] Van Setten, E. et al., (2002), *Rev. Sci. Inst.*, *73*(1), 156-161.