Fabrication and Testing of Micro-Cylindrical Ion Trap Arrays for Miniaturized Mass Spectrometer Development

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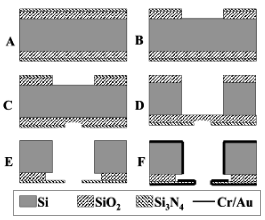
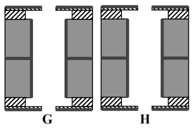
Introduction

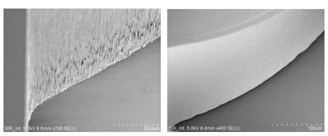
Microelectromechanical systems (MEMS) methods were used to fabricate micro-cylindrical ion trap (μ-CIT) arrays in silicon for mass spectrometry applications.





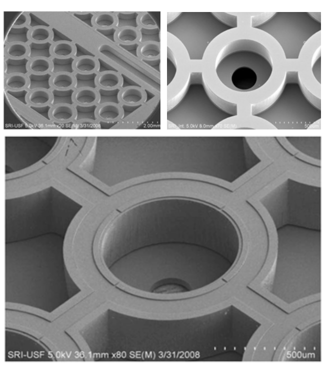
Fabrication Methods

To obtain the 750 μm diameter cylindrical ion trap electrodes, lithography on silicon oxide and silicon nitride was followed by deep reactive ion etching (A–F). Two arrays of half-structures were bonded back-to-back (G and H).



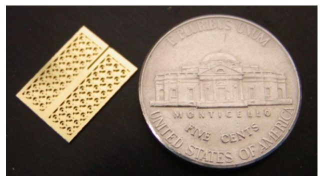
Smoothing of the Electrodes

Smoothing of the surfaces after DRIE was accomplished by applying a KOH (potassium hydroxide) dip.



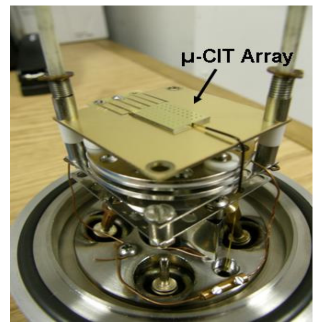
Microfabricated Electrodes

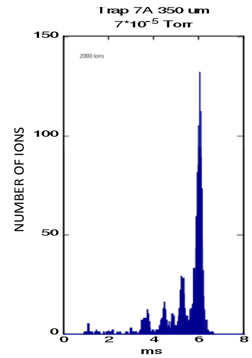
Several fabrication iterations were performed to improve the electrodes, reduce capacitance, and obtain electrodes with a range of diameters for characterization of the optimum geometry for mass separation of ions.

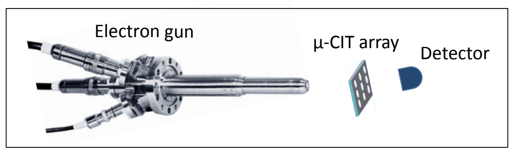


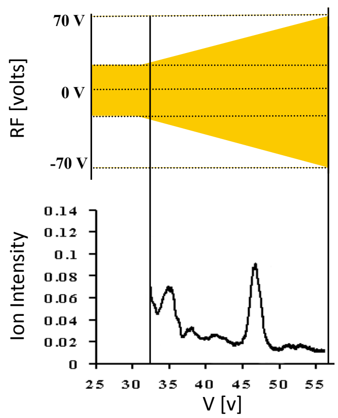
Test Set-up and Characterization

The fabricated samples were mounted onto a flange containing an electrical feedthrough for RF voltage (~60 V, 7 MHz). Analyte was ionized inside each μ -CIT using an electron gun.





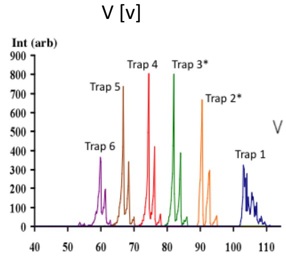


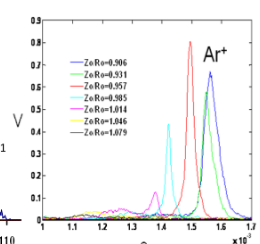


Experiment

An electron gun was directed through each μ-CIT, ionizing the gas molecules inside. By scanning the RF voltage, ions with increasing mass obtained unstable trajectories and were ejected from the μ-CIT. The ions impinged on a micro channel plate ion detector and a mass spectrum was recorded.

z_0 = 350 μm		
Trap #	z_0 / r_0	r_0 (μm)
1	0.92	381
2	0.97	360
3	1.02	343
4	1.07	327
5	1.13	310
6	1.19	294



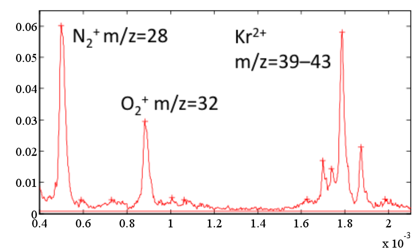


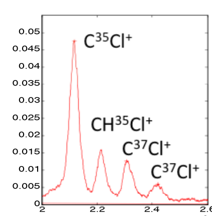
Simulations Compared with Measurements

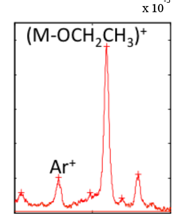
Simulations using ITSIM and SIMION were performed to predict optimum geometries, and indicated that the z_0/r_0 for Traps 2 and 3 gave the best mass separation. Experiments using argon confirmed prediction.

Multipole Components in Electric Potential

Simulations were also performed to investigate non-linear resonances. In the above spectrum, ions were ejected at several resonance lines. This phenomenon was also observed in experimental data. The strength of resonance ejection varied for different geometries. Axial modulation on one endplate was subsequently used to control resonance ejection.







Mass Spectra Obtained from μ-CITs

Top: A spectrum of gas ions. Bottom left: Isotopes of chloroform. Bottom right: fragment of ethyl acetate (m/z = 43).

Acknowledgements

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