METHOD AND APPARATUS FOR SELECTIVE FILTERING OF IONS

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FIELD OF THE INVENTION

The present invention relates generally to a method for selective filtering of ions. More particularly, the invention relates to a method for selective filtering of low-m/z ions that is used in conjunction with, e.g., an electrodynamic ion funnel conductance limit, or terminating, electrode. The invention finds application in, e.g., analytical instruments and associated systems including, but not limited to, e.g., mass-selective instruments and components, coupled stages, and/or ionization sources and components including, but not limited to, e.g., MS, IMS/MS, FAIMS/MS, GC-MS, LC-MS, ESI-MS, and the like.

BACKGROUND OF THE INVENTION

Electrospray ionization (ESI) mass spectrometry (MS), or ESI-MS, has become a vital tool in biological research. Central to ESI-MS is the manipulation, transmission, and increasingly the trapping of ion populations. In a population of ions, electric fields of the ions influence each other and the collective effect is known as space charge. The detrimental effects of excessive space charge on instrumental performance are well known in the art. For example, like-charged ions repel each other, and the electric field of an ion cloud distorts the electric fields from the elements, optics, and mass analyzer of the mass spectrometer. Further, space charge reduces the mass measurement accuracy in various instruments, including, e.g., Fourier transform ion cyclotron resonance (FTICR) MS. Similarly, 3-D ion traps suffer from detrimental effects from excessive space charge which leads to shifts in secular frequencies, changes in optimal excitation amplitudes, and plasma effects. Space charge can also cause radial stratification of ions and unwanted fragmentation in accumulation quadrupoles or multipoles in general. Various strategies and techniques have been employed in an attempt to reduce the influence of space charge, including, e.g., data-dependent corrections and calibrations and automated methods which regulate and decrease the variation of ion populations in a mass analyzer. However, data-dependent corrections and calibrations do not reduce or eliminate space-charge effects. Further, such approaches are limited in that they cannot distinguish ions of interest from those that constitute background ions.

Accordingly, there remains a need for methods and devices that significantly reduce and/or eliminate space-charge effects in analytical instruments and related components or systems thereby improving analysis results.

SUMMARY OF THE INVENTION

In one aspect, the invention is a low m/z filtering apparatus, comprising a filtering plate or electrode positioned at an exit point or a terminating aperture of an ion funnel, wherein the filtering plate is biased in conjunction with a power supply for applying adjustable DC voltage(s) to the filtering plate or electrode without affecting voltages of the funnel. Voltage(s) when applied to the filtering plate or electrode generates a barrier potential prohibiting ions introduced to the funnel from exiting the funnel having a kinetic (m/z) energy lower (i.e., lower mass-to-charge ratio) than the barrier potential thereby filtering the lower m/z ions.

In another aspect, the invention is a method for reducing and/or eliminating space charge contributed by low m/z ion species comprising: providing an ion funnel including a filtering plate or electrode coupled thereto at an exit point for ions traveling therethrough, wherein the filtering plate or electrode is isolated from the DC and/or RF voltages of the funnel and biased in conjunction with an independent DC power supply for applying DC voltages to the filtering plate or electrode without affecting voltages of the ion funnel. Voltages when applied to the filtering plate or electrode generate a barrier potential that prohibits ions introduced to the funnel having a lower kinetic energy (lower m/z) than the barrier potential from exiting the ion funnel thereby filtering lower m/z ions.

In another aspect, the invention is a method for filtering low m/z ions, comprising: providing a filtering plate or electrode in an ion funnel at the exit point for ions traveling through the funnel, wherein the filtering plate or electrode is biased in conjunction with a power supply operable for applying adjustable DC voltage(s) to the filtering plate or electrode without affecting voltages of the funnel; and wherein the voltage(s) when applied to the filtering plate or electrode generate a barrier potential prohibiting ions introduced to the funnel from exiting the funnel having a kinetic energy lower (i.e., lower mass-to-charge ratio) than the barrier potential thereby filtering the lower m/z ions from an ion stream exiting the funnel thereby reducing or eliminating space charge effects contributed to ion current by the lower m/z ions.

In an embodiment, the operating pressure for the filtering member is in the range from about 1 Torr to about 30 Torr, or in the range from about 1 Torr to about 3 Torr.

In another embodiment, the voltage of the filtering member is dynamically adjustable providing a linear voltage adjustment for effecting ion separation of an analysis instrument or analysis system in real-time.

In another embodiment, filtering comprises selection of m/z values for ions in the range from about m/z of 50 to about m/z of 500.

In another embodiment, filtering comprises selection of m/z values for ions above an m/z of about 500 in conjunction with enhanced voltage gain to compensate for loss of signal or signal attenuation.

In another embodiment, the filtering apparatus is sequentially coupled to one or more devices or systems for gas-phase ion separation and analysis selected from ion mobility spectrometry (IMS), field asymmetric waveform ion mobility spectrometry (FAIMS), mass spectrometry (MS), tandem MS, multiple MS stages of any kind, gas chromatography (GC), LC-MS, photoelectron spectroscopy, photodissociation spectroscopy, ionization sources, ESI-MS, or combinations thereof.

In another embodiment, the filtering apparatus is coupled on-line or off-line to at least one apparatus for separations and analysis of substances in solid or liquid phases selected from the group consisting of liquid chromatography (LC), normal phase LC, reversed phase LC, strong-cation exchange LC, supercritical fluid chromatography, capillary electrophoresis, capillary isoelectric focusing, gel separations in one or more dimensions, SDS-PAGE, 2-D gel, or combinations thereof.

In another embodiment, ions are biological or macro-molecular ions selected from the group consisting of proteins, protein complexes, peptides, polypeptides, oligonucleotides, DNA, RNA, polymers, oligosaccharides, dendrimers, fragments thereof, or combinations thereof.