

LENS FREE COLLISION CELL WITH IMPROVED EFFICIENCY

BACKGROUND

[0001] This application is in the field of mass spectrometers and, more specifically, to a mass analysing spectrometer and method for fabricating a lens free collision cell. Various mass spectrometers are known in the art. An example of a prior art multi-pole mass spectrometer is illustrated in Figure 1. For convenience of description, the mass spectrometer example of Figure 1 is specific to a quadrupole mass analyser, however embodiments of the invention may be used in other types of mass analysers, e.g., a hexapole, an octapole, etc. In the mass spectrometer of Figure 1, the sample molecules are delivered, e.g., by injector 105, into an ionization chamber 110, which ionizes the molecules, thereby acting as an ion source 110. Ions from the ion source 110 are focused and transferred to the mass analyser 125 via ion guide or transfer optics 115, which is driven by voltage generator 120. The operation of a mass spectrometer is well understood by the skilled in the art.

[0002] An ion collision cell is incorporated in various designs of mass spectrometers, such as the triple quadrupole mass spectrometer instrument described in Figure 3. The function of a collision cell is to modify the ions generated in the ion source, by either colliding them into fragments or reacting them with other molecules. In both cases, a parent ion from the ion source is introduced into a higher-pressure region for a given time. A specifically selected gas, such as argon, nitrogen, helium, etc., is injected into the high pressure region of the collision cell, so that the ions will collide with molecules of the injected gas. The resulting fragment or product daughter ions then exit the collision cell and are analysed by another mass analyser and further directed to the detector.

[0003] The collision or reaction energy can be varied by the parent ion's initial velocity, the size and type of the collision gas molecules, and the number of collisions encountered. The number of collisions is depended on the gas pressure and the reaction time. If a parent ion hits a collision gas molecule, its flight path will be altered. For this reason most cell designs are built around multi-pole structures containing an ion focusing RF field.

[0004] The high pressure inside the collision cell needs to be accurately controlled, while the remaining interior of the mass spectrometer needs to be maintained in vacuum. However, gas may leak from the collision cell into the mass spectrometer through the openings for ions entering and exiting the cell. Prior art
5 collision cells utilize seals at the entrance and exit to the cell to reduce the gas leak. However, such seals may be insufficient for high performance cell. Further information can be found in U.S. Patent 6,576,897.

[0005] Accordingly, there is still a need for an improved and effective collision cell.

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SUMMARY

[0006] The following summary is included in order to provide a basic understanding of some aspects and features of the disclosure. This summary is not an extensive overview of the invention and as such it is not intended to particularly identify
15 key or critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented below.

[0007] In a first aspect of the present invention, there is provided an ion collision cell, comprising: an insulating plate having two surfaces; a plurality of conductive
20 elements, each element having a cross-section configured for forming an electrode surface; wherein all of the elements are attached to one surface of the insulating plate along their length, whereby the electrode surfaces of all of the elements define an ion transport tunnel.

[0008] In a second aspect of the present invention, there is provided ion
25 collision cell assembly, comprising: an insulating plate having two surfaces; and four elongated conductive elements attached to one surface of the insulating plate along their length to thereby form an ion transport tunnel, wherein each of the conductive elements is curved such that the transport tunnel forms a 180 degree turn.

[0009] In a third aspect of the present invention, there is provided a mass
30 spectrometer comprising: an ion source; a mass analyser having ions entering at its inlet and selected ions exiting at its outlet; and an ion collision cell receiving the selected ions

from the mass analyser and facilitating ion collisions with gas molecules, the collision cell comprising an insulating plate with two surfaces, a plurality of conductive elements, each element having a cross-section configured for forming an electrode surface, wherein all of the conductive elements are attached to one surface of the insulating plate along their length, whereby the electrode surfaces of all of the elements define an ion transport tunnel.

