Development of scanning ion microscope with H_3^+ gas field ionization ion source

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It is well documented that three kinds of ion species (H^+, H_2^+, and H_3^+) can be generated by field ionization [1]. In particular, an energy spread of H_3^+ ions is expected to be smallest among these three ion species because of their generation process [2]. This property must be advantageous for convergence of the ion beam, but there have been a few arguments for practical use of H_3^+ ions in scanning ion microscopy (SIM) or in the direct lithography. First, a stable ion emission of gaseous species with low ionization field, such as H^+, H_2^+, H_3^+, N_2^+, and Ar^+, is generally difficult because of impurities migrating on the emitter tip and reaching the emission area under a relatively small electric field. Second, it has been thought that the intensity of H_3^+ current is relatively small compared with that of H^+ or H_2^+. We have overcome these problems as follows. We have shown a stable H_3^+ emission by using our own hydrogen gas purifier [3]. We have also shown that H_3^+ current is enhanced by terminating emitter tip with one atom [3]. As a result we achieved enough H_3^+ current with sufficient stability to take H_3^+ SIM images in our own SIM. In addition it has been revealed that the energy distribution of H_3^+ ions is actually narrower comparing with that of H_2^+ ions by this equipment [4]. In this presentation, we also describe a new result on switching the hydrogen ions for imaging and the heavy ions for processing.

[1] T. C. Clements and E. W. Mueller, “Occurrence of H_3^+ in the Field Ionization of Hydrogen,” J. Chem. Phys. **37** (1962) 2684.

[2] T. T. Tsong , “Atom-Probe Field Ion Microscopy,” Cambridge U. P. New York (1990) p. 25.

[3] S. Matsubara, H. Shichi, Y. Kawanami and H. Hashizume, “Stable H_3^+ emission from hydrogen gas field ion source by single-atom terminated emitter tip,” HeFIB (2016) Luxembourg City.

[4] S. Matsubara, H. Shichi, Y. Kawanami and H. Hashizume, “Novel Scanning Ion Microscope with H_3^+ Gas Field Ionization Source,” Microscopy and Microanalysis (2016), Columbus, Ohio.

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