art for ion transfer tube designs that achieve further reductions in ion loss and are operable over a greater range of experimental conditions and sample types.

SUMMARY OF THE INVENTION

[0012] Against this background, and in accordance with a first aspect of the present invention, there is |provided|

[0013] an ion transfer arrangement for transporting ions between a relatively high pressure region and a relatively low pressure region, comprising:

[0014] a DC electrode assembly defining an ion transfer channel having a longitudinal axis, the DC electrode assembly including a first plurality of electrodes extending along the longitudinal axis a first distance D**1**, and a second plurality of electrodes extending along the longitudinal axis a second distance D**2**>D**1** and being arranged in alternating relation with the said first plurality of electrodes; and

[0015] means for supplying a DC voltage of a first polarity $+V_1$ to the first plurality of electrodes and for supplying a DC voltage $-V_2$ ($|V_1|>|V_2|$) of a second polarity, relative to the average voltage distribution in the longitudinal direction of the electrode assembly, to the second plurality of electrodes.

[0016] According to a second aspect of the present invention, there is provided

[0017] A method of transferring ions between a relatively higher pressure region and a relatively lower pressure region, comprising:

[0018] arranging a first set of electrodes of a first width D**1** in a longitudinal direction alternately with a second set of electrodes of a second width D**2** in a longitudinal direction (D**1**<D**2**) so as to form a DC electrode assembly defining an ion transfer channel in that longitudinal direction:

[0019] applying a first DC voltage V_1 to the first set of electrodes; and

[0020] applying a second DC voltage V_2 ($|V_1|>|V_2|$) of opposed polarity relative to the average voltage distribution in the longitudinal direction of the DC electrode assembly, to the second set of electrodes;

[0021] wherein the widths D1 and D2, and the voltages V_1 and V_2, are selected so as to create, successively, a series of alternating relatively high electric field and relatively low electric field regions within the ion transfer channel, each high field region being shorter than each low field region in the longitudinal direction.

[0022] Roughly described, an ion transfer channel constructed in accordance with one embodiment of the invention utilizes a periodic electrode structure to generate spatially alternating asymmetric electric fields that tend to focus ions away from the inner surface of the channel wall and toward the channel plane or axis of symmetry. A first plurality of electrodes are arranged in alternating relation with a second plurality of electrodes, the electrodes of the first plurality having a width (axial extent) that is significantly shorter relative to the width of electrodes in the second plurality. First and second DC voltages are respectively applied to the first and second plurality of electrodes, the first voltage having a magnitude significantly greater than and a polarity opposite to the second DC voltage. As used herein, the polarity of a DC voltage is referenced to the smoothed (i.e. averaged over the spatial period) potential distribution along the flow path; DC voltages greater or less than the corresponding potential are respectively considered to have positive and negative polarities. Ions traversing the ion transfer channel in the region proximate to the channel inner surface experience an alternating succession of high and low field strength conditions, the high field strength condition having a duration significantly shorter than the low field strength condition due to the relatively shorter widths of the first plurality of electrodes. The net radial movement of an ion or other charged particle within the channel will depend on the relation between its high and low field mobilities; for A-type ions (which exhibit positive dependence of ion mobility on field strength, and which encompasses many analytes of interest, especially low molecular weight ions), ions may be moved away from the channel inner surface and toward the channel centerline by matching the first DC voltage polarity to the ion polarity.

[0023] The foregoing ion transfer channel embodiment may be utilized in relatively high pressure regions of a mass spectrometer, wherein ion motion through the channel is dominated by and defined by the gas flow conditions. In many cases the flow through the channel is characterized by a substantially constant velocity for ions and molecules of all masses. Additional forces may arise from net (i.e. smoothed) DC gradients. Successful operation of the ion transfer channel will generally require that that mean free path of ions within the channel is substantially (hundreds to thousands times) shorter than the period defined by the electrode dimensions. Under these conditions (typically on the order of hundreds to 1000 mbar), traditional RF ion guides (e.g. RF-only multipoles or ion funnel according to U.S. Pat. No. 6,583,408 by Smith et al.) become inefficient and can not improve transmission. In such cases, the ion transfer channel of the present inventions offers an operationally significant advantage over the prior art.

[0024] In a variant of the foregoing embodiment, a focusing/guiding structure is constructed from a multiplicity of ring electrodes, and DC voltages of opposite polarities are applied to adjacent ring electrodes. The dimensions of the ring electrodes (width and inner dimension) are selected such that the field experienced by an ion (entrained in gas flow) traversing the ion tunnel experiences alternating electric fields at a frequency that approximates a conventional radio frequency (RF) field, and ions are focused to the flow centerline in a manner similar to focusing in an RF ion guide. The ring electrodes may be arranged to define a flow path having at least one directional change (e.g., a ninety-degree bend) to assist in ion-neutral separation. This embodiment is especially applicable (and actually might be preferable) for the transport of ions within pressure regions of several tens mbar.

[0025] Further features and advantages of the present invention will be apparent from the appended claims and the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. **1** shows a cross-sectional diagram of an ion transfer arrangement in accordance with a first embodiment of the present invention . . . ;

[0027] FIG. **2** shows an example of an ion entry region for the ion transfer arrangement of FIG. **1**;

[0028] FIG. **3** shows the ion entry region of FIG. **2** with an aerodynamic lens to optimize flow;

[0029] FIGS. **4***a*, **4***b* and **4***c* together show examples of envelopes of shaped embodiments for the ion entry region of FIGS. **2** and **3**.

[0030] FIG. **5** shows, in further detail, the ion entry region having the shape shown in FIG. **4***b;*