[0010] In a fourth aspect of the present invention, there is provided method for fabricating an ion collision cell assembly, comprising: obtaining an insulating plate having two surfaces; obtaining a plurality of elongated conductive elements, each element having a cross-section configured for forming an electrode surface; and attaching the plurality of elongated conductive elements to one surface of the insulating plate along the length of the conductive elements, such that the electrode surfaces of all of the elements define an ion transport tunnel.

[0011] Embodiments of the invention address the issues present in the prior art and enable simplified fabrication of a collision cell that reduces gas leakage and improves alignment of the cell's poles. According to disclosed embodiments, the cell is formed by four elongated semi-circle profile elements, all of which attach along their length to the same reference plate. Consequently, all four elements remain aligned to the same reference plate. The four elements form a semi-circular channel with semi-circular quad electrodes. The quad electrodes receive electrical potential to form the field required to maintain the ions at the centre of the channel, i.e., at the centre of the transport axis of the collision cell. Semi-circular insulators are provided on all sides of the channel so as to seal the channel over most of its length from the interior of the mass spectrometer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Other aspects and features of the invention would be apparent from the detailed description, which is made with reference to the following drawings. It should be appreciated that the detailed description and the drawings provides various non-limiting examples of various embodiments of the invention, which is defined by the appended claims.

[0013] Figure 1 is a schematic of a quadrupole mass spectrometer which may be adapted for implementing an embodiment of the invention.

[0014] Figure 2 is a schematic illustrating ion mass analyser according to an embodiment of the invention.

5 [0015] Figures 3a-b are cross-sections of the collision cell shown in Figure 2, according to embodiments of the invention.

[0016] Figure 4 is an exploded view of the collision cell shown in Figure 2, according to embodiments of the invention.

10 [0017] Figure 5 is a schematic according to another embodiment of the invention.

DETAILED DESCRIPTION

[0018] The embodiments disclosed herein provide a collision cell for a mass analyser. The disclosed cell is easier and cost effective to fabricate, yet maintains high alignment of the field poles, and high efficiency pressure management. The
15 embodiments illustrated and described are for a quadrupole, but it should be appreciated that the disclosed features are equally applicable for fabricating other multi-pole collision cells having, e.g., hexapole, octapole, etc. The collision cell constructed according to embodiments of the invention may be used in any mass
20 spectrometer type where the ions are made to collide with gas species.

[0019] The details of an embodiment of the invention will now be described with reference to the drawings. Figure 2 illustrates parts of a mass spectrometer relevant to the collision cell. Various ions from the ion source enter mass analyser 225 and are separated according to their mass to charge ratio, m/z , such that only selected ions
25 having the filtered m/z exit the mass analyser 225. The selected ions then enter the collision cell 260. In this embodiment, no lens is provided between the mass analyser 225 and the collision cell 260. In the collision cell 260 the ions enter an area of injected gas at increased pressure, i.e., pressure higher than the vacuum environment prevailing inside the mass analyser. The ions collide with the gas species and ions exit the
30 collision cell 260 and enter the second mass analyser 227. After exiting from the mass analyser 227 the ions may enter a detector (not shown).

[0020] Collision cell 260 is formed of four semi-circular conductive elements that form the required field for the ion transport. The four elements are made of conductive material and are attached to a common insulating plate, so that their alignment is referenced to a single plane. This ensures accurate alignment of the poles during
5 fabrication and at various operating temperatures.

[0021] Figure 3a is a cross-section along the line A-A of Figure 2. Each of the electrodes 361-364 of the quad collision cell is made of a conductive semi-circular element, having a profile that terminates to form the electrode surface 367 of the quad. All four elements 361-364 are attached along their length to insulating plate 365, as
10 exemplified by bolts 370. In this manner, all of the quad elements have a common reference plane for the alignment of the quad electrode surfaces. This ensures proper alignment at assembly.

