DEVELOPMENT OF ISOTOPE IMAGING SYSTEM WITH TWO-DIMENSIONAL ION DETECTOR SCAPS FOR IMS-1280 SECONDARY ION MASS SPECTROMETER. K. Nagashima[1], G. R. Huss[1], K. Kosaka[2], T. Kunihiro[3], K. Keil[1], A. N. Krot[1], G. J. Taylor[1], and H. Yurimoto[4]. [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA. (kazu@higp.hawaii.edu). [2]Tech Concierge Kumamoto Ltd., Fukuoka, Japan. [3]The Pheasant Memorial Laboratory, Institute for the Study of the Earth's Interior, Okayama University, Tottori, Japan. [4]Department of Natural History Sciences, Hokkaido University, Hokkaido, Japan.

Recently several technical developments of secondary ion mass spectrometry (SIMS) have been applied to isotope imaging, which allows us to visualize the distribution of isotopes in samples. One approach for isotope imaging is to use the stigmatic optics of SIMS (i.e., direct ion imaging). Direct imaging uses the mass spectrometer as an ion microscope. A two-dimensional ion detector for quantitative imaging has been of great interest since stigmatic ion optics was first realized. Recently, Yurimoto et al. [1] developed an "isotope microscope" system consisting of an ims-1270 SIMS instrument and a new, state-of-the-art, solid-state, imaging detector called SCAPS (Stacked CMOS-type Active Pixel Sensor) [2]. The SCAPS is a high-efficiency stacked CMOS-type active pixel sensor, which has several advantages over conventional two-dimensional detection systems, including 608×576 pixels, wide dynamic range, no insensitive period, direct detection of charged particles, and constant ion-detection sensitivities from hydrogen to uranium [3, 4]. Hence SCAPS can measure high ion flux with an accuracy of the statistical error and with a detection limit corresponding to ~3 incident ions [2]. The isotope microscope has been successfully applied to cosmochemistry studies including a discovery of presolar silicate grains in meteorites by *in situ* analysis [5], microscopic oxygen-isotope distributions in chondrite matrix and CAIs [6, 7], and a discovery of a unique Fe-O-S-bearing material, called Cosmic Symplectite (COS), which is extremely enriched in ^{17}O and ^{18}O [8]. In collaboration with Prof. Yurimoto of Hokkaido University, Japan, we are developing a new imaging detector system using the SCAPS in combination with the University of Hawaii Cameca ims-1280 SIMS instrument.

During the past year, we have designed and constructed the required vacuum chamber assembly and have installed it on the UH ims-1280 (Fig. 1). The vacuum chamber assembly consists of an interface with ims-1280, an isolation valve, a linear drive and bellows system, a liquid nitrogen Dewar, and a turbo molecular pump. The UH ims-1280 has an original imaging detector composed of a microchannel plate and a fluorescent screen. Since this detector is still very useful for tuning the instrument, the vacuum assembly is designed to retain the original detector and to insert the SCAPS in front of the original one when we want to do quantitative imaging. The linear drive and bellows assembly inserts and retracts the SCAPS detector to and from an imaging plane where the isotope image is projected. The liquid nitrogen Dewar and cold finger are used to cool the detector at cryogenic temperatures. This minimizes the thermally generated noise in the detector. The Dewar can hold liquid nitrogen for ~12 hours. The entire vacuum housing assembly can be closed off from the rest of the SIMS by the gate valve for servicing and modifications. The separate turbo-molecular pump, backed by a separate rotary roughing pump, is mounted above the detector position. We have installed a SCAPS detector in the vacuum housing to evaluate the ion optics and the thermal performance of

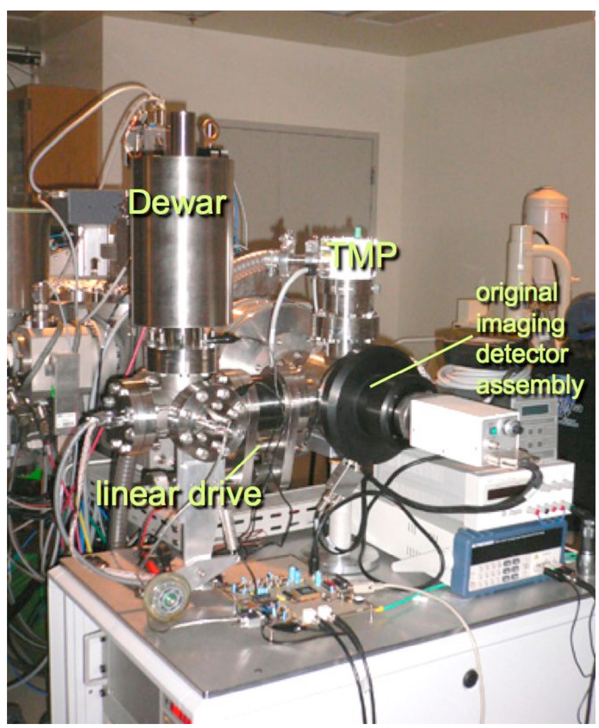

Fig. 1: The vacuum chamber assembly for the SCAPS detector attached to the UH ims-1280. TMP = turbo molecular pump.

