PROPOSED RADAR-REFLECTIVE MINERALS TESTED UNDER VENUS SURFACE AND ATMOSPHERIC CONDITIONS. E. Kohler[1], V. Chevrier[1], N. Johnson[2] P. Craig[3] and C. Lacy[1,4]. [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR, 72701; [2]NASA Goddard Space Flight Center, Greenbelt, MD, 20771; [3]NASA Johnson Space Center, Houston, TX 77058; [4]Dept. of Physics, University of Arkansas, Fayetteville, Arkansas, 72701, USA. enkohler@email.uark.edu

Introduction: Radar mapping of the surface of Venus shows areas of high reflectivity (low emissivity) in the Venusian highlands at altitudes between 2.5-4.75 kilometers [1-5]. The origin of the radar anomalies found in the Venusian highlands remains unclear. Most explanations for these radar anomalies come from theoretical work [1, 7, 9, 10]. Previous studies suggest increased surface roughness or materials with higher dielectric constants as well as surface-atmospheric interactions [1, 7]. Several possible candidates of high-dielectric materials are tellurium, ferroelectric materials, and lead or bismuth sulfides.

This work intends to experimentally constrain the source of the radar anomalies on Venus. Possible materials that could potentially cause the high reflectivities on the surface of Venus are investigated and their behavior tested under simulated Venusian conditions, with special emphasize on the combined effect of pressure and temperature.

Methods: Stability experiments were conducted in the Venus simulation chamber at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center. This chamber is approximately twelve inches deep, about five inches in diameter and is constructed of stainless steel. It can maintain temperatures of 467°C and pressures of 95.6 bar for roughly 48 hours under a CO_2 atmosphere [13].

Several compounds thought to exist on Venus were tested. These include bismuthinite (Bi_2S_3), tellurobismuthite (Bi_2Te_3), galena (PbS), coloradoite (HgTe), and pyrite (FeS_2). One gram of each sample was heated in the chamber to average Venusian surface conditions, and separately to highland conditions (460°C and 90 bar, 380°C and 55 bar, respectively). The latter conditions are those at 10 km of elevation, thus encompassing the altitude range at which the anomalies exist. This was accomplished by filling the chamber with CO_2 at room temperature and then heating to the desired temperature thus reaching the desired pressure. After each run, the samples were weighed (Table 1) and then analyzed using X-Ray Diffraction (XRD).

Results: The bismuth sulfide sample heated to 460°C decreased in mass and showed a faint surface discoloration to a lighter grey. At 380°C the sample mass increased and there was less discoloration. Tellurobismuthite decreased marginally at 460°C and at 380°C. It showed no remarkable change in appearance and XRD analysis showed no phase change.

Table 1: *Sample mass difference after the simulation experiment at 460°C and 380°C.*

Sample (with sample holder)	Mass Change at 460°C (g)	Mass Change at 380°C (g)
Bismuth sulfide	- 0.004	+ .017
Tellurobismuthite	- 0.002	- 0.001
Coloradoite	- 0.427	- 0.210
Galena	- 0.030	+ 0.061
Pyrite	- 0.103	- 0.088

Coloradoite decreased in mass at both temperatures and did not show discoloration. XRD analysis revealed the samples as mercury telluride but also indicated elemental tellurium.

Galena decreased at 460°C and increased at 380°C. It showed evident discoloration under both temperatures and XRD analysis showed that oxidation took place leaving evidence of lead sulfate ($PbSO_4$). Pyrite decreased in mass at both temperatures and did not show evident discoloration. XRD analysis indicated a partial crystal structure change to monoclinic pyrrhotite $Fe_{0.875}S$ in the sample heated to 460°C.

Discussion: Several of the compounds show promising results when tested under Venusian surface conditions. The least likely candidate is galena, which oxidized under both temperatures. This indicates that it would be an unlikely source for the anomalies. The XRD analysis for bismuthinite indicates a complex structure although no major phase change occurred in the chamber. However, several peaks still need to be resolved and compared to the database, even though preliminary data suggests that bismuthinite would be stable.

Tellurobismuthite is a new compound to this project. Both bismuth sulfide and tellurium have been suggested as potential candidates in the literature and tellurobismuthite is a likely product between both [8, 11]. Tellurobismuthite is a semiconductor meaning, if it is stable, it would have a higher dielectric constant than the surrounding basalt [16]. In these investigations the compound showed insignificant mass change suggesting stability. When analyzed by XRD the 380°C sample showed no change in mineral composition. Further analysis on the 460°C sample needs to be completed to determine candidate status. If the compound is stable at higher temperatures it would be ruled out as a candidate.

