EPSC Abstracts
Vol. 6, EPSC-DPS2011-1860, 2011
EPSC-DPS Joint Meeting 2011

Changes in size of nano phase iron inclusions with temperature: Experimental simulation of space weathering effects at high temperature

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Abstract

The mean size of nano phase iron inclusions ($npFe^0$), produced during the space weathering of iron-rich regolith of airless solar system bodies, significantly affects visible and near-infrared (VNIR) spectra. To experimentally simulate the change in the size of $npFe^0$ inclusions with increasing temperature, we produced sputter film deposits on a silicon dioxide substrate by sputtering a pressed pellet prepared from fine olivine powder using 600V Ar^+ ions. This silicon dioxide substrate covered with the deposit was later heated to 450°C for 24 hours in an oven under argon atmosphere. Initial TEM analysis of the unheated silicon dioxide substrate showed the presence of a ~ 50 nm-thick layer of an amorphous deposit with nano clusters that has not yet been identified.

1. Introduction

Space weathering of the regolith of airless solar system bodies produces nanometer-thick patinas on regolith grains. These patinas contain $npFe^0$ inclusions, which has been well documented for lunar soils [1]. The mean size of $npFe^0$ inclusions has been experimentally shown to affect the VNIR spectra [2]. For solar system bodies with high surface temperatures, for example, Mercury, the $npFe^0$ inclusions can grow within an amorphous matrix to larger sizes due to a process called Ostwald ripening [3]. However, it is difficult to calculate the absolute or mean size of the $npFe^0$ inclusions at particular temperature, because there has been no experimental work on the diffusion of $npFe^0$ inclusions within an amorphous matrix.

2. Samples and Experimental Procedures

Thin film was deposited by an Ar-ion beam sputtering technique. Ar-ions were produced from a Kaufmann type ion source and accelerated towards the target with an acceleration voltage of 600 V. The Ar-ions were neutralized before striking the target using an electron pulse and the ion beam had a diameter of approximately 40 mm. Sputtering was carried out at room temperature and the pressure inside the UHV chamber was maintained at $2\text{-}3\times10^{-4}$ mbar. An electronic grade Si substrate, which was oxidized in an oven, was used as the substrate for the sputtered products. The target was produced by crushing San Carlos olivine crystals to a fine powder and pressing the powder into a pellet of 8 cm in diameter. For TEM characterization, electron-transparent cross-sections were prepared by grinding and ion milling using a Gatan PIPS. Transmission electron microscopy was carried out using a Zeiss Libra 200FE TEM operating at 200 kV. A part of the sputter-deposited silicon wafer was placed in an evacuated glass tube (with Ar gas) and heated to 450°C for 24 hours.

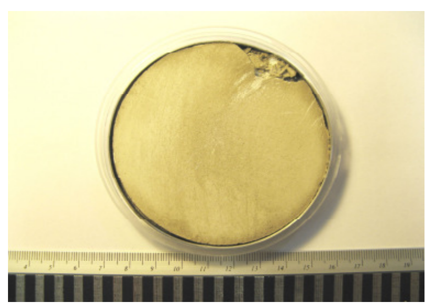

Figure 1: Image of the San Carlos olivine pellet after irradiation. Top right corner of the sample was broken during the preparation of the pellet. The white region near the broken part has been scratched to show the original color of the olivine powder.

3. Preliminary Results and Planned Experiments

The San Carlos olivine (Target) was darkened after the irradiation experiment (Fig. 1). However the cause of darkening can be due to the production of nano phase iron inclusions or it can be caused due to the breakdown of contamination (organic) under the Ar ion beam. The Visible and Near Infra Red (VNIR) spectrum of the sample will be carried out. Initial TEM result shows the presence of a ~ 80 nm-thick amorphous layer over the silicon oxide substrate (Fig. 2). This film deposit is composed of two different layers: one is almost structureless and has the thickness of ~ 30nm, while the other (~ 50 nm-thick) shows numerous nano-sized clusters. We do not have any clear explanation for the first structureless layer´s origin and further studies need to be performed to explain its origin. The nanoclusters in the uppermost ~ 50 nm layer could not be identified due to their very small size and specialized techniques have to be used for their identification. These clusters are very abundant within the layer and may represent $npFe^0$ inclusions similar to those detected in lunar soil grains [1]. However, the mean size of nano phase inclusions in the patinas on lunar soil grains are larger compared to the inclusions in our experimentally produced sputter deposits. We further plan to investigate the structure of the sputter film deposit within the heated silicon oxide sample.

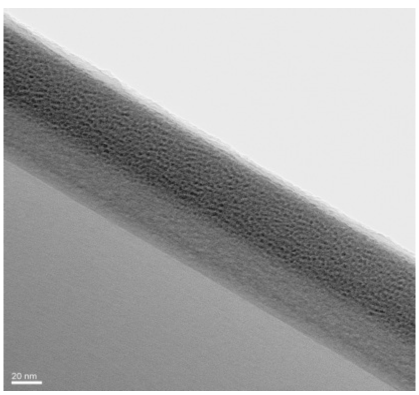

Figure 2: Dark field TEM image of the sputter deposit.

Acknowledgements

We thank Ludmilla Rettich and Michael Kasprzak for their help during sample preparation. This work is supported by DLR MERTIS project.

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