LUNAR X-RAY FLUORESCENCE SPECTROMETRY FROM SELENE LUNAR POLAR ORBITER. T. Okada[1,4], K. Shirai[1], Y. Yamamoto[1], T. Arai[1,2], K. Ogawa[1,3], K. Hosono[1,4], and M. Kato[1,3,4], [1]ISAS/JAXA, 3-1-1 Yoshinorai, Sagamihara, Kanagawa 229-8510 JAPAN, okada@planeta.sci.isas.jaxa.jp, [2]Grad Univesity for Advanced Studies, [3]Tokyo Institute of Technology, [4]University of Tokyo.

Introduction: We have been developing an X-ray fluorescence spectrometer, XRS, for SELENE mission, a Japanese lunar polar orbiter that awaits its launch in FY2006. The XRS will map major elemental composition of lunar surface with less than 20km in spatial resolution and 90% surface coverage except for polar region. The XRS has been designed to improve energy resolution and detection efficiency at soft x-rays by adopting new technologies such as X-ray CCD and ultra-thin beryllium window. The current status of the instrumental development is also described.

As was proven during the Apollo 15 and 16 missions, major elemental composition can be determined through remote XRF method for atmosphere-free planetary surfaces. Solar X-rays irradiate planetary surface to excite each atom of the uppermost surface materials. Immediately those atoms settle to the ground state and X-rays characteristic of major elements are illuminated off the surface. However, intensity and spectral profiles of solar X-rays varies time to time, which affects those of XRF off the planetary surfaces as well. Therefore major elemental composition can be mapped from the orbiting altitude with remote XRF spectrometry, together with concurrent monitoring of solar X-rays.

Remote XRF spectrometry is the commonly used method to map major elemental composition of atmosphere-free planetary surface that have explored and will explore the Moon, Mercury, and asteroids such as the Apollo 15 and 16, ESA's Smart-1, ISAS/JAXA's SELENE, Chinese Chang'e, and Indian Chandrajaan-1 for the Moon, NASA's Messenger and ESA-JAXA's Bepi Colombo for the Mercury, and NEAR-Shoemaker, ISAS/JAXA's Hayabusa (MUSES-C) for near-earth asteroids.

As for the SELENE mission, lunar science is the first priority by conducting lunar global mapping with combinations of panoramic and high resolution imagery, X-ray and gamma-ray spectrometry, laser altimetry, radar surface and subsurface sounding, gravity anomaly, and remnant and responded magnetic field as well as its surrounding plasma environment. Then the XRF spectrometry aims at mapping major elemental composition, especially in Mg, Al, and Si, of the lunar uppermost surface with higher accuracy, with better spatial resolution and at larger coverage than those of that have been done in the previous lunar missions. To achieve those purposes, the XRS instrument consists of CCD-based main detector with a direct monitor of solar X-rays as well as XRF calibrator aboard. We present here the scientific objectives and instrumentation of the XRS as well as its current status of development.

Scientific Objectives: Scientific objectives of the XRS observation are (1) global mapping of major elements of lunar surface materials except for polar regions through remote XRF spectrometry during day time observation, (2) understanding the physical processes of lunar X-ray illumination in the night time that happens by impact of solar wind particles and comic rays as well as natural radioactivity in the uppermost layer of lunar surface, and (3) regional variation of surface microscopic roughness as the results of particle size effect on XRF intensities.

Lunar XRF experiments have mapped about 10 % of the lunar equatorial regions during the Apollo 15 and 16 missions in 1971-1972 and implied that lunar maria are covered with lava flows in basaltic composition and lunar highlands are dominantly occupied with aluminous anorthosetic materials (Adler and Trombka, 1977). Tsiolkovsky crater shows more mafic, mare-basaltic composition relative to its surrounding anorthosetic area. Impact ejecta of Picard crater that is located even in the mare basin reveals remarkably mafic composition in comparison to the average composition of Mare Crisium. The effective spatial resolution of the Apollo XRF map is about 30km after compilation of data from several orbits.

ESA's Smart-1 will map lunar surface composition with using array of newly developed SCD detectors in 2004-2005, but its ecliptic orbit of 300km x 10000km might limit its spatial resolution (Grande *et al.*, 2002).

