MICROENGINEERED ELECTRODE ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to United Kingdom Application GB0714316.7, filed Jul. 23, 2007, which is hereby incorporated by reference.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable.

TECHNICAL FIELD

[0003] This invention relates to electrode assemblies and in particular to the provision of a miniature stacked ring electrode assemblies capable of acting as either RF or DC ion guides in the context of mass spectrometry.

BACKGROUND OF THE INVENTION

[0004] There is increasing interest in miniaturized ion optical systems for mass spectrometric analysis. For example, small quadrupole electrostatic lenses have been constructed by stacking together multilayer silicon substrates containing etched mounting features for cylindrical electrode rods and used as quadrupole mass spectrometers (Geear 2005; U.S. Pat. No. 7,208,729). Potential applications for such components include portable mass spectrometers for space exploration and the detection of pollutants, drugs, explosives and chemical and biochemical weapons.

[0005] Depending on the mode of operation of the system, other ion optical components may be required. For example, the ions may be generated at high or atmospheric pressure, and must be transported through a differentially pumped vacuum interface into a low pressure (or "high vacuum") chamber for analysis. In the process, the ions must be separated as far as possible from neutral species and concentrated to increase the intensity of the ion beam. Lens systems based on electrostatic fields that generate essentially ballistic ion trajectories are often inadequate for such purposes, due to the effect of collisions with background molecules.

[0006] However, time-varying fields at radio frequency (RF) frequencies may provide focusing at moderate pressure, due to the combined effect of an effectively static "pseudopotential" field derived from the time-varying potential distribution and the action of the ion-molecular collisions themselves. RF ion optical devices providing such pseudopotential fields are collectively known as ion guides and can be constructed using a variety of electrode arrangements. These electrode arrangements may in general be subdivided into types providing fields with and without an axial variation in potential (Douglas 1998; Gerlich 2004).

[0007] FIG. **1** shows the main principle of a stacked ring ion guide. A set of ring electrodes **101** is arranged at regular intervals along an axis, which serves as the axis of an ion beam **102**. Alternate rings are connected together by bus bars **103***a* and **103***b* that are connected to a RF source **104**, so that each alternate ring carries a voltage of opposite polarity. The motion of the ion beam in the resulting field may be divided into two components. The first is a fast-varying component due to the direct action of the alternating field, and the second is a slow-varying component due to an effective DC pseudopotential derived from the field. The second component acts to drive the ions towards the axis and provides the focusing exploited in beam concentrators and collision cells (Gerlich 2004).

[0008] An application of ion guides is in collision cells, in which previously selected ions are fragmented by application of energy in a region of locally higher pressure in tandem mass spectrometry (or MS-MS) systems. A further application is ion traps, in which ions are first stored and then released in a prescribed manner (Douglas 1998; Gerlich 2004).

[0009] One method of providing a suitable time-varying field is to use a RF-only quadrupole lens. Such an element provides a field with a strong transverse variation but no axial variation. This approach has been used inside a vacuum interface to assist in coupling between an atmospheric pressure ionization source and a high vacuum analysis chamber (Cha 2000; U.S. Pat. No. 4,963,736).

[0010] Another method of providing a suitable field is to use a set of stacked ring electrodes, with RF voltages applied between alternating electrodes (Bahr 1969; Gerlich 1992). Such an approach provides a field with both a transverse and an axial variation. Stacked ring ion guides have again been used to transport ions through differentially pumped chambers (U.S. Pat. No. 6,642,514), and in collision cells (GB 2,402,807A). Similar electrode arrangements have been used with direct current (DC) voltages (Shenheng 1996; Takada 1996), but these require high axial ion energy. Arrangements with gradually decreasing apertures have been used very successfully for ion concentration in the so-called 'ion funnel' (Shaffer 1997; WO 97/49111), and arrangements with travelling wave fields have been used to assist in ion transportation (Giles 2004; GB 2,400,231).

[0011] Generally, the stacked assembly is constructed from separate electrodes and insulators, with separate electrical connections. This approach becomes increasingly inconvenient as the size of the system is reduced. Methods of forming the electrodes from two interleaved machined blocks, each containing one of the two sets of electrodes, have also been described (GB 2,397,690). However, this approach requires three-dimensional machining operations to be carried out, which again becomes increasingly difficult as feature sizes reduce. Furthermore, these operations cannot easily be adapted to geometries involving curved or tapered ion paths.

[0012] Accordingly there is a need to provide a solution to the problems identified above. A further need arises in the provision of a ion guide that allows curved or tapered paths.

SUMMARY OF THE INVENTION

[0013] These needs and other are addressed by a microengineered ion guide formed in accordance with the teaching of the present invention. Such a guide may be fabricated as a miniature stacked ring electrode assembly that is monolithic or involves a small numbers of parts. By fabricating such a guide using known planar processes and whose operation is essentially independent of the layout of the electrodes, the techniques provided in accordance with the teaching of the invention may be carried out on wafers to yield devices in small batches. It is possible following the teaching of the invention to provide curved or tapered ion paths in miniature stacked ring ion guides.

[0014] Microengineered ion guides provided in accordance with the teaching of the invention are formed from miniature stacked ring electrode assemblies capable of acting as either RF or DC ion guides in an ion optical system. The electrodes