Chip-Scale Quadrupole Mass Filters for a Micro-Gas Analyzer

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Microelectromechanical systems (MEMS) technology holds the promise of making devices smaller, faster, better, and cheaper. The Micro-Gas Analyzer (MGA) project at MIT attempts to leverage MEMS capabilities to create a low-cost, high-performance, portable mass spectrometer. Batch-fabrication of various components for the MGA such as ionizers and electrometers have been demonstrated to date, but the mass filter component still has room for exploration.

Chip-scale quadrupole mass filters achieved entirely through wafer-scale processing have been designed, fabricated, and characterized. The device integrates the quadrupole electrodes, ion optics, and housing into a single monolithic block, eliminating the electrode-to-housing misalignments inherent in other quadrupoles that results in degraded performance. To achieve this integration, unconventional square electrode geometry was utilized. Since the quadrupole potential is a boundary value problem, the electric fields around the central axis of the device has minimal distortion arising from the non-ideal electrodes. This concept formed the basis of the micro-square electrode quadrupole mass filter (MuSE-QMF).

The MuSE-QMF demonstrated mass filtering with a maximum mass range of 650 amu and a minimum peak-width of 0.5 amu at mass 40, corresponding to a resolution of 80. These results are equal to or better than other reported MEMS-based quadrupoles. More importantly, the design concept can be extended to much more complex architectures that were previously unachievable. Batch-fabricated quadrupoles in arrays, in tandem, or with integrated pre-filters can have significant impact on the future of portable mass spectrometry. Additionally, experimental characterization of the MuSE-QMF makes a case for operation in the second stability region as a means for achieving good performance with non-ideal electrodes. Results also suggest some novel behavior for the square geometry, motivating new studies on quadrupole ion dynamics.