Characterization, Simulation, and Fabrication of a CNT Based Micro Mass Spectrometer

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Mass Spectrometers are widely considered the best all-around chemical sensor due to their sensitivity and their ability to detect a wide range of chemical and biochemical species. The size and cost of traditional mass spectrometers have typically limited their application to laboratory settings. Utilizing a microelectromechanical system (MEMS) electrode microfabrication process [Fig. 1], in this work we seek to miniaturize the physical dimensions of a manufactuable mass spectrometer for use as an easily portable, on-site, real-time chemical detection and analysis tool.

Our current designs are based on the use iron catalyst carbon nanotube (CNT) fiber bundles as a cold cathode field emission electron source, in conjunction with several MEMS electrodes (approx. 2 microns thick) fabricated in the form of a triode electron gun with cathode to grid spacing of between 25 and 75 microns, and a grid to anode spacing of between 100 and 400 microns [Fig. 3]. The electrodes are used to extract electrons from the CNTs, as well as to control the flight paths of the electrons into an ionization chamber containing a gaseous sample of interest. Subsequently formed ions are steered into the field of a 0.5 Tesla permanent magnet based magnetic sector of the mass spectrometer.

We have successfully fabricated working electron sources [Fig. 4], housed within an on-chip MEMS-platform gas sampling and ionization region [Fig. 5], as well as a micro scale Faraday cup array (FCA) detector [1,2] [Fig. 6 and 7]. We are now working to bridge the gap between the ionization area and the FCA with a series of MEMS fabricated ion lens panels, and integrate a coded aperture system that will aid in device calibration.

We extensively utilize the charged particle simulation program SIMION, both in the design phase, and in conjunction with testing and characterization of MEMS devices [Fig. 2]. SEM imaging of devices throughout the fabrication process has been instrumental in identifying factors leading to device failures, and for characterization of the CNT source development. This work should result in a total device size and power consumption reduction in mass spectrometry of more than two orders of magnitude.

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1 High voltage MEMS-platform for on-chip vacuum electronic devices, S. Natarajan, J.R. Piascik, K.H. Gilchrist, C.A. Bower and B.R. Stoner, C.B. Parker and J.T. Glass, accepted for publication. Applied Physics Letters vol. 92 (2008)

2 On-chip electron-impact ion source using carbon nanotube field emitters, C.A. Bower, S. Natarajan, K.H. Gilchrist, J.R. Piascik and B.R. Stoner, C.B. Parker and J.T. Glass, Applied Physics Letters, 90, 124102 (2007)

