Introduction: Apollo Next Generation Sample Analysis (ANGSA) project is currently studying recently opened samples that for the past ~50 years were specially storage to assess lunar regolith chemistry using modern instrumentation and methodologies. Oxidation states of metals in the lunar regolith have not been extensively explored, though in general, species are shown to be more reduced relative to terrestrial equivalents [1]. Preliminary works have been performed on simulated space weathering minerals that mimic spectral behavior expected to the lunar regoliths [2]. Most signatures of oxidation state are influenced by other factors including covalency and the overall electronic structure, so this lead the oxidation states of major elements (e.g., Fe and Ti) being probed considering these processes are mainly surface sensitive [3]. This study will employ synchrotron-based soft X-ray absorption spectroscopy (XAS) and tender X-ray emission spectroscopy (XES) to get a complete picture of the overall redox environment on the moon and to investigate whether terrestrial oxidation has occurred in these conditions.

Samples and Experiments: Four samples extracted from the 73002 upper drive tube collected on the Apollo 17 mission were analyzed. This set of samples were compared with 70003-70009 cores samples. O K-edge and Fe L$_{3,2}$-edge XAS spectra were collected at beamline 10-1 at the Stanford Synchrotron Lightsource (SSRL), a wiggler side-station beam line for soft X-ray core-level spectroscopy. Data were acquired to probe a depth of ~ 2 nm for surface-sensitive detection in total electron yield mode under ultrahigh vacuum conditions. Si K$_\beta$ XES spectra were recorded on SSRL beamline 6-2a using a high-energy resolution Johannson-type X-ray spectrometer specifically designed for the tender X-ray regime (1.6–5.0 keV).

Results and discussions: O K-edge and Fe L$_{3,2}$-edge XAS spectra are shown in Figure 1. Feature around 531 eV in O K-edge old core samples indicates different local electronic structure around than 73002 samples. Fe L$_{3,2}$-edge XAS show a decrease intensity and slight shift to higher energy for L$_3$ peak is related to more oxidized Fe species. From Si K$_\beta$ XES in Figure 2, main SiO$_2$-like spectrum features are observed for 73002 samples, in particular, K$_\beta'$ peak appears more intense for new core samples than for the older core samples indicating changes in the chemical processes in the lunar regolith’s. Si-O bonding is corroborated.

Conclusions and Outlook: Element-specific local electronic structure of 73002 samples were revealed and signatures of oxidation were studied. EELS measurements will be included to get higher resolution information about Fe oxidation. Ti L$_{3,2}$-edge XAS is currently under analysis to reveal Ti oxidation state. This methodology will be used to analyze 73001 samples that were specially sealed.


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