the system. Using a very basic set of electronics consists of a driving pulse generator, an amplifier, and a 12-bit analog-to-digital (A/D) converter, we have obtained the first images from the new system (Fig. 2). So far, the system has met all expectations for image sharpness and electronic noise. The smallest features that can be resolved on Fig. 2 are ~0.6 microns across.

We have designed a new and improved version of the electronics to drive the SCAPS. This electronics has several advantages over the previously developed system including a state-of-the-art operation system, high resolution A/D converters, and a pixel command module which controls each pixel independently. The A/D conversion process introduces an error, called quantization error, which is the difference between the actual analog value and quantized digital value due either to rounding or truncation. In order to minimize possible quantization error, it is necessary to have a high resolution of A/D converter. The new system has 18-bit (pipeline) and 20-bit (∑-Δ) A/D converters compared to the 16-bit resolution of the earlier generation of electonics. The pixel command module dynamically controls pixel readout rate, reset operation, and number of readouts for each pixel. This function can be utilized for an individual pixel reset operation, which allows to discharge accumulated signals for only pixels approaching saturation, while other pixels continue to accumulate signals. This operation can potentially increase the dynamic range of the detector overall. Fabrication of the new system is almost completed. We have done a series of factory tests on the new system with the SCAPS device and confirmed most of functions of the system are operational. Noise of the new system with the 18-bit A/D converter was measured to be ~35 μV as an output voltage of the SCAPS, which is less than half of the system noise of ~85 μV with the previous system [2]. Since the noise of ~85 μV corresponds to ~2 incident ions [2], single ion detection may be possible with the new system. We are expecting to install the new system to UH ims-1280 during this January. We will present results of initial tests of the system as well as details of the system at the conference.

Acknowledgements: This work was supported by NASA Grants NNG05GH25G (G. R. Huss, PI) and NNX07AM84G (K. Nagashima, PI).

References: [1] Yurimoto H. et al. (2003) *Appl. Surf. Sci., 203-204,* 793-797. [2] Takayanagi I. et al. (2003) *IEEE Trans. Electron Devices, 50,* 70-76. [3] Nagashima K. et al. (2001) *Surf. Interface Anal., 31,* 131-137. [4] Kunihiro T. et al. (2001) *Nucl. Instr. Meth. A., 470,* 512-519. [5] Nagashima K. et al. (2004) *Nature, 428,* 921–924. [6] Kunihiro T. et al. (2005) *GCA, 69,* 763-773. [7] Nagashima K. et al. (2004) *Workshop on Chondrites and Protoplanetary Disk, #9072*. [8] Sakamoto N. et al. (2007) *Science, 317,* 231-233.

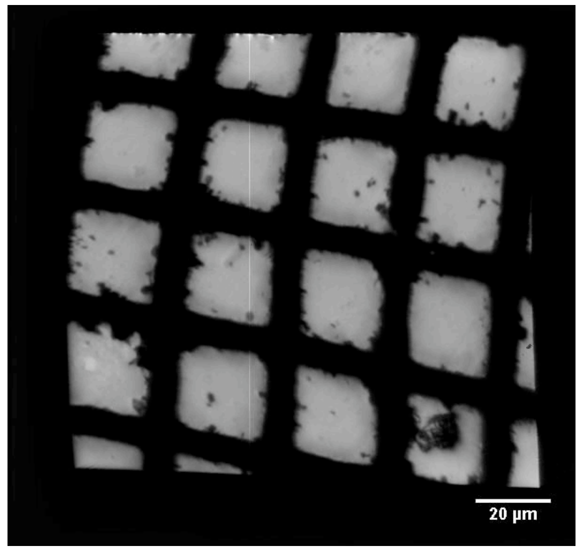

Fig. 2: Ion image in $^{27}Al^{+}$ ions of a tuning grid consisting of copper bars on an aluminum substrate. The bright areas are aluminum. The image was obtained with a contrast aperture of 50 μm. The lateral resolution of the image is estimated to be ~0.6 μm. The stripe on the second column of squares from the left is due to bad line of pixels on our test device.