High speed MCP anodes for high time-resolution low-energy charged particle spectrometers

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Time resolution required for the low energy charged particle measurements is becoming higher and higher due to the demand for resolving electron scale phenomena. There exist several items that should be developed in order to realize time resolution to acquire 3-D phase space density higher than 10 msec. The 3-D phase space density measurement should be made independent of the spacecraft spin motion. The sensitivity of the analyzer should be high in order to secure good enough counting statistics with short sampling time especially for measuring tenuous plasmas, for example, in the Earth’ s magnetotail. The charged particle detector should be fast enough to accept high count rate generated by high sensitivity analyzer.
One of the solutions for the 3-D phase space density measurement independent of the spacecraft spin motion is to use two analyzers with hemispherical field of view installed on a spacecraft back to back. An example of such an analyzer is ASKY-ESA (All SKY-ElectroStatic Analyzer) originally developed for the 3-D phase space density measurement on 3-axis stabilized spacecraft. ASKY-ESA consists of FOV (Field Of View) scanning deflectors at the entrance and spherical/toroidal electrostatic deflectors inside. The FOV is electrically scanned between +−45 degrees around the center of the FOV, which is 45 degrees inclined from the axis of symmetry. ASKY-ESA was flight verified as MAP-PACE sensors on Japanese lunar orbiter Kaguya.
In order to realize high sensitivity, an electron energy analyzer FESA (Fast Electron energy Spectrum Analyzer) was developed. FESA consists of two electrostatic analyzers that are composed of three nested hemispherical deflectors. Single FESA functions as four top-hat type electrostatic analyzers that can measure electrons with four different energies simultaneously. By measuring the characteristics of the test model FESA, the validity of the design concept of FESA was proved.
The charged particle detector should be fast enough to accept high count rate generated by high sensitivity analyzer. 1D circular delay line anode and MCP anode with ASIC have been developed as high-speed MCP anodes. The 1D circular delay line anode has zigzag patterns on the front side and a microstrip line with a characteristic impedance of ~50ohm is formed with a ground plane on the back of the anode. The maximum count rate of the 1D circular delay line anode is around $1X10^7$/sec/360deg., which is much higher than the widely used resistive anode, whose maximum count rate is around $1X10^6$ /sec/360deg..In order to achieve much higher speeds, an MCP anode with ASIC has been developed. We decided to adopt an anode configuration in which a discrete anode is formed on a ceramic substrate, and a bare ASIC chip is installed on the back of the ceramic. The ASIC contains 64-channel fast amplifiers and counters that enable the 5.625deg. angular resolution necessary for measuring solar wind ions. The whole ceramic substrate, except for the discrete anode pads that collect charged particles, is coated with parylene in order to protect the ASIC and the bonding wires from humidity and dust and to prevent electric discharge. It has been found that the anode can detect at a high count rate of 25 MHz/channel ($1.6X10^9$/sec/360deg.). The ASIC anode has been successfully flight verified by three Norwegian sounding rocket experiments ICI-2, ICI-3, and ICI-4 (Launched from Ny Alesund, Svalbard, Norway in Dec. 2008 and 2011, and from Andoya, Norway in Feb. 2015). In the near future, this anode will be used for detecting low energy ions with Mercury Ion Analyzer (MIA) on BepiColombo/MMO. The ASIC chip and its implementation will be widely used for the future missions that require lightweight low power consumption, high time resolution charged particle measurements.

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