

D⁺ IRRADIATION EXPERIMENTS TO INVESTIGATE THE H₂O/OH THERMAL STABILITY IN LUNAR SOIL. X. H. Fu, Y. C. Zhu, and Y. L. Zou, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China (fuxh@bao.ac.cn).

Introduction: Space weathering on the Moon and other airless bodies is the physical and chemical alteration due to irradiation from solar wind particles, collisions of galactic cosmic rays and solar cosmic rays, and bombardment by micrometeorites. Mature lunar soil contains large amounts of noble gases concentrated near soil grain surfaces. Examination of various noble gas isotopic ratios in Apollo samples confirms that solar wind is the major contribution. Recent analysis of infrared spectroscopic measurements from the lunar surface obtained by three independent missions, M³ on Chandrayaan-1, VIMS on Cassini and Deep Impact, indicate the existence of modest concentrations of H₂O (and OH groups) within the uppermost layers of the lunar surface. It was proposed that implanted or trapped protons from the solar wind may attach to those broken bonds and result in the hydroxyl absorption features of lunar surface.

Several experiments have been performed to test this hypothesis. Burke et al. (2011) performed a series of laboratory simulations that examine the effect of proton irradiation on two minerals: anorthite and ilmenite. Bidirectional infrared reflection absorption spectra do not show any discernable enhancement of infrared absorption in the 3 μ m spectral region following 1 or 100 keV proton irradiation at fluences between 10¹⁶ and 10¹⁸ ions/cm². On the other hand, Zent et al. (2010) and Ichimura et al. (2011) reported producing hydroxyl in Apollo lunar soil samples by proton irradiation at solar wind energies. Pre-dried soils (500°C) were bombarded with 1.1 keV protons and deuterons and provide unambiguous evidence for the formation of OH or OD in both samples. The contradictory results of two experiments suggests that solar wind may contribute to surficial lunar water, but we don't know if the formed H₂O/OH could be preserved in lunar soil, especially considering the vacuum environment, micrometeorites bombardment and diurnal temperatures on lunar surface (125°C to -150°C). The special environment conditions are the key for the presence of H₂O/OH in lunar soil and minerals. However, the above results totally ignore the migration and mobility of H₂O/OH in lunar materials.

To better understand the thermal stability and evolution of water on the lunar surface, Dyar et al. (2010), Hibbitts et al. (2011), Poston et al. (2013) investigated the adsorption of molecular water onto lunar analog materials (JSC-1) using Temperature programmed desorption (TPD). The results reveal that lunar-analog

basaltic composition glass is hydrophobic, with water-water interactions dominating over surface chemisorption. This suggests that lunar agglutinates will tend not to adsorb water at temperatures above where water clusters and multilayer ice forms. However, water molecular may be not the best choice for lunar water investigation since 3 μ m absorption feature should be dominated by hydroxyl in lunar soil and minerals. Proton irradiation is a better way to simulate solar wind interactions on the Moon and introduce hydroxyl into lunar analog materials.

Experiments: We performed D⁺ irradiation experiments to investigate solar wind contribution to lunar surficial water and volatiles migration mechanism. D⁺ ion is chosen to distinguish with the residual water in the samples. The experiments were carried out at room temperature, in an ion pumped ultra-high vacuum (UHV) chamber with residual pressure of 10⁻⁷ mbar. The energy of D ions is 50 keV with irradiation dose is 5 \times 10¹⁶ ion/cm².

Four different samples are chosen in the experiments, Luobusha olivine (~Fo80), plagioclase feldspar, pyroxene, and Panzhihua ilmenite. These are all nominally anhydrous minerals (NAM), which means they are nominally anhydrous but can accommodate tens to hundreds of parts per million (ppm) H₂O or "water" in the form of protons incorporated in defects in their mineral structure.

IR spectra were obtained from 400 to 4000 cm⁻¹ on a Nicolet 5700 FTIR spectrometer coupled with a Continuum microscope installed at the University of Science and Technology of China, using a KBr beam-splitter and a liquid-nitrogen cooled MCT-A detector. All IR measurements were carried out using transmission technique. A total of 128 scans were accumulated for each spectrum at a 4 cm⁻¹ resolution. The aperture size was set as 100 \times 100 μ m. Measurements were made under a continuous dry air flush. Background was collected at every temperature. Spectra were collected on one selected area at different temperatures for high temperature and another area of the same sample for low-temperature measurements.

In situ FTIR at varying temperatures will be used to explore temperature dependence of IR absorption of hydrous/hydroxyl species in the irradiated samples. These results will help us reveal solar wind contribution to surficial lunar water and estimate the possibility of water preservation in minerals under lunar surface environment.

Primary Results: Fig. 1 shows infrared spectra of olivine samples taken before and after D^+ irradiation. Irradiation induces clear modifications of the IR spectral signature of olivine, which may be due to disappearance of the features characteristic of the initial crystalline material. And the spectra of the olivine samples before and after irradiation all exhibit an inherently weak H₂O absorption band between the wavenumber 3200-3300 cm^{-1} . This is the result of residual water that was not removed by baking before IR experiments. However, D^+ irradiation seems not enhance infrared absorption in the O-H spectral region but results in OH loss. More experiment results are still under investigation.

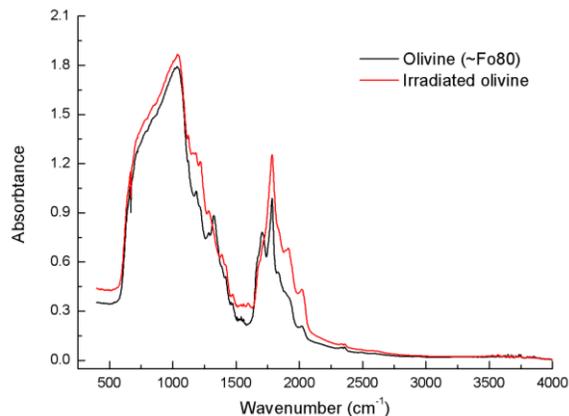


Fig.1 Infrared spectra for olivine before and after D^+ irradiation.

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