Global Mapping of elemental abundance on lunar surface by SELENE gamma-ray spectrometer. [1]M. -N. Kobayashi, [1]A. A. Berezhnoy, [6]C. d'Uston, [1]M. Fujii, [1]N. Hasebe, [3]T. Hiroishi, [4]H. Kaneko, [1]T. Miyachi, [5]K. Mori, [6]S. Maurice, [4]M. Nakazawa, [3]K. Narasaki, [1]O. Okudaira, [1]E. Shibamura, [2]T. Takashima, [1]N. Yamashita, [1]Advanced Research Institute of Sci.& Eng., Waseda Univ., 3-4-1, Okubo, Shinjuku-ku, Tokyo, 169-8555, Japan, (masanori@mse.waseda.ac.jp), [2]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, Kanagawa, 229-8510, [3]Niihama Works, Sumitomo Heavy Industry Ltd., Niihama, Ehime, Japan, Moriya Works, [4]Meisei Electric Co., Ltd., 3-249-1, Yuri-ga-oka, Moriya-shi, Ibaraki, 302-0192, [5]Clear Pulse Co., 6-25-17, Chuo, Ohta-ku, Tokyo, Japan, 143-0024, [6]Centre d'Etude Spatiale des Rayonnements, CNRS/UPS, Colonel Roche, B.P 4346, France.

Introduction: Elemental composition on the surface of a planet is very important information for solving the origin and the evolution of the planet and also very necessary for understanding the origin and the evolution of solar system. Planetary gamma-ray spectroscopy is extremely powerful approach for the elemental composition measurement. Gamma-ray spectrometer (GRS) will be on board SELENE, advanced lunar polar orbiter, and employ a large-volume Ge detector of 252cc as the main detector [1]. SELENE GRS is, therefore, approximately twice more sensitivity than Lunar Prospector GRS, four times more sensitive than APOLLO GRS. The high sensitivity of SELENE GRS will enable us to map element abundances of O, Mg, Fe, Al, Si, Ti, K, Ca, Th, and U, with lower detection limit than the past missions. The Japanese lunar polar orbiter SELENE is scheduled for launch in 2007 and the GRS will observe the whole area of the moon including the polar region. Orbiting the GRS at 100 km in a nominal operation for one year will provide the global mapping of the chemical composition of lunar surface material for more elements than Lunar Prospector did [2]. Now, the flight model of SELENE GRS was built and will be qualified by several environment test. Fig. 1 shows the schematic drawing. It shows an energy resolution of 3 keV @ 1.33 MeV in the GRS system. In this study, we will exhibit expected performance of SELENE GRS in lunar orbits predicted by preliminary Monte Carlo simulation results and discribe scientific topics acheivable by SELENE GRS.

Instrument and Performance: In SELENE mission, we adopted a Ge detector as the main detector of the GRS because of its excellent energy resolution. This will be the first time to use a Ge detector for lunar mission to provide a global mapping of chemical composition. A Stirling cryocooler, developed of the vibration and the power consumption to be reduced, makes this possible. The Ge crystal can be cooled down to 80-90K through a flexible copper de-coupler and the energy resolution is not so degraded much because the mechanical vibration is enough suppressed. In this mission, a high purity n-type Ge crystal is used exploiting its high resistance against proton/neutron induced radiation damage [3]. The Ge detector has a volume of 252 cc and is hermetically encapsulated in a high vacuum-tight Al canister. In order to increase the sensitivity of GRS, it is essential to reduce background gamma-ray. The major background components are cosmic ray particles entering the detectors, produced particles due to the primary and secondary cosmic ray interactions with materials of spacecraft, and scattered gamma-rays produced in planetary surface and detector itself. For reduction of those background, SELENE GRS employs BGO and plastic scintillators as an active shield. The Ge detector is surrounded by a horseshoe-shaped BGO detector (Fig.1). The thickness of a part facing the spacecraft is so enough thick that background from the spacecraft can be greatly reduced, while lunar side is not covered by BGO detector, instead a 5mm plastic scintillator is placed for albedo particle rejection, in which gamma-ray can pass through without energy loss due to the low density. The BGO shield also reduces Compton background by anti-coincidence measurement on board.

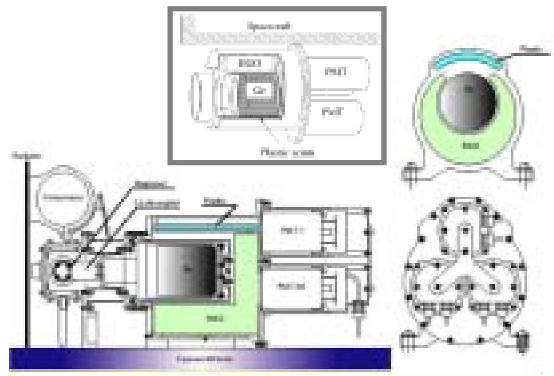

Figure 1: The schematic drawing of SELENE Gamma-ray Spectrometor.

