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Hydrogen Ion Beams from Nanostructured Gas Field Ion Sources

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Hydrogen ion beams have been discussed as useful for scanning ion microscopy because of hydrogen's low mass and low sputtering rates. Hydrogen ion beams have been reported from various nanotips including pure iridium tips and noble metal covered tungsten tips.[1, 2] However, hydrogen ion beams are known to occur as mixtures of H^+, H_2^+ and H_3^+ depending on the electric field strength.[3] There is some evidence that various tip orientations contribute differently to the ratios of the ions and also that site specific regions also affect the gas species but it has not been clearly determined. Understanding the relationship between tip shape and apex termination with specific hydrogen ion creation is important in order to prepare pure hydrogen ion beams of a single species. This would be beneficial to future applications related to hydrogen ion beam production using gas field ion sources.

In this manuscript, we prepared various nanotips, including single atom tips, trimers and other structures and compared the contents of hydrogen ion beams. The beam contents were separated using a magnetic field in order to compare the ratios of H^+, H_2^+ and H_3^+.

The experimental setup included a home built field ion microscope. The tip was mounted on a heating loop wire for degassing and could was cooled with a liquid helium flow cryostat. Nanotips were prepared from tungsten single crystal wire, W(111) using the field assisted chemical etching method.[4, 5] A magnetic field was generated using two permanent magnets mounted in vacuum between the extractor and the micro-channel plate. Testing of the magnetic field using a mixture of helium and neon gases revealed the field strength to be ~0.9 Tesla.

Figure 1 shows the images from a single atom tip. At low voltages the H_2^+ beam dominates. As the voltage is increased, H_3^+ is also observed until it dominates at larger voltages. In this manner, a particular species can be selected depending on the operating voltage. By integrating the total intensity of the spots separated by the magnet, the ratios could be determined. Figure 2 shows the integrated intensity for the individual species and for the same experiment when no magnet is applied. Figure 2 also shows data for a trimer tip and a hexamer tip. For the trimer case, H_2^+ becomes a significant species and equals the H_3^+ current. H_3^+ can become dominate at higher voltages. For the hexamer tip structure, H_2^+ almost completely dominates with less H_3^+ being produced. H^+ is only observed in small quantities for all tip structures until a high voltage regime, where apex atom resolution is not observed.

We have determined that the tip structure and apex termination plays an important roles in the production of hydrogen ion beams from gas field ion sources by analyzing the ratios of H^+, H_2^+ and H_3^+ in the beam profile from various nanostructured tips.

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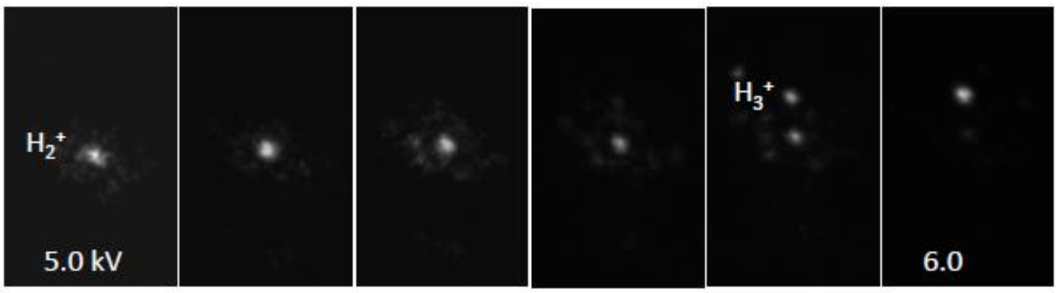
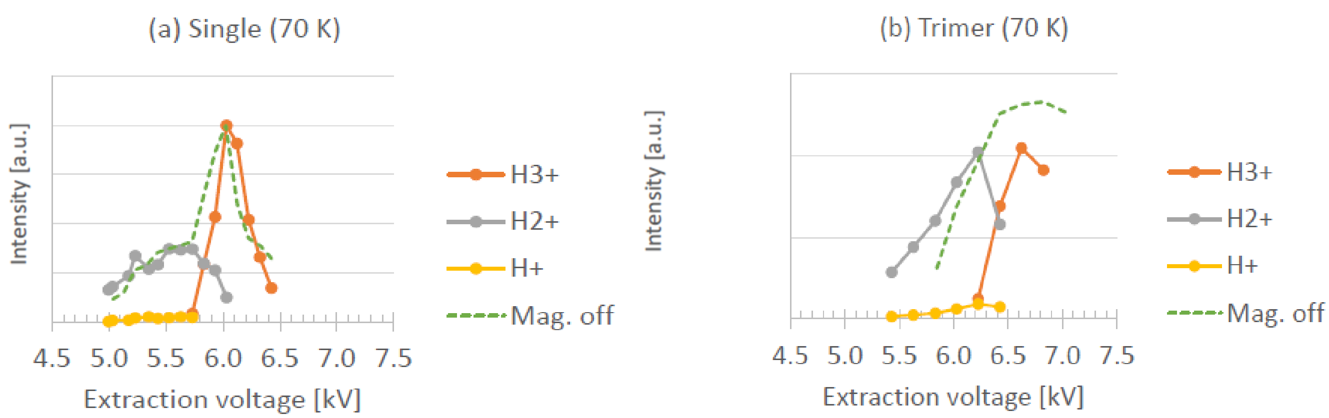


Figure 1: Single atom tip producing a hydrogen ion beam. At low voltage, the H_2^+ species is prevalent. As the voltage increases the H_3^+ spot is observed. At higher voltages the H_3^+ species dominates for the SAT.



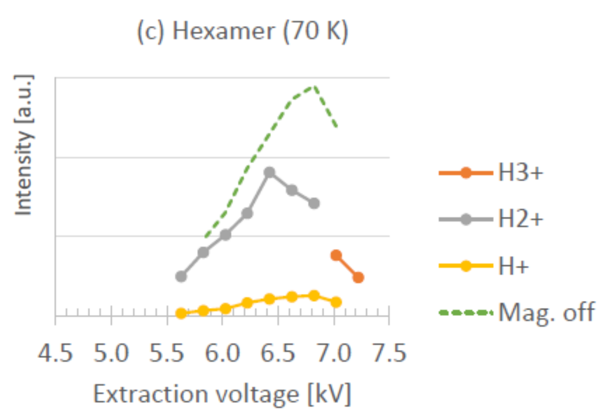


Figure 2. H^+, H_2^+ and H_3^+ ratios from tips with different terminations. A) single atom tip, B) trimer tip, C) hexamer tip. Solid lines indicate the integrated intensity from the magnetic field split spots. The dashed line indicates the total intensity with no magnetic field applied.

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