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Laboratory Simulation of Space Weathering: Changes of optical properties of planetary surface materials

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S-type asteroids, majority in asteroids, are believed to be parent bodies of ordinary chondrites, which are a large majority in meteorites. Although both S-type asteroids and ordinary chondrites contain the same mineral assemblage, mainly olivine and pyroxene, the spectra of them are not in conformity. Asteroids indicate more overall depletion (darkening) and reddening of spectra, and more weakening of absorption bands relative to meteorites. This spectral mismatch between asteroids and meteorites is explained by a so-called ``space weathering" process, where high-velocity dust particle impacts should alter the optical properties of the uppermost regolith surfaces of asteroids.

In order to simulate the space weathering by impact heating of dust particles, I irradiated nanosecond pulse laser beam onto planetary surface materials (e.g. olivine, pyroxene, olivine + pyroxene mixtures) using a solid-state Nd-YAG pulse laser, whose pulse duration and energy rate are comparable with those of real dust impacts. All samples pulverized particles smaller than 75 micro meters were irradiated in a vacuum chamber. All laser-irradiated samples show significant reduction of overall spectra (250-2500 nm) and reddening with weakening absorption bands.

To confirm that the space-weathered spectra can be reproduced theoretically, I fitted the irradiated spectra of olivine + pyroxene mixtures using each end-member spectrum of them by the least-squares method. As a result, I found that the space-weathered spectra of the mixtures can be predicted using the end-member spectra, and the fitting ratios are not consistent with the real mixing ratios.

After laser-irradiations, I also observed the samples by a scanning electron microscopy (SEM), a transmission electron microscopy (TEM), and an electron spin resonance (ESR) to discuss the changes of the physical properties of the space-weathered samples. By SEM measurements, all samples after laser-irradiation show micrometer-sized holes on smooth surfaces. Nanophase metallic iron particles, which had been found in olivine samples already, were also found in enstatite samples by TEM measurements. Although nanophase metallic iron particles in olivine samples were contained in amorphous rim of olivine grains, those of enstatite samples exist in amorphous grains. I also found that the quantities of iron nanoparticles in olivine and pyroxene increase with the space weathering degree using ESR measurements. Finally, I discuss the relation between the changes of the reflectance spectra of samples and the occurrence of nanophase metallic iron particles in the samples.