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Development of a Planetary X-Ray Fluorescence Spectrometer and Standard Samples for on-board Calibration

A. Dreißigacker (1), O. Fabel(1), E. Köhler(1,2), S. van Gasselt (1) and M.Meyer (3)

(1) Freie Universität Berlin, Institute of Geological Sciences, Planetary Sciences and Remote Sensing, Malteserstr. 74-100, 12249 Berlin, Germany (anne.dreissigacker@fu-berlin.de) (2) EKTECH GmbH, Werrastr.1, 12059 Berlin, Germany (3) University of Applied Sciences Berlin, Institute for Mechanical Engineering, Engineering Sciences, Wilhelminenhofstr. 75a, 12459 Berlin, Germany

1. Introduction

At the Planetary Sciences and Remote Sensing research group at Freie Universität Berlin an SCD-based X-Ray Fluorescence Spectrometer (XRF-X) is being developed to be employed on planetary orbiters. It performs direct, passive energy-dispersive X-ray fluorescence measurements of planetary surfaces by measuring the emitted X-ray fluorescence induced by solar X-rays and high-energy particles.

2. Instrumentation

The XRF-X experiment consists of two subsystems: the main instrument (XRF-X) targeting the Moon's surface, and a zenith-pointing Indirect Solar Monitor (XRF-X-ISM) with calibration targets to measure the solar flux.

Quantitative data are being obtained through synchronous measurement of fluorescence of the Moon’s surface by the XRF-X main instrument and the emitted X-ray fluorescence of calibration samples by the XRF-X-ISM (Indirect Solar Monitor).

Calibration measurements are obtained by indirectly monitoring incident solar X-rays emitted from a calibration sample. This also minimizes the risk of detector overload and damage during extreme solar events such as high-energy solar flares as only the sample targets receive the higher radiation load directly.

2.1 XRF-X main Instrument

The XRF-X will use a new generation of large-area SCD-detectors to achieve high X-ray returns. The X-ray spectra are acquired by single photon counting with nearly 100% quantum efficiency and on-board histogramming (MCA) [3].

The spatial resolution is 10 km/px at an orbit altitude of 50 km. The spectral range is 1 - 10 keV (1.2 - 0.12 nm) with no sharp limits, achieving a spectral resolution of 160eV at 6 keV. At these conditions, elemental abundances of lighter elements (atomic no. 11-32, K-Lines) and heavier elements (atomic no. 33-80, L-lines) will be observable. XRF-X is intended to produce a detailed set of measurements of the chemical composition of a planetary surface target, (in particular for Na, Mg, Al, Si, K, Ca, Ti, Mn, and Fe). This allows us to map the spatial extend of geologic units on planetary surfaces.

A scalable and modular design allows for instrument adaption to desired resolution, to weight and power consumption constraints, expected sun emission intensities and employment on different observation platforms.

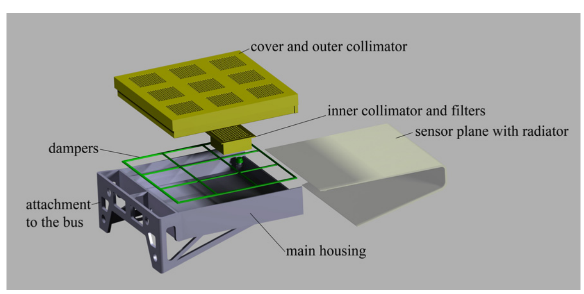

Figure 1: Assembly module of XRF-X main instrument.

2.2 XRF-X Indirect Solar Monitor

The XRF-X-ISM instrument is equipped with the same type of SCD detectors and data processing software as the main instrument. The ISM incorporates 2 or 3 calibration targets.

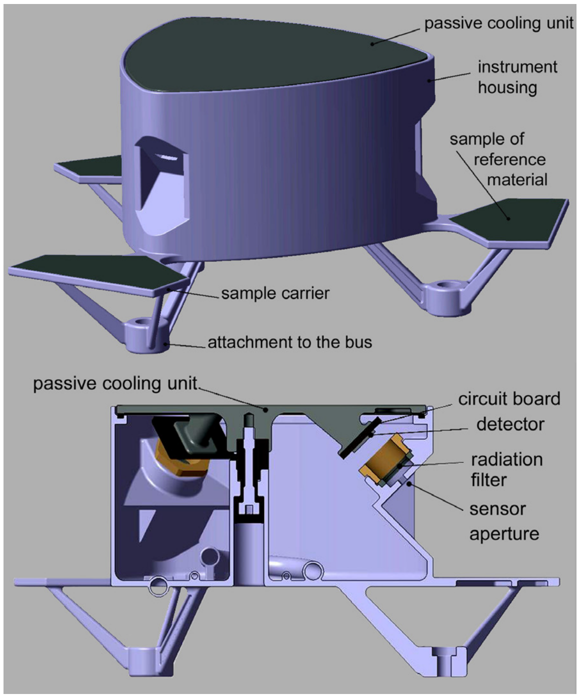

Figure 2: XRF-X-Indirect Solar Monitor (ISM) design (top view and cross section). At least one of the calibration samples is completely illuminated at all times. A single SCD detector is pointed towards each sample.

3. Calibration technique and sample development

As the Sun is a highly variable radiation source [1, 2], the intensity of solar X-ray radiation has to be monitored constantly to allow for comparison and signal calibration of X-ray radiation from lunar surface materials [4, 5].

We are currently developing requirements for three sample tiles for onboard correction and calibration of XRF-X, each with an area of 3-9 cm^2 and a maximum weight of 45 g. This includes development of design concepts, determination of techniques for sample manufacturing, manufacturing and testing of prototypes and statistical analysis of measurement characteristics and quantification of error sources for the advanced prototypes and final samples.

Apart from using natural rocks as calibration sample, we are currently investigating techniques for sample manufacturing including laser sintering of rock-glass on metals, SiO_2-stabilized mineral-powders, or artificial volcanic glass. High precision measurements of the chemical composition of the final samples (EPMA, various energy-dispersive XRF) will serve as calibration standard for XRF-X.

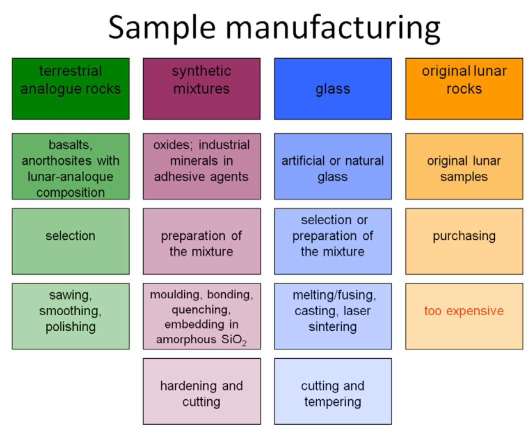

Figure 4: Techniques of sample manufacturing.

Acknowledgements

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