[0022] Additionally, in the illustrated embodiment, gas seals are provided to confine the injected gas to the volume defined by the electrodes, i.e., around the ion
15 transport axis. As seen in the cross-section of Figure 3a, four elongated seals are provided about the quad electrodes, two vertical electrodes 366 and two horizontal electrodes 368. Together the four seals generate a seal tunnel about the axis of ion transport. In this manner, the injected gas is confined to within the tunnel of ion transport. Also, this eliminates the need for end seals, as was done in the prior art.

20 Since the injected gas is confined to the small space within the ion transport tunnel, very little gas needs to be injected, so that the injected gas is generally confined to the area of injection and the pressure gradually lowers towards the edges of the collision cell. The gas is injected via inlet 372.

[0023] The embodiment of Figure 3a illustrates a quad electrode arrangement,
25 wherein each of the four elements 361-364 has a profile defining one electrode of the quad. Each electrode is separated from its neighbouring electrode by a distance indicated as "g" in Figure 3b which shows an alternative embodiment with similar design. In this embodiment, each of the four elongated seals 366 and 368 is positioned behind one of the gaps – at a distance indicated as "d", which is not larger than the gap
30 distance g. Also, each of seals 366 and 368 is in the shape of a thin strip. Each of the thin strips is inserted between two electrodes in a perpendicular orientation. This

minimizes the capacitance between each two adjacent electrodes. That is, since the seals are in the form of a thin strip oriented perpendicularly to the surface of the electrodes, it does not serve as a dielectric with respect to parasitic capacitance that may exist between the two electrodes.

5 **[0024]** Since the elongated seals are placed just behind the electrode surfaces, the injected gas is confined to the area of the quad field. Therefore, gas flow can be reduced without changing the collision rate. Consequently, gas leakage from the collision cell is minimal. Accordingly, unlike the prior art, the embodiment of Figure 2 need not have a pre and/or post evacuation regions. That is, in the embodiment of
10 Figure 2, the gas is injected at the centre of the semi-circular collision cell, such that the pressure at the centre of the collision cell is highest and it gradually decreases towards the entrance and exit – there are no defined high and low pressure regions. On the other hand, this design enables early collision of ions with the injected gas, thereby reducing ion energy as the ions enter the collision cell. Conversely, early collisions also
15 enhances collisional focusing, thereby reducing the ion losses in the pre-evacuation region of the prior art. Additionally, since gas flow out of the collision cell is reduced, the mass analysers can be placed closer to the entrance and exit of the collision cell.

[0025] According to one embodiment the common plane to which all of the elements are attached to is a ceramic plate, upon which all of the electrical elements,
20 circuitry and connections are made. In other embodiments, the plate may be a printed circuit board, upon which all of the electrical connections are made. Either arrangement eliminates all wiring for the collision cell. The electrical connections to the elements may be made using pogo pins, also eliminating wiring.

[0026] Figure 4 is an exploded view of the collision cell shown in Figure 2,
25 according to embodiments of the invention. The four poles 461-464 are connected to insulating plate 465. An inner vertical seal 466i and an outer vertical seal 466o are inserted together with horizontal seals 468, so as to form a seal transport tunnel around the four field generating surfaces of the poles. In this embodiment, an optional cover
30 plate 470 is provided on top of the assembly.

[0027] The above description relates to a specific embodiment of the invention; however, the invention can be implemented using other embodiments to achieve the

same improvements and features. It should be understood that processes and techniques described herein are not inherently related to any particular apparatus and may be implemented by any suitable combination of components. Further, various types of general purpose devices may be used in accordance with the teachings described herein. It may also prove advantageous to construct specialized apparatus to perform the method steps described herein.

