Surprises in Small Packages: What We Have Learned Making Miniaturized Linear Ion Traps

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In recent years we have created and demonstrated several types of ion traps using lithographically patterned plates, and we have worked at miniaturizing and ruggedizing these systems. In such devices, electrodes patterned onto insulating substrates replace conventional machined electrodes; an ion trap consists of an assembly of two such plates. Alignment of two plates encompasses only six degrees of freedom—much fewer than any other type of ion trap—and the effect of these have been explored both in simulations and experiments. Electrode misalignment is linked to both fabrication strategies and the ruggedness of the resulting device. Although patterned features can be made arbitrarily small, the dimensions of an ejection slit are limited by plate thickness and cutting techniques. We show that a backside taper on the ejection slit avoids problems of charge build-up in an otherwise narrow, deep, insulating slit. Vias have previously been a weak link in the design, and these have been replaced with single-side patterning and wire bonding to printed circuit boards. The choice of substrate material affects ease of fabrication and device ruggedness. Simulations on space-charge effects yield scaling laws for size reduction given constraints of electrical breakdown and trapping efficiency. Recent results show promise for further miniaturization and for maximizing the benefits of ion trap miniaturization in the context of a portable chemical analyzer.