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$_3^+$, H$_2^+$, 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.