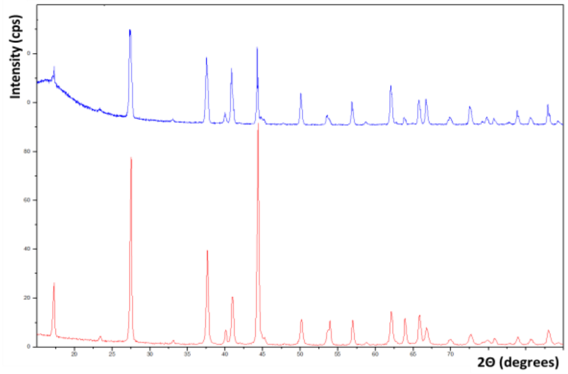

Figure 1. XRD results of tellurobismuthite untreated (bottom) and at 380°C.

Coloradoite was previously investigated in Kohler et al. 2012, 2013 [14, 15]. With the correct conditions coloradoite would likely form under Venusian conditions and would have a higher reflectivity than the surrounding basalt. XRD analysis on the samples at both temperatures showed that while the majority of the sample was stable, some residual tellurium was left while mercury vaporized. This resulted in a deficit in mass. While elemental tellurium was evident in the sample at 380°C, the majority of the sample (73%) remained as coloradoite. At 460°C, only 38% of the sample remained in its original form. Therefore, coloradoite was shown to be more stable under Venusian high altitude conditions.

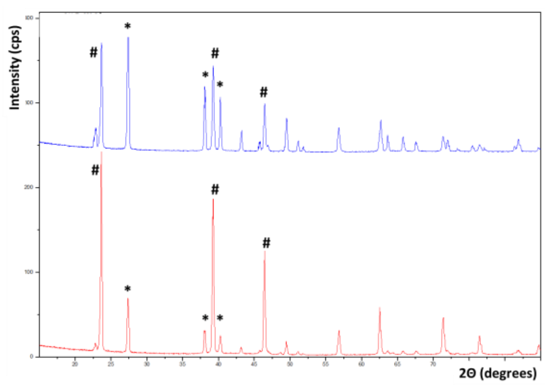

Figure 2. XRD results of coloradoite at 380°C (bottom) and 460°C (top). # indicates mercury telluride and * elemental tellurium.

Pyrite was previously suggested as a potential source for the anomalies [2]. The existence of pyrite would explain the high reflectivities as iron sulfides have high conductivities. The slight mass change of the pyrite samples suggested a phase change, however, when analyzed using XRD the sample at 460°C showed a structural change. Approximately 37% of the sample transformed into $Fe_{0.875}S$ (Fig. 3). While pyrite itself may be thermodynamically unstable under Venusian conditions, iron sulfides may still be a potential candidate for the anomalies.

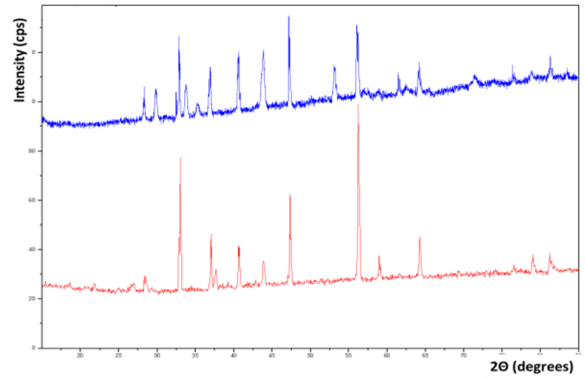

Figure 3. XRD results of pyrite untreated (bottom) and at 460°C.

Conclusion: Several compounds theoretically existent on Venus were tested under both surface and highland conditions in a Venus simulation chamber. Three of these compounds were found to be potentially stable at the conditions at which the anomalies are found. Two of these, tellurobismuthite and coloradoite, have not been previously suggested in the literature. However, both of these would exhibit a higher dielectric value than the surrounding and low-lying basalt, creating a different radar signature. More research needs to be done to determine candidate status for these two. Pyrite has been previously proposed, however, this project has shown that while pyrite itself is not stable under Venusian conditions, iron sulfides are still a prospective source.

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