3 SIMION version 8.0.4 Scientific Instrument Services, Inc.

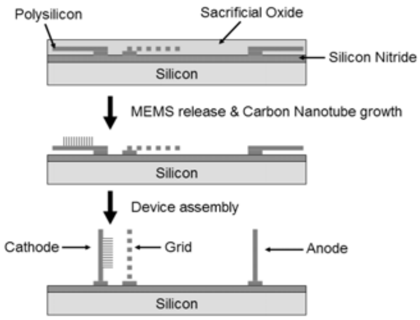

Fig. 1

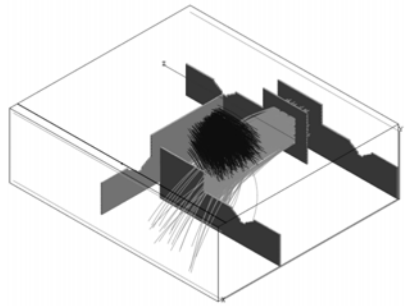

Fig.2

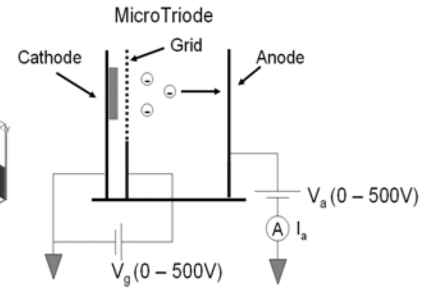

Fig. 3

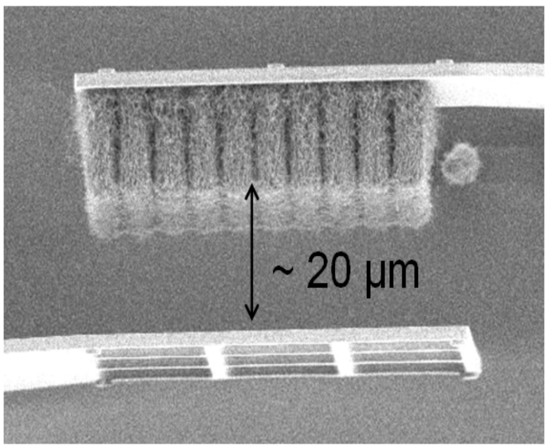

Fig. 4

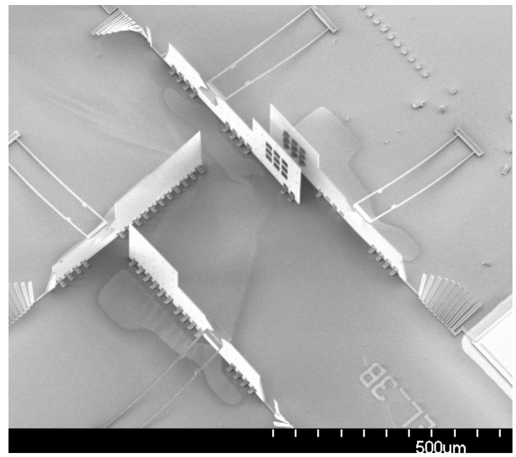

Fig. 5

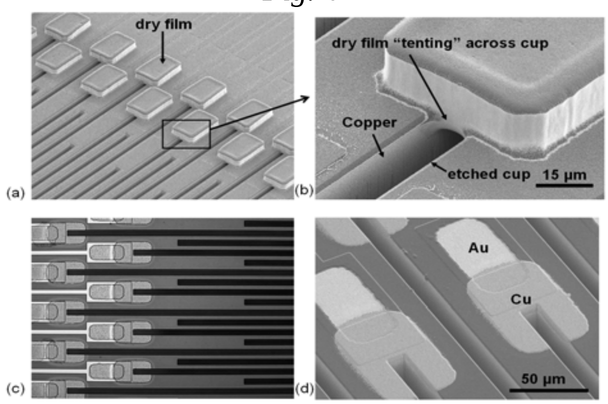

Fig. 6

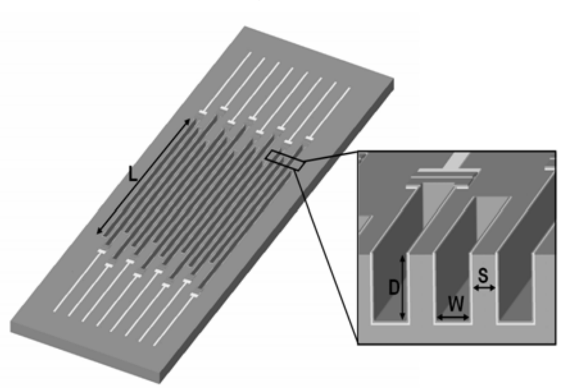

Fig. 7

Fig. 1: MEMS Electrode Fabrication Process
Fig. 2: SIMION 8.0 Simulation of Triode with Ion Collector (Electron trajectories are grey, gas molecule trajectories are black)
Fig. 3: Circuit Layout of Triode Device
Fig. 4: SEM Micrograph of CNT Cold Cathode Field Emission Source
Fig. 5: Micrograph of Working Triode and Ion Collector
Fig. 6: Images of Micro Faraday Cup Array
Fig. 7: Concept Design of Micro Faraday Cup Array