

BISMUTH TELLURIDES AND SULFIDES MIXTURES AND THEIR RELATION TO METAL FROST ON VENUS. S. T. Port¹, E. Kohler¹, and V. Chevrier¹, ¹University of Arkansas, Fayetteville, AR, 72701 (sara-port@uark.edu)

Introduction: Unusually high radar reflectivity on the surface of the Venusian highlands has been observed as early as the mid-1960s [1-2]. These reflective regions only manifest from 2.5 to 4.75 km above the planetary radius of 6051.0 km [3-6]. However, above this critical altitude the reflectivity rapidly decreases until it matches the same reflectivity as the surface [3].

The origin of this phenomenon is currently unknown, though it has been postulated that it occurs due to surface roughness, some unknown interaction between the atmosphere and the surface, or condensation of sulfides onto the surface [2, 7]. Modern researchers believe that the latter scenario, the metal frost model, is the most probable case [7, 8-11].

Potential candidates suggested in the literature of the metal frost model include pyrite (FeS₂), tellurium (Te), galena (PbS), bismuthinite (Bi₂S₃) and a lead bismuth sulfosalt [3-5, 7, 10]. Both bismuth sulfide and tellurium have been suggested as potential candidates in the literature and tellurobismuthite (Bi₂Te₃) is a likely product between both [9]. It is a semiconductor which would account for the high reflectivity [9]. However, preliminary experimentation completed by my colleague on Bi₂S₃ showed stability at all tested temperatures, thus demonstrating that it can not be the metal frost [9]. Te and Bi₂Te₃ were also tested and it was found that Te and Bi₂Te₃ oxidize in a CO₂ environment, but is stable in a Venus simulated atmospheric environment [9]. We propose that some formation created through a mixture of bismuth, tellurium and sulfur might provide the same emissivity as observed on Venus.

Methods: The two chosen mixtures were a 1:1 molar ratio of Bi₂S₃ and Bi₂Te₃ and a 1:3 molar ratio of Bi₂S₃ and Te, respectively. Each mixture was tested at three different temperatures representing the temperature gradient from the Venus lowlands, to the critical altitude, to the highest point on Venus, the top of Maxwell Montes. These three temperatures were 460°C (0km), 427°C (4.5km), and 380°C (11km). Each mixture was first weighed and then inserted into a CO₂ filled Lindberg tube oven for 24 hours. After completion of each experiment, each sample was weighed once more and run through an X-Ray Diffraction (XRD) which will inform us of any compositional changes that occurred to the sample during the experiments.

Results: The Bi₂S₃/Bi₂Te₃ and Bi₂S₃/Te mixtures all exhibited a color change from a dark grey after each experimental run. Samples run at 460°C were bright

silver, whereas the samples heated to 380°C and 427°C only experienced a slight lightening in color. Table 1 displays the mass change for each of the experiments. The Bi₂S₃/Te mixture experienced a much greater mass change than the Bi₂S₃/Bi₂Te₃ mix.

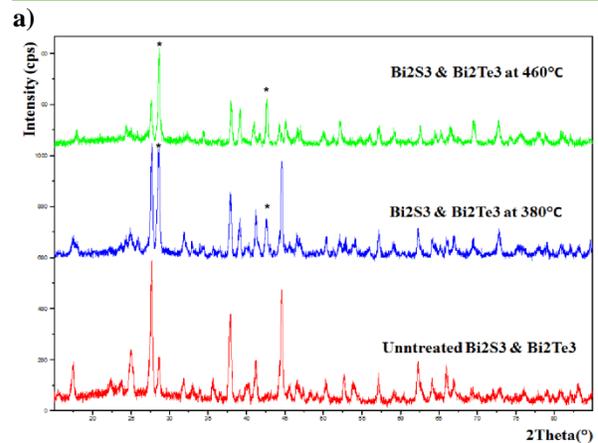
Table 1: The change in mass of the sample from before and after the experiment.

	460°C	427°C	380°C
Bi₂S₃/Bi₂Te₃	-14mg	0mg	-5.4mg
Bi₂S₃/Te	-290mg	-85mg	-79mg

XRD analysis showed that both the 380°C and 460°C heated Bi₂S₃/Bi₂Te₃ samples consisted of tetradyte (Bi₂Te₂S), Bi₂Te₃, Bi₂S₃, and tsumoite (BiTe), in order of abundance. The Bi₂S₃/Te sample heated to 380°C identified as a mix of Bi₂Te₂S, Te, and Bi₂S₃. The Bi₂S₃/Te heated to 460°C only identified as Bi₂Te₂S and Bi₂Te₃. The products for the 427°C experiments have not been determined yet due to mechanical issues. The final products of each experiment is summarized in Table 2.

