The Development of the High Energy Particle Detector onboad the SELENE spacecraft

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Abstract

The PS (Particle Spectroscopy) sensor, that will be onboard the SELENE spacecraft for the first Japanese lunar mission to be launched in 2005, will measure the high energy cosmic ray particles to study their origin, acceleration and propagation in the solar system. The PS sensor consists of 4 detectors (HID, LPD-HE, LPD-p, LPD-e, these are Si stuck detectors using the $\Delta E \times E$ method) that are cover the energy range from 100keV to 60MeV for proton, from 30keV to a few MeV for electron and from 3MeV/n to 400MeV/n for heavy ions, respectively. We use a new type B^+ doped Si(Li) detector of which thickness is from 1 to 6mm with high energy resolution for each sensor. We can identify the isotopes for heavy ions from He to Xe.

1. Introduction

The SELENE mission will be launched in 2005 by H-IIA rocket as the first Japanese lunar mission. The mission has been proposed to study the origin and evolution of the Moon by means of global mapping of element abundances and mineralogical composition. Measurement of the lunar environment and observation of the solar-terrestrial observation for lunar bases in the future. The SELENE spacecraft will observed from about 100km altitude polar orbit for one year. If extra fuel to keep and control the orbit is available, the mission will be extended for optional observation.

PS (Particle Spectrometer) subsystem is designed to observe several species of charged particles in the wide energy range in the vicinity of spacecraft to understand the charged particle environment. The objectives of the PS subsystem can be divided into two categories. The first category is the study of electron acceleration in magnetospher and the second category is the studies of the anomalous cosmic ray particles and the galactic cosmic ray particles.

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The PS consists of 4 different type detectors (HID, LPD-HE, LPD-p, LPD-e), electronics boards and a data processing unit (OnBoard Computer). LPD-e and -p are mainly used to measure low energy particles, which reflect electron acceleration in the tail geomagnetosphere. On the other hand, HID and LPD-HE are mostly sensitive to solar particles and cosmic rays which reflect physical condition of interplanetary space, their acceleration and the origin of these particles. These sensors are silicon detector telescopes with a large geometrical factor for measuring the particle flux. These are newly developed $\Delta E \times E$ silicon detector telescopes with large geometric factor compared with those used in space so far. LPD-HE measures isotope abundances of particles from helium to iron in the medium energy region and HID does isotope abundances of high energy particles included in galactic cosmic rays.

2. Science objectives

The interplanetary space is filled with magnetic field and there are planets with a large magnetosphere. Interplanetary shock waves frequently formed accelerate electrons and ions to MeV/n or more in Interplanetary Magnetic Field (IMF). PS instruments will make a comprehensive measurement of energetic particle events from interplanetary or planetary origin. Energetic particle observation, moreover can be used to study the propagation of ions from the point where particles were accelerated to the earth, and it is very useful in the investigation of the structure and properties of the interplanetary medium.

3. Instruments description

The PS has been designed to understand (1) the particle acceleration mechanism, energy flow, the propagation mechanism through the interplanetary space, and (2) the origin, propagation mechanism of heavy ions in cosmic rays. Characteristics of PS instruments to observed high energy particles are shown in Table 1 and overview of PS instruments are shown in Fig. 1.

HID and LPD-HE instruments are all silicon semiconductor detector telescopes utilizing the well-known dE/dx x E algorithm for isotope identification. For particles passing through the ΔE-detector with a given thickness and stopping at the E-detector, the mass and nuclear charge can be identified by simultaneous measurements of the energy loss, $DeltaE$, and the total energy of E (=$\Delta E + E'$). Both isotope telescopes consist of several layers of Si detectors, of which top two layers are position-sensitive detectors. Each PSD provides a two-dimensional position information using charged-division method. The PSDs determine the trajectory of each particle so that an accurate measurement of path length Δx can be obtained in each layer. Each has a square ion-implanted resistive surface and charge is collected at each corner of the square surface. Distortion in the

