Development of ion imaging system capable of single ion detection

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Recently visualizing the distribution of isotopes on the sample surface is not only applied to cosmochemistry, but also semiconductor and biological sample. Isotope imaging has been realized by a combination of a stigmatic SIMS (Secondary Ion Mass Spectrometry) instrument and 2-dimentional ion detector SCAPS (Stacked CMOS Active Pixel Sensor). The SCAPS can directly detect ion image projected on the SCAPS detector using 600x576 pixels array. Noise of conventional SCAPS system is about 85 micro volts corresponding to 2~3 incident ion. We developed a new SCAPS system in order to reduce the system noise for single ion detection which is theoretical maximum sensitivity.

New SCAPS control system consists of power supply module (PXI-4110, National Instruments), drive pulse module (NI PXI-7811R), analog-to-digital (A/D) conversion module (NI PXI-5922), system control module (NI PXI-8186) installed on a PXI chassis (NI PXI-1042) based on the open industry-standard PXI architecture (PCI eXtensions for Instrumentation) and a custom constant voltages generation circuit. The constant voltages generation circuit generates high precision voltages to drive the SCAPS with a power supply module. The drive pulse module generates driving pulses described by LabVIEW programming language downloaded to the field programmable gate array on the module. Output signal of the SCAPS is digitized by the A/D conversion module which can maximize vertical resolution based on the selected sample rate, from 24 bits at rates up to 500 kS/s to 16 bits at 15 MS/s using delta-sigma modulation. This capability allows us to decrease the noise by averaging of multiple samples for each pixel instead of hardware low-pass filters which restrict flexible driving speed of SCAPS. All modules are controlled by the newly developed software written in LabVIEW on the PXI control module.

Noise of this system was measured to be about 35 micro volts corresponding to about single ion. We developed noise reduction method in order to detect single ion accurately. As with the case of averaging of multiple samples for each pixel, averaging several frames could reduce the noise. After the averaging of 10 image frames, the noise was decreased less than 10 micro volts corresponding to about 0.3 ion. This result indicating single ion detection may be possible with the new system.