Solid State Detection of Medium-energy Electrons for Space Plasma Missions

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The information on energy spectra of 1-100 [keV] electrons is expected to provide an important clue to understand heating and acceleration mechanisms of magnetospheric plasmas, because distribution functions of electrons vary over from the thermal one (several keV) to the non-thermal (100 [keV]) in this energy range. The reliable measurement of electrons in this energy range is important and connected directly with verifications of the scientific paradigm in the magnetospheric physics, such as the particle acceleration by magnetic reconection and physics of the collisionless shocks, etc. Therefore, more detailed observations of non-thermal electrons in these regions are indispensable to clarifying the acceleration and heating mechanisms. However, electrons of several keV to several tens of keV are not properly verified by observations owing to the problems in the measurement techniques. This study aims to bridge this 'gap' by applying Avalanche Photodiodes (APDs) to the detection of electrons.

The APD is a kind of p-n junction semiconductor with an internal gain due to the avalanche amplification of electrons and holes in the strong electric field within its depletion region, which is usually applied for photoelectronic devices. Our first experimental result showed that the pulse height distribution from the APD (Type Z7966-20, Hamamatsu Photonics Co. Ltd.) signal exhibits a significant peak for the electrons with energies above 8keV to 20keV. In that particular energy range, positions of peaks shows good linearity and incident electron energy can be highly resolved. For low-energy electrons (lower than 10keV), it has a characteristic tail on the low energy side. As we have confirmed by Monte Carlo simulation Method, low energy tail features is caused by the dead-layer on the surface of the device and its inhomogeneity. Then, for electrons of over 30keV, the pulse height distributions from the APD output signal shows characteristic double peaks. This result is understood that the impinging electrons has transmitted the avalanche region (10 microns from the surface) where the e-h pairs are multiplicated inside the APD. In addition, the double peak feature was reproduced by our Monte Carlo simulation. Then we have tested a new APD (Type spl 3989, Hamamatsu Photonics Co. Ltd.) whose active layer is as thick as 30 microns and whose surface dead-layer is much thinner. The APD responded to 2-40 keV electrons with good peaks of the pulse hight distribution. The energy resolution is lower than 1 keV at 2-20 keV electrons and 5keV at 40keV. The linearity of the response is also good.