Chip-Scale Quadrupole Mass Filters for a Micro Gas Analyzer
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In recent years, there has been a desire to scale down linear quadrupoles. The key advantages of this miniaturization are the portability it enables and the reduction of pump-power needed due to the relaxation on operational pressure. Various attempts at making MEMS-based linear quadrupoles have met with varying degrees of success [1]–[3]. Producing these devices involved some combination of precision machining or microfabrication followed by electrode assembly. For miniature quadrupole mass filters to be mass-produced cheaply and efficiently, the electrode assembly should be removed from the process.

A chip-scaled quadrupole mass filter comprising a planar design and square electrodes was conceived, fabricated, and tested. Rectangular electrodes were utilized since this is the most amenable geometric shape for planar microfabrication. This deviation from the conventional round rod geometry required optimization and analysis, which was conducted with Maxwell 2D and MATLAB [4]. The fabrication process consists of thermal oxidation, the use of DRIE to define the features, and the fusion bonding of five patterned silicon wafers. This relatively simple process flow furthers the case for mass-production of these devices. A completed device measures 33 x 15 x 4 mm$^3$ and contains integrated ion optics as shown in Figure 1.

This non-conventional design introduces non-linear resonances that degrade the peak shape in the mass spectrum. Reported work with linear quadrupoles shows improved peak shape by operation in the second stability region [3]. Characterization of the device was conducted using FC-43, a standard calibration compound, and air as the analytes. The MuSE-QMF demonstrated a mass range of 250 amu using the first stability region and a minimum peak width of 0.7 amu in the second stability region. The main peaks for air (nitrogen, oxygen, argon, carbon dioxide) can be clearly distinguished in Figure 2.

In future work, we plan on modifying the processing and the mask layout to improve device performance. The design and fabrication concepts of this device can be expanded into arrayed configurations for parallel analysis and aligned quadrupoles operated in tandem for enhanced resolution.

REFERENCES

FIGURE 1: Fabricated micro-square electrode quadrupole mass filter (MuSE-QMF) next to a U.S. quarter.

FIGURE 2: Mass spectrum for air using the MuSE-QMF driven in the second stability region at 2 MHz.