Nanophase Iron Production through Laser Irradiation: Space Weathering Analog.

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Introduction: Microspherules (MSP's) of iron and all other nanophase iron ($npFe^0$) particles is produced during space weathering (SW) laboratory simulations using laser irradiation [1, 2]. The importance of these nano-materials is they heavily influence the spectral and magnetic properties of the minerals they form on, and therefore influence our interpretation of remotely sensed data of minerals. A variance of sizes and volumes of MSP particles can affect the spectral reflectance of silicate minerals by darkening the overall reflectance, increasing the overall near-infrared reflectance (NIR) as the wavelength increases (or reddening), and decreasing the depth of the characteristic 1 μm silicate band [3, 4, 5]. Magnetic studies of these MSP's can physically detect the variances in sizes and volumes, and in turn be used as a measure of the relative degree of SW and determining the spectral alteration.

Results: To simulate micrometeorite impact energies at Mercury, the Moon, and the asteroid belt samples of powdered olivine irradiated with energies corresponding to each heliocentric distance. Measurements found darkening of 3%, 15%, and 18% occurred in the visible region (~600nm) and 7%, 4%, and 3% in the NIR region (~1600nm) of the asteroid, lunar and Mercury spectra, respectively. Reddening of 12%, 21%, and 22% was seen in the NIR region of the samples. The absorption band shallows 1%, 2%, and 8% from the asteroid belt to Mercury samples. SEM observations confirmed as a quick check that vaporization occurred during irradiation. Temperature dependent magnetic susceptibility (MS) measurements reveal that with each increased level of irradiation, more and more paramagnetic iron is being reduced to $npFe^0$. Frequency MS data revealed patterns of increasing changes to the MSP sizes. The fresh olivine has some nanophase magnetic sources due to lower MS for 16 kHz than 4kHz. For the lunar analog, the 4 kHz MS increased indicating more iron was transformed into the magnetic phase. The lunar 16 kHz decreased even more, revealing that more $npFe^0$ was formed (<10nm). In the Mercury analog, the 16 kHz MS was significantly increased as to the lunar analog. Excess energy from the laser saturated the sample with $npFe^0$, lumping <10 nm particles into an increasing volume of >10 nm particles. Even the asteroid analog revealed lower 16 kHz MS, evidence that laser irradiation produced $npFe^0$, while retaining mostly similar 4 kHz MS as fresh olivine. Our data like thermal processing of olivine [2], suggests that with laser irradiation there is a linear increase of nanoparticles with SW time, and a logarithmic increase in spectral change also with SW time.

Conclusions: SW via laser irradiation spectrally darkened, reddened, and reduced spectral features of olivine, and magnetic results confirmed the formation sizes and volumes of $npFe^0$ to correctly produce those spectral alterations.

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