Effects of transmitted electrons on an avalanche photodiode for measurements of low-energy electrons

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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 processes of magnetospheric plasmas. However, the distribution functions in the transition energy range of thermal to non-thermal energies are not well known due to problems in the measurement techniques in space. This study aims at a new measurement technique to detect these electrons with high reliability by using a solid-state APD (Avalanche PhotoDiode) detector instead of the conventional SSDs and MCPs.

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 signal exhibits a significant peak for the electrons with energies above 8keV to 20keV. As long as referring to that energy range, positions of peaks shows good linearity and incident electron energy can be highly resolved. Although the pulse height distribution shows an energy resolution better than 1.5keV in FWHM, the energy resolution depends on the incident electron energy. 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 can be caused by the dead-layer on the surface of the device and its inhomogeneity. For incident electrons at higher energies (near 20keV) the energy resolution gets a little worse and the position of the peak appears at a bit lower channel than should be expected. This nonlinearity and worse resolution of high-energy peaks may have caused by space charge effect of created e-h pairs. Nevertheless, the problem of our expelimental resource has kept us from further understanding of the effect of the higher-energy electrons impinging onto the APD.

Now we have had a chance of an experiment by higher energy electrons (up to 50keV) using the system in The Institute of Space Technology and Aeronotics, JAXA. Over 35keV, the pulse height distributions from the APD output signal shows characteristic double peaks. This result is to be explained that the impinging electrons has transmitted the avalanche region where the e-h pairs are multiplicated inside the APD. In addition, the effect of the space charge by the created e-h pairs will be further discussed. Similarly to the former case, we have used Monte Carlo Method for quantitative understandings. Although APDs of deeper active layer (30 microns = 60keV) is available right now, the new APD, whose active layer is much deeper (over 50 microns), is to be needed for a reliable measurement of 100keV electrons.