SIMULATION OF HELIUM-3 EXTRACTION FROM LUNAR ILMENITE

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Introduction: Knowledge of the trapping mechanisms and diffusion characteristics of solar-wind implanted isotopes in the minerals of the lunar regolith will enable the optimization of the processes to extract solar wind gases from regolith particles. Extraction parameters include the temperature and duration of extraction, particle size, and gas yield [1]. Diffusion data will increase the efficiency and profitability of future mining ventures. This data will also assist in optimizing the evaluations of various potential mining sites based on remote sensing data. For instance, if magnesian ilmenite ($Mg_xFe_{1-x}TiO_3$) is found to retain He better than stoichiometric ilmenite ($FeTiO_3$), remote sensing data for Mg could be considered in addition to Ti and maturity data.

The context of the currently discussed work is the mining of helium-3 for potential use as a fuel for fusion energy generation [e.g. 2]. However, the potential resources deposited by the solar wind include hydrogen (and derived water), helium-4, nitrogen and carbon. Implantation experiments such as those performed for helium isotopes in ilmenite are important for the optimized extraction of these additional resources. These experiments can easily be reproduced for most elements or isotopes of interest.

Helium-3 Implantations of Ilmenite: Helium isotopes were implanted into terrestrial ilmenite using plasma source ion implantation (PSII), a non-line of sight technique developed for uniformly implanting a variety of atoms orthogonally into materials [3]. It is very conducive to simulation of solar wind implantation because implantation energies of 1 keV/amu are easily achieved. The target -- in this case a silicon wafer with thin polished samples of terrestrial ilmenite lying on top -- is placed in a 1 m^3 chamber which is evacuated to a base pressure of about 10^{-6} torr. Helium-4 and helium-3 gas is allowed to flow through the chamber at a pressure of several millitorr. A plasma is generated using tungsten filaments to ionize the gas by energetic primary electron impact. The evolution of helium isotopes from the implanted samples was performed using isochronal and isothermal annealing similar to the experiments performed on the Apollo samples. The measured release profiles were found to be quite similar to the release profiles measured for regolith samples from the Apollo 11 site [4].

Reconnaissance of Lunar Solar-wind Resources: Since remote sensing of helium-3 has been shown to be impossible without an added source of protons or neutrons [5], helium-3 concentrations are currently associated with titanium concentrations and maturity indices measured by remote sensing. We propose that in-situ mapping of lunar helium-3 concentrations or other species of interest is possible using well-developed borehole neutron or proton sources in concert with gamma-ray detectors. Such instruments should be considered for in-situ discovery of in-situ resources on both the Moon and on Mars.

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