SIMULATING MICROMETEOROID IMPACTS ON MAGNETITE: IMPLICATIONS FOR REMOTE SENSING OBSERVATIONS AND RETURNED SAMPLE ANALYSIS

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Introduction: The surfaces of airless bodies are altered by high-velocity micrometeoroid impacts and solar wind irradiation in a process known as space weathering [1]. Space weathering results in vesiculation, amorphization, the production of melt and vapor deposits, and the formation of iron nanoparticles (npFe) [2, 3]. In lunar and ordinary chondritic styles of space weathering, these microstructural and chemical changes result in spectral modifications that include darkened and reddened reflectance spectra and attenuated absorption bands in the visible to near-infrared (VNIR) wavelengths. These optical alterations can make the characterization of airless surfaces through remote sensing observations difficult. To understand the effects of space weathering on planetary materials, we can perform laboratory experiments to simulate micrometeoroid impacts and solar wind irradiation on analog samples. Historically, space weathering studies have focused on silicates, as these are major mineral phases on lunar grains and meteorites [2, 4, 5]. However, there is recent interest in investigating how space weathering affects Fe oxide minerals relevant to asteroidal regoliths. Among oxide minerals, magnetite (Fe_3O_4) has been identified in remote sensing observations of asteroid Bennu [6]. Similarly, experimental simulations of micrometeoroid bombardment of carbonaceous chondrites revealed the production of nanophase magnetite grains after laser irradiation [7]. These observations indicate that understanding how space weathering affects magnetite will be important for developing a more complete picture of the space weathering of carbonaceous regoliths. Here, we report the results of the first laboratory experiments to simulate micrometeoroid impacts on magnetite.

Methodology: To recreate the effects of micrometeoroid bombardment (e.g., heating, melting, vaporization, and recondensation), we performed pulsed laser irradiation experiments on magnetite pressed pellets. Pulsed laser irradiation has been shown to effectively reproduce the effects of high-velocity impacts on the surfaces of airless bodies [8]. The irradiation was performed using an Nd-YAG laser under ultra-high vacuum (10^{-8} torr), similar to previous studies [7]. We prepared three magnetite pellets from a powder with a grain size of <45 µm and each was pressed to a total of 1000 psi. Each magnetite pellet was subjected to different number of laser rasters (1x, 2x, and 5x) to mimic increasing timescales of exposure to micrometeoroid impacts. In situ reflectance measurements were performed before and after irradiation of each pellet between the 0.3 µm – 2.5 µm wavelengths. We used scanning electron microscopy (SEM) to analyze the morphology of pellet surfaces after irradiation with a Hitachi TM 4000 Plus SEM at Purdue University. We will extract electron transparent thin sections using the focused ion beam to perform transmission electron microscopy (TEM) measurements in order to characterize the microstructural and chemical alterations on the pellets.

Results and Discussion: The reflectance spectra of the 1x, 2x, and 5x samples show a decrease in overall reflectance with the increase in the number of rasters. However, no attenuation of the band centered at ~1.1 µm nor spectral reddening were identified after irradiation. Spectral models have shown that micro and nanophase magnetite can produce bluing in the VNIR [9]. Future TEM analyses will determine if micro or nanoparticles were developed after the laser experiments. Preliminary SEM observations show the presence of melts and vesicles on the surfaces of the magnetite grains. Compared to sulfide and silicate minerals, the extent of melt production and the development of vesiculated textures appears to be more limited in magnetite [10]. We will present microstructural and chemical results for these experiments.

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