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A MINERALOGICAL INSTRUMENT FOR PLANETARY APPLICATIONS. David F. Blake,[1] David T. Vaniman[2] and David L. Bish[2] [1]Planetary Biology Branch, MS 239-4, NASA/Ames Research Center, Moffett Field, CA 94035-1000, [2]EES-1, MS D462, Los Alamos National Laboratory, Los Alamos, NM 87545

The mineralogy of a planetary surface can be used to identify the provenance of soil or sediment and reveal the volcanic, metamorphic and/or sedimentological history of a particular region. We have discussed elsewhere the applications[1,2] and the instrument design of possible X-ray diffraction and X-ray fluorescence (XRD/XRF) devices for the mineralogical characterization of planetary surfaces.[3] In this abstract we evaluate some aspects of sample-detector geometry and sample collection strategies.

For XRD/XRF, the two X-ray photon - sample interactions of interest are coherent Bragg diffraction and X-ray fluorescence. In our prototype design, diffracted primary-beam X-rays and secondary fluorescence X-rays are detected by one or several X-ray sensitive CCD arrays operated in single-photon counting mode.[4] A diffraction pattern can be generated by displaying an image made only of X-rays having the energy of the primary X-ray beam. An X-ray fluorescence analysis can be obtained by summing all of the X-rays recorded by the CCD which have energies lower than that of the primary beam into a multichannel analyzer.

In order to obtain an optimal angular dispersion for X-ray powder diffraction the CCD arrays may be arranged as shown in Figure 1 (edge and plan views). In this arrangement, the sample powder is collected on an adhesive tape that can be advanced for collection of subsequent samples. The tape mechanism can be rotated around the axis of the direct beam to improve particle statistics. The direct beam is allowed to pass through a narrow slit (0.126 cm) between a set of 1-cm 512 X 512 CCD arrays. These CCD arrays supply the "flat plate" for collection of the diffracted Cu radiation. In the geometry shown, the CCD plates are capable of covering the 2Θ range from 4° to 50°, including most of the characteristic diffraction peaks for a broad range of mineral types (oxides, silicates, complex water-rich ices) that might be encountered on a range of extraterrestrial objects. For accurate analysis, particularly in quantitative studies of mineral mixtures, a pattern precision of 0.05° is desirable. In the edge-view configuration shown in Figure 1, the actual angular range encompassed by each pixel varies from 0.123° 2Θ at pixel 1 to 0.052° 2Θ at pixel 512. These precisions are acceptable for prototype work, but they can be easily cut in half - within the acceptable range for a highly accurate XRD instrument-by substituting 1024 X 1024 CCD arrays that are commercially available but rather expensive for prototype studies.

The flat-plate geometry presents some problems in XRD pattern interpretation because of the different solid angles subtended by each of the 262,144 pixels in a 512 X 512 array. However, the increasing angular resolution at higher 2Θ makes this geometry attractive for small instrument applications. Commercial diffraction instrument manufacturers are currently working on software improvements that may facilitate the use of flat-plate geometries in XRD. With regard to data reduction, our goal is to develop applications of both determinative and quantitative Rietveld analysis[5] that will make the optimal use of such geometries.

A critical aspect of instrument development is sample collection and manipulation. The option shown in Figure 1 is based on drum-fed adhesive tape mounted in a rotating sample head. The sample head can be swung away from the analysis position to be pressed against powders (from passive dust collectors, abrasive chucks or regolith surfaces). Disposable adhesive plates or fibers provide other options as sample holders. Many other sample acquisition systems are possible but the test of each must be ruggedness and simplicity. Since the XRD/XRF technique is non-destructive, the instrument is amenable to inclusion in a sequential analysis strategy in which the sample is passed on to another instrument after analysis.

XRD/XRF INSTRUMENT FOR PLANETARY APPLICATIONS: Blake, D.F. et al.

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Figure 1. (insert, upper right) Plan view of two possible configurations of CCD detector arrays. The direction of view is directly down the X-ray beam path toward the detector array. A crystalline powder pattern is shown superimposed onto arrays using two and four detectors. The remainder of the figure shows an edge view of the instrument illustrating the diffraction angles subtended by the CCD arrays.