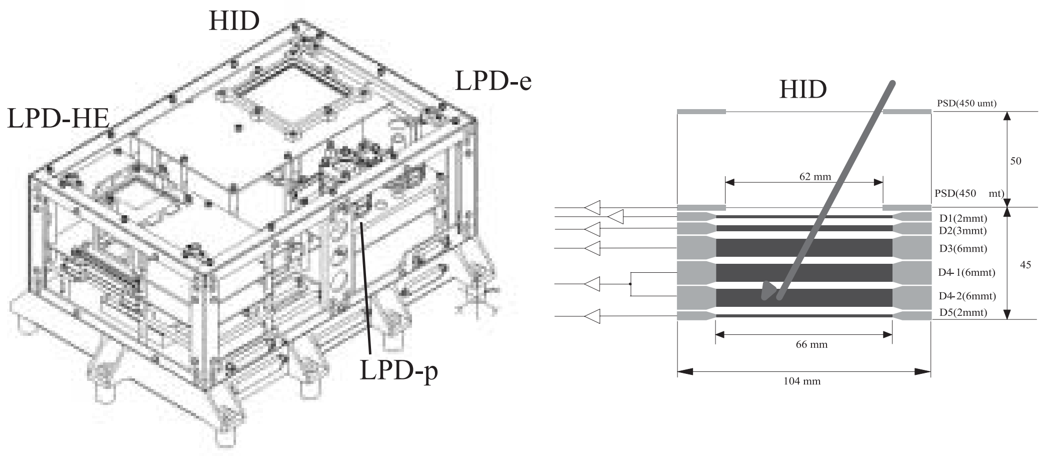

Fig. 1. Overview of PS instruments(left) and Cross-sectional view of HID instrument(right)

resultant position linearity has been greatly reduced by a new approach in which the four corners have been connected by an additional ion-implanted strip-line with a low resistively. The PSDs also measure the energy loss in those layers. The application of the PSDs th the $\Delta E - E$ detector telescopes greatly improves the geometric factors of the telescopes so that even rare elements and isotopes in SEPs and GCRs cane be observed by the in-flight telescopes.

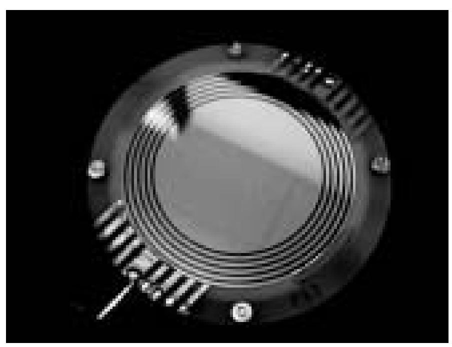

Fig. 2. New developed B^+ doped Si(Li) detector with gird rings for SELENE

The other several layers are Si-detectors for measuring energy losses or residual energy of stopping ions, which have graded thickness from thin to thick one to optimize the detector system due to the energy loss straggling of ions. The bottom layer is an anti-coincident Si-detector which rejects energetic ions penetrating out of the detector stack. These Si-detectors, called B^+ doped Si (Li) detector, are developed for the SELENE mission (Fig. 2). The mass resolution of heavy ions expected for both HID and LPD-HE spectrometers is designed to

Table 1. Characteristics of PS instruments

Inst.	HID	LPD-HE	LPD-p	LPD-e
Energy	Be 18 - 95	He 3.0 - 25	P 1.0 - 50	e 0.3 - 0.7
Range	Fe 45 - 310	C 8.0 - 80	He 3.0 - 50	—
(MeV/n)	Xe 55 - 470	Fe 10 - 105	—	—
Mass Ident.	Be - Zn	He	He	—
Atom Ident.	Ga - Xe	He - Ni	P + e	e
Res.	< 0.35	< 0.4	< 200keV	< 20keV
(FWHM)	amu@Fe	amu@C		
G-Factor				
($cm^2 sr$)	50	6	1	0.3
Structure	PSD 450μm	PSD 50 μm	Si(II) 18μm	Si(B^+Li) 2mm
	PSD 450μm	PSD 50 μm	Si(B^+Li) 3mm	—
	Si(B^+Li) 2mm	Si(B^+Li) 3mm	Si(B^+Li) 3mm	—
	Si(B^+Li) 3mm	Si(B^+Li) 3mm	Si(B^+Li) 3mm	—
	Si(B^+Li) 6mm	Si(B^+Li) 3mm	—	—
	Si(B^+Li) 6mm	Si(B^+Li) 3mm	—	—
	Si(B^+Li) 6mm	Si(B^+Li) 3mm	—	—
	Si(B^+Li) 2mm	—	—	—

be 0.35 amu for the isotopes of nickel, and even better for lighter elements.

LPD-p instrument is similar to HID instrument without PSDs. The field of view for LPD-p are collimated by the signals from gird-rings of Si(Li) detectors. The particle identification method is as same as others, however, low-energy electrons are contaminated to proton data because the $\Delta E \times E$ method can not be used for low-energy electron stop in ΔE detector.

4. Summary

We developed newly B^+ doped Si(Li) detectors for the SELENE mission to observe charged particles in the wide range energy. PS flight models are under the calibration experiment now and that initial data show the good performance of the PS instrument.