Tip shaping of gas field ion sources for optimal ion beam generation

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The success of the Scanning Helium Ion Microscope was dependent on the development of an appropriate Gas Field Ion Source (GFIS) to generate the helium ion beam. Current commercial sources are prepared from a “trimer” tip where three tungsten atoms generate the helium beam under a large electric field. Single atom tips have also been under development for their potential to generate large probe currents.

We have prepared W(111) single atom tips from the field assisted chemical etch method using nitrogen gas. Etching to a single atom tip occurs through a symmetric structure and leads to a predictable last atom unlike etching with polycrystalline tungsten tips. The single atom tip formation procedure is shown in an atom by atom removal process. Rebuilds of single atom tips occur on the same crystalline axis as the original tip such that ion emission emanates along a fixed direction for all tip rebuilds.

During tip formation, we also used neon as an imaging gas to evaluate a W(111) tip shape during nitrogen-assisted etching. The neon image allows for the observation of atomic structure not available while imaging with helium and helps to elucidate the atomic structure of the tip during and after the etching to a single atom.

We have also developed a simple procedure to control global tip shape during etching to a single atom. It is demonstrated that the base of a single atom tip can be designed, using custom shaping algorithms, in order to alter the final operating voltage of single atom tips. Using that method, the operating voltage for single atom tips was varied between 6 and 17 kV. We also evaluated the magnification of the helium beam emitted from nanotips prepared on tip bases of various curvatures. It was determined that, for the voltage range studied, the magnification increases with operating voltage, indicating that there is a forward focussing effect for small etched protrusions on large emitter bases. The forward focussing effect can be used to increase the angular current intensity leading to brighter ion beams. These results have consequences in designing emitters for Gas Field Ion Sources where etching is used to prepare the emitter.