Novel Ion Traps using Planar Resistive Electrodes: Implications for Miniaturized Mass Analyzers

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In radiofrequency ion traps, electric fields are produced by applying time-varying potentials between machined metal electrodes. The electrode shape constitutes a boundary condition and defines the field shape. We have developed a new approach to making ion traps in which the electrodes consist of two ceramic discs, the facing surfaces of which are lithographically imprinted with sets of concentric metal rings and overlaid with a resistive material. A radial potential function can be applied to the resistive material such that the field between the plates is quadrupolar, and ions are trapped between the plates. The electric field is independent of geometry, and can be optimized electronically, or even changed while ions are trapped or between segments of a scan. Preliminary data demonstrate ion formation, trapping, and mass analysis.

This design has some advantages that make it an attractive choice for miniaturization. Obstacles to miniaturization of ion traps include fabrication tolerances, surface smoothness, alignment, limited access for ionization or ion injection, limited stopping distance for trapping externally-injected ions, small trapping volume, and device capacitance—especially for arrayed devices. This trap solves the mechanical issues by utilizing microlithography. Alignment is simplified because there are only two pieces. The open structure of the trap facilitates ion injection. The trap can take on a toroidal trapping geometry, in which case the trapping volume and sensitivity are increased, or it can produce a traditional Paul-trap field, providing higher mass resolution. Miniaturization is frequently associated with increased pressure in a mass analyzer, the idea being that as the trap dimensions decrease, the mean free path of ions can decrease, hence higher pressure and smaller pumps. With this planar electrode arrangement, the amplitude of ion motion can be decreased simply by moving the plates closer together (which does not increase capacitance nor change the field shape) and increasing the trapping frequency, rather than producing a smaller trap.