Scientific interest of element measurement: The major topics of lunar science from SELENE/GRS observation are as follows:

(1) Fe, Mg The ratio of Mg to Fe is refered as the magnesium number. Global mapping of the magnesium number is greatly important in advancing our understanding of the evolution of the Moon. The mag-

nesium number will be compared to one on the earth and will show how the moon was formed and was evoluted. Suppose that the moon formed from the debris of a collision between the Earth and some other body, then the magnesium number across the moon's surface should be within a certain range. It is expected of the number to be lower for the moon than it is for Earth; the difference would mean that those bodies have different thermal histories after the supposed collision. SELENE GRS has a sensitivity to both of Fe and Mg and will show global mapping the magnesium number including the polar region. The X-Ray Spectrometer (XRS) will also provide the global mapping of major elements, Mg, Al, and has a high spatial resolution less than 20km. The GRS result will be compared and combined with the XRS result to provide more precise global mapping of the magnesium number.

(2) Radioactivity (U, Th, K) The radioactive decay of U, Th out of the refractory element is energy of thermal flow in the moon. Measuring precisely the abandance of those isotopes shows the thermal flow leading to the thermal history of the moon. SELENE GRS observation will provide more precise measurements of those isotopes, which can indicates the thermal flow precisely and help us to understand the thermal history.

(3) Refractory element (Ca, Al, U, Ti) Refractory element abundance can provide useful information of the differentiation and the formation of lunar crust. Abundance ratio of the refractory element, Ca, Al, U, Ti, etc. of primitive meteoroid is almost same as of earth-type planet, however the absolute abundance depends on planet and so the differentiation is thought to occur after collection into the planet, that is, refractory element abundance couldn't be changed from just after the planet formation, independent of the thermal history. That idea can be applied to lunar study, so quantifying the abundance is a key to study the origin. SELENE GRS can provide global mapping of refractory elements, Ca, Al, U, Ti with high sensitivity.

(4) Volatile element (H, C, S) The existence of water ice has been expected since 1960's and has been not only a scientific interest that comet and meteoroid bombardment could transport it to the moon, also interest in terms of lunar utilization, which is very necessary for human activity. Lunar Prospector and Clementine observation indicate the existence. SELENE/GRS, however, can provide direct evidence of the existence observing the capture gamma ray of 2.223 MeV from hydrogen nucleus. Accumulation time of more than 10 hours will show hydrogen existence if there is more than 0.1 W% within 10 cm in depth(Fig. 2). For determining precisely water ice laid on lunar surface with gamma-ray/neutron spectroscopy, not only hydrogen abundance also other light elements as carbon or silicon abundances have to be measured because the existence of light elements may affect the fast/epi-thermal neutron fluxes in lunar material leading to modulating the flux [5]. SELENE GRS will measure such light elements as Ca and Si with high sensitivity and the observation will lead to precise estimation of the amount of hydrogen in lunar soil. In the lunar permanent shade, there may be other olatiles, C and S [6]. Gamma rays from carbon nucleus of 1.262 MeV, 3.684 MeV, 4.438 MeV and 4.945 MeV are interfered by gamma rays from oxygen which is very abundant in lunar material, so that carbon is hardly detected even by SELENEGRS. On the other hand, the capture gamma ray of 5.421 MeV from sulpher nucleus, which is not interfered, can be detected with more than 2 σ minimum detectable limit by 10 hours observation if the abundance is more than 1.1 W%.

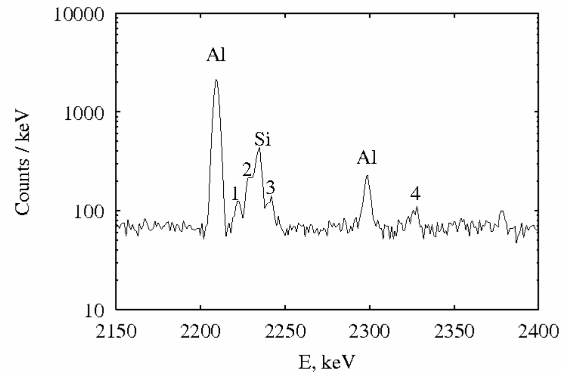

Figure 2: Expected energy resolution of SELENE GRS by numerical simulation [6]. No.1 show H peak, No.2 for S and single peak of O and No.3 for Mg.

Furthermore we can combine the topographic data from the Laser Altimeter (LALT) and the Terrane Camera onboard SELENE and the GRS data and may obtain the chemical composition of the lunar deep crust, which is possibly in exposure to space, and then will obtain important knowledge on the origin and the evolution of the moon.

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