Then the XRS onboard SELENE mainly aims at global

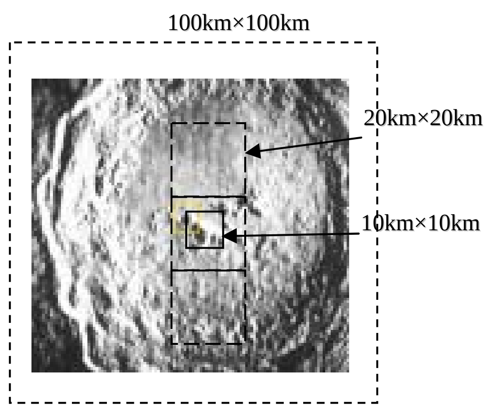

Figure 1. Schematics of the foot print of the XRS observation at Copernicus crater. Solid squre reveals 10km resolution, dashed square reveals 20km, and doted square reveals 100km.

mapping in energy resolution by using CCD as well as in spatial resolution by observing at 100km altitude of polar orbit for more than one year (Okada *et al.*, 2002). The foot-print of the XRS observation is set about 20km by 20km and the compiled spatial resolution is less than 10km after recal-culation of data from many orbits (see Figure 1). With these data sets along with those by other instruments, materials from deep interior can be determined when observing the central peaks of craters and impact ejecta. Global regional variation of base rock composition will be informed as well as mantle materials at some areas. Crust and mantle differen-tiation processes, evolution of lunar highland crust, and mag-nesium number of the lower crust and mantle will be investi-gated.

Instruments: The XRS instrument consists of a main detector to observe X-rays off the lunar surface, XRF-A, a direct solar X-ray monitor and an onboard XRF calibrator with standard sample, SOL-BC, and the electronics, XRS-E (Okada *et al*., 2002). The specification of the XRS is tabu-lated in Table 1..

To achieve those scientific objectives mentioned in the previous section, we have adopted new technologies such as X-ray charge-coupled devices (1-inch square sized, 1K by 1K pixels, full-frame transfer method, buttable shape, manu-factured by Hamamatsu Photonix, K.K.), ultra-thin beryllium window in 5 to 10 micron thick, latticed collimators to limit the FOV in 12 x 12 deg, advanced thermal design to keep CCD chips sufficiently cool with passive radiation, and the 60MHz and 32 bit fast RISC-type onboard computer, SH-OBC, of voting majority technique to improve radiation tol-erance. Then, in comparison to the previous planetary remote X-ray spectrometer, the XRS has higher energy resolution of < 160eV at 5.9KeV, and larger detection area of 100cm^2 by using array of CCD chips. Since the allocation of telemetry rate is limited in 4Kbytes/sec for the XRS in the daytime nominal mode operation, the XRS has functions to extract X-ray events from all of the readout data of CCD at 125KHz, to classify the grade for each X-ray event, and to produce X-ray energy spectrum by using the onboard logic circuits of FPGA and the software program in the SH-OBC.

Current Status: We have been examining functions and performances of the XRS in the laboratory. So far the functions are basically confirmed to work in order as planned. Its performances have been achieved to the level more than that could be used for X-ray analysis but it should be much improved by selecting more appropriate parameters.

We have examined all of the mounted CCD chips in good performance that show 140 eV full width at half maximum of peaks of Fe-55 radiooisotope X-ray source in 5.9KeV (Kα) and 6.5KeV (Kβ), respectively. The XRS must drive in order 16 chips for XRF-A and another single chip ofr SOL-C in line-binned mode during observation. Current status of performance is about 150 to 160 eV at the same energy range. Several months remain left to improve and adjust the performances for the XRS flight model.

References:

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Table 1. Specification of the XRS

	XRF-A Lunar XRF Detector	SOL-B Solar X-ray Monitor	SOL-C XRF Calibrator
Detector	2D Si-CCD x 16chips Hamamatsu Photonix	SiPIN diode x 2 AMPTEK	2D Si-CCD x 1chip Hamamatsu Phtonix
Detection Area	100 cm^2	Pinhole	6 cm^2
Fields of View	12 x 12 deg	Hemispherical	Hemispherical
Footprint Resolution	20km @100km altitude	N/A	N/A
Energy Range	0.7 – 10 KeV	1 – 20 KeV	0.7 – 10 KeV
Energy Resolution	< 160eV @Fe55	< 250eV @Fe55	< 160eV @Fe55
Operation Temperature	< -40 degC	< -20 degC	< -40 degC
A/D Conversion	12bits	8bits	12bits
Telemetry Modes	Spectrum, Image	Spectrum	Spectrum, Image
Other Resources:			
Total Mass	21Kg (XRF-A: 9.0Kg, SOL-B/C: 4.5Kg, XRS-E: 7.5Kg)		
Total Power	40W (nominal operation mode)		
Total Telemetry Rate	32Kbps (nominal operation mode. 3.2Kbps for BG mode)		
CPU and RAM	Super-Hitachi SH-3 OBC (16MHz), 256KB-EEPROM, 8Mbytes-DRAM		