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

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The ultimate goal of SRI International (SRI) mass spectrometer miniaturization efforts is to develop a method for very cost-effective fabrication of highly sensitive miniaturized mass spectrometers. Microelectromechanical systems (MEMS) fabrication technologies appear to offer the best opportunity for achieving this goal. Researchers at SRI have investigated the possibility of extreme miniaturization of cylindrical ion trap mass spectrometers (CIT MSs) by using MEMS fabrication methods, and have validated the MEMS approach for fabricating arrays of very small CITs (radii ≈ 0.35 mm) in silicon. Arrays of CITs operating in unison offer the possibility to recover the sensitivity losses encountered by miniaturizing individual CITs.

The approach in CIT array design has been to fabricate two identical arrays of half-CIT structures (each trap with a half-thickness ring electrode and an aperture endplate) which were then bonded back-to-back to form a full CIT array chip. Design and fabrication iterations optimized operation and performance. Experimental data from CIT arrays demonstrated the ability to increase mass spectral sensitivity by integrating signals from individual CITs in the array. Further optimization of the CIT geometry and fabrication process produced mass spectra with better than unit mass resolution.

Computer simulations to guide fabrication processes avoid excessive manufacturing iterations by predicting optimum CIT geometries, primarily with respect to the axial-to-radial dimension ratio (z_0/r_0) and aperture size. These simulations predict optimum operating pressures for the micro-CITs that are several orders of magnitude higher than those for conventional size commercial ion trap mass spectrometers. Therefore, high vacuum pumps may not be required for mass spectrometer systems based on this technology. To realize truly handheld mass spectrometer technology, further miniaturization and integration of ion sources, detectors, and vacuum systems will be necessary.