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Development of a position and time sensitive ion detector MALPIX for stigmatic imaging mass spectrometry

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Imaging mass spectrometry (IMS) is an analytical technique to simultaneously obtain spatial distributions of multiple atoms and molecules. Molecules such as lipids, proteins, and administered drugs in a biological tissue can comprehensively be observed without labeling. Matrix-assisted laser desorption/ionization (MALDI) is the most major ionization method used for IMS. Higher spatial resolution and shorter measuring time compared with conventional scanning IMS are possible with stigmatic IMS. A spatial resolution of 1 μm for an artificial pattern has been shown with a stigmatic IMS device developed by the authors and coworkers. In the stigmatic IMS, spatial distributions of the analytes on the sample surface are magnified and projected on the detector surface with electrostatic lenses. The detector for the stigmatic IMS is required to simultaneously detect the position and flight time of an ion with spatial and temporal resolutions of 50 μm and 1 ns, respectively. To enable such high speed response, we are developing a position and time sensitive ion detector named MALPIX using the silicon-on-insulator (SOI) CMOS process. Ions are converted to electrons by a microchannel plate (MCP). Each pixel of MALPIX has a metal pad which works as an input electrode, source follower, a discriminator, and a memory. When the electrons from the MCP arrive at the metal pad, the source follower outputs the voltage amplitude. If it is over the threshold, the discriminator outputs a signal to latch the time information and to allow the memory inside the hit pixel to store the time stamp at that time. Time information is generated by a gray code counter and time memory cell (TMC) located outside the pixel array. The time data stored in each pixel can be read out when addressed after the time counter overflows.
Using a 3 x 3 mm3 prototype of MALPIX, the basic function of TMC was confirmed. The voltage controlled oscillator normally used at a frequency of 62.5 MHz oscillates up to 120 MHz, and the phase-locked loop stably operated with a time jitter below 170 ps. In the ion irradiation experiment inside a vacuum chamber, a sample plate, extraction electrode, electrostatic lenses, and MCP were set in front of MALPIX, and the appropriate potentials were given to them so that ion distributions at the sample surface are projected on the MCP. Cesium is put on the sample plate, and a metal mask with a 1 mm dimeter hole is placed in front of MCP. Only ions which pass the mask hole can reach MCP and they are detected by MALPIX. In this experiment with the flight distance of about 50 cm, an ion image corresponding to the hole of the mask was successfully observed at theoretically expected flight time for Cs+ ion.

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