Table 2: A list of the compounds identified by XRD in each sample for each experiment.

	460°C	380°C
Bi₂S₃/Bi₂Te₃	Bi ₂ Te ₂ S Bi ₂ Te ₃ Bi ₂ S ₃ BiTe	Bi ₂ Te ₂ S Bi ₂ Te ₃ Bi ₂ S ₃ BiTe
Bi₂S₃/Te	Bi ₂ Te ₂ S Bi ₂ Te ₃	Bi ₂ Te ₂ S Bi ₂ S ₃ Te



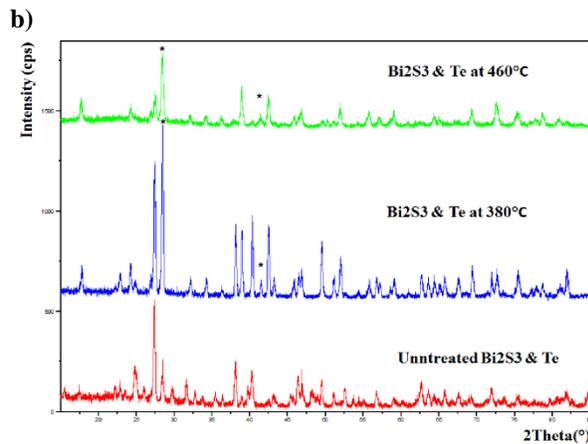


Figure 1: a) XRD patterns of the Bi_2S_3 and Bi_2Te_3 mixture experiments in a CO_2 atmosphere. Untreated mixture is found at the bottom, followed by 380°C (middle), then by 460°C (top). b) XRD patterns of the Bi_2S_3 and Te mixture experiments in a CO_2 atmosphere. Untreated mixture is found at the bottom, followed by 380°C (middle), then by 460°C (top). (*) represents the formation of tetradymite.

Discussion: The XRD patterns of our samples can be found in Figure 1. In Figure 1a&b the peak at 27° has a higher intensity than the peak found at 28° in the untreated sample, however as the temperature increases the intensities flip. This demonstrates the formation of $\text{Bi}_2\text{Te}_2\text{S}$ from Bi, Te, and S because the 27° peak is representative of Bi_2Te_3 and Te, and the peak located at 28° is $\text{Bi}_2\text{Te}_2\text{S}$. Also, in both figures the control pattern does not exhibit a peak at 42° , but a peak does appear after heating. This peak is also representative of tetradymite. Within both figures the Bi_2S_3 signals noticeably decrease from untreated up to 460°C . Tetradymite is the most favored mineral in all experiments.

In the 460°C $\text{Bi}_2\text{S}_3/\text{Te}$ mixture Bi_2Te_3 and $\text{Bi}_2\text{Te}_2\text{S}$ were both created demonstrating some replacement of S with Te. However, the corresponding amount of sulfur is absent. This may be due to the vaporization of sulfur. Based on the CRC handbook, gaseous sulfur at this temperature is a definite possibility [12]. Unfortunately at this time we cannot analyze the constituents of the atmosphere in our experiments. Vaporization of sulfur would also explain the loss in mass of the sample.

Conclusion: Though the $\text{Bi}_2\text{S}_3/\text{Bi}_2\text{Te}_3$ and $\text{Bi}_2\text{S}_3/\text{Te}$ mixtures do form other minerals such as $\text{Bi}_2\text{Te}_2\text{S}$ and BiTe , both Bi_2S_3 and Bi_2Te_3 are stable at both lowland and highland conditions. However, our experiments were completed at ambient pressure and in a pure CO_2 atmospheric environment. It is possible that different results could occur if experiments are completed at Venus pressures and in a Venus simulated atmosphere.

Therefore it is important to carry out multiple experiments at varying temperatures, pressures, and atmospheric conditions to try to recreate the same patterns of emissivity as seen on Venus.

Future Work: We plan to study a larger range of pressures and temperatures using the oven and to run experiments in a Venus simulated atmosphere (95.6% CO_2 , 3.5% N_2 , and 150 ppm of SO_2). We will be obtaining a Venus chamber in the near future that can simulate temperature and pressure conditions on Venus and will be attached to a gas chromatograph. With this new equipment we hope to measure the atmospheric composition during the experiments. An understanding of the transformation of the atmospheric composition will uncover more about the chemical reactions that can take place on Venus.

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