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TOMOX: an x-ray tomographer for lunar and planetary exploration

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Abstract

The TOMOX instrument has recently been founded under the ASI DC-EOS-2014-309 call. The TOMOX objective is to acquire both X-ray fluorescence and diffraction measurements from a sample in order to:

a. perform a no destructive, in situ analysis of chemical and mineralogical composition of rocks and soils based on in X-ray fluorescence (XRF) and diffraction (XRD) mode

b. reconstruct a 3D mapping of the sample exposed surface combining chemical and mineralogical information by tomographic approach

c. give hints regarding the rock age by comparing the total contents of Rb and Sr elements and the supposed isotopes which are commonly used for geochronology.

Nevertheless, this technique has applicability in several disciplines other than planetary geology, especially archaeology. The proposed instrument is based on the MARS-XRD heritage, an ultra miniaturised XRD and XRF instrument developed for the ESA ExoMars mission [1-3].

1.Concept design and objectives

The word ‘tomography’ is nowadays used for many 3D imaging methods, not just for those based on radiographic projections, but also for a wider range of techniques that yield 3D images. Fluorescence tomography is based on the signal produced on an energy-sensitive detector, generally placed in the horizontal plane at some angle with respect to the incident beam caused by photons coming from fluorescence emission. So far, a number of setups have been designed in order to acquire X-rays fluorescence tomograms of several different sample types.

The general idea of TOMOX is to distribute both sources and detectors along a moving hemispherical support around the target sample (Figure 1). As a result, both sources move integrally with the detectors while the sample is observed from a fixed position, thus preserving the geometry of observation. In that way, the whole sample surface is imagined and XRD and XRF measurements are acquired continuously.

We plan to irradiate the target sample with X-rays emitted from ^{55}Fe and ^{109}Cd radioactive sources. ^{55}Fe and ^{109}Cd radioisotopes are commonly used as X-ray sources for analysis of metals in soils and rocks. The excitation energies of ^{55}Fe and ^{109}Cd are 5.9 keV, and 22.1 and 87.9 keV, respectively. Therefore, the elemental analysis ranges are Al to Mn with K lines excited with ^{55}Fe; Ca to Rh, with K lines excited with ^{109}Cd. ^{55}Fe will be primarily dedicated to XRD measurements, as it has been already tested for the MARS-XRD development. ^{109}Cd will be used to reinforce the efficiency of ^{55}Fe source in the production of fluorescent X-rays generated in the sample as a consequence of irradiation and to extend the analytical range of elements.

Two different detectors has been used in order to increase the total amount of events collected and allow the spatial distribution of events to be recorded as well. The detectors are a SDD (Silicon Drift Detector) and a stand-alone CCD (Coupled Charge Detector). The SDD has higher count rate and stability and has been successfully used for XRF applications. On the other hand, the CCD is able to record the spatial position of each event of X-ray emission, together with its energy. Therefore, we plan to dedicate this detector to XRD measurements, where the spatial position of the event is directly correlated to the type of crystal through the Bragg's law.

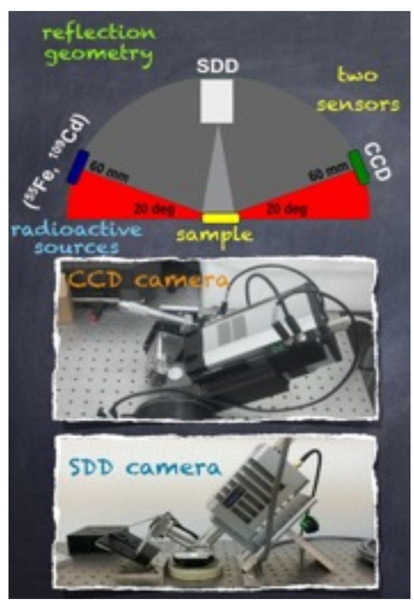

Figure 1: Schematic drawing and photos of the preliminary prototype setup.

TOMOX will be able to measure the total content of Rb and Sr but not the isotopic ratio as commonly used for geochronology purposes. However, we’ll try to estimate possible rock or soil age by make a comparison with rocks of known isotopic ratios for Rb/Sr in terrestrial rocks or meteorites. We know that the the isotopic ratio varies with the different igneous rock formation process on Earth, differences which are also recorded in the rocks petrography. Thus, we plan to build a database of isotopic Sr and Rb ratio of terrestrial and extraterrestrial materials to compare the total Rb and Sr contents as preliminary information on the rock age.

2.Future development

We are currently performing experimental tests for the sensors characterisation and signal calibration using different types of rock samples. Afterward , we will focus on the merging of XRD and XRF measurements to obtain the 3D tomographic modelling.

An appropriate mechanical design will be also developed to mount sources and sensors with movements to acquire in tomography mode.

As final evaluation of the TOMOX performance we will make measurement of artefact (mostly ceramics) for archeaometry application. This part of the experimental work will be realised with the archeologists involved in the team.

Acknowledgements

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