[0028] The present invention has been described in relation to particular examples, which are intended in all respects to be illustrative rather than restrictive. Those skilled in the art will appreciate that many different combinations of hardware, software, and firmware will be suitable for practicing the present invention. Moreover, other implementations of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

CLAIMS

1. An ion collision cell, comprising:
 - an insulating plate having two surfaces;
 - a plurality of conductive elements, each element having a cross-section configured for forming an electrode surface;
 - 5 wherein all of the elements are attached to one surface of the insulating plate along their length, whereby the electrode surfaces of all of the elements define an ion transport tunnel.
- 10 2. The ion collision cell of claim 1, wherein the plurality of elements comprises four elements.
3. The ion collision cell of claims 1 or 2, further comprising a plurality of elongated seals provided at the periphery of the transport tunnel to thereby seal most of or the entire length of the transport tunnel.
- 15 4. The ion collision cell of claim 3, wherein the plurality of elongated seals comprise a plurality of thin flat strips.
- 20 5. The ion collision cell of claims 3 or 4, wherein each of two adjacent electrode surfaces are separated by a gap of length g , and wherein each of the elongated seals is positioned behind a corresponding gap at a distance d of length greater than length g .
- 25 6. The ion collision cell of any one of claims 3 to 5, further comprising a gas injection inlet enabling gas injection into the ion transport tunnel.

7. The ion collision cell of any one of claims 1 to 6, wherein the insulating plate comprises a printed circuit board.
- 5 8. The ion collision cell of claim 7, further comprising pogo pins making electrical contact to each of the elements.
9. The ion collision cell of any one of claims 1 to 8, wherein the conductive elements are curved and form an ion transport tunnel making 180 degrees turn.
- 10 10. The ion collision cell of claim 9, wherein the plurality of elements comprises four elements and the electrode surfaces define an ion transport tunnel having a square cross-section.
11. An ion collision cell assembly, comprising:
15 an insulating plate having two surfaces; and
four elongated conductive elements attached to one surface of the insulating plate along their length to thereby form an ion transport tunnel, wherein each of the conductive elements is curved such that the transport tunnel forms a 180 degree turn.
- 20 12. The assembly of claim 11, wherein the ion transport tunnel has a square cross-section.
13. The assembly of claims 11 or 12, further comprising four elongated seals, each
25 provided between two of the conductive elements, thereby sealing the transport tunnel throughout its length.
14. The assembly of claim 13, further comprising gas inlet for injecting gas into the ion transport tunnel.
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15. A mass spectrometer comprising:
an ion source;
a mass analyser having ions entering at its inlet and selected ions exiting at its outlet; and
- 5 an ion collision cell receiving the selected ions from the mass analyser and facilitating ion collisions with gas molecules, the collision cell comprising an insulating plate with two surfaces, a plurality of conductive elements, each element having a cross-section configured for forming an electrode surface, wherein all of the conductive elements are attached to one surface of the
- 10 insulating plate along their length, whereby the electrode surfaces of all of the elements define an ion transport tunnel.
16. The mass spectrometer of claim 15, wherein the plurality of elements comprises four elements.
- 15 17. The mass spectrometer of claims 15 or 16, further comprising a plurality of elongated seals provided at the periphery of the transport tunnel to thereby seal the entire length of the transport tunnel.
- 20 18. The mass spectrometer of claim 17, wherein the plurality of elongated seals comprise a plurality of thin flat strips.
19. The mass spectrometer of claims 17 or 18, wherein each of two adjacent electrode surfaces are separated by a gap of length g , and wherein each of the
- 25 elongated seals is positioned behind a corresponding gap at a distance d of length greater than length g .
20. The mass spectrometer of any one of claims 17 to 19, further comprising a gas injection inlet enabling gas injection into the ion transport tunnel.

21. A method for fabricating an ion collision cell assembly, comprising:
- (a) obtaining an insulating plate having two surfaces;
 - (b) obtaining a plurality of elongated conductive elements, each element
5 having a cross-section configured for forming an electrode surface; and
 - (c) attaching the plurality of elongated conductive elements to one surface of
the insulating plate along the length of the conductive elements, such that
the electrode surfaces of all of the elements define an ion transport tunnel.
- 10 22. The method of claim 21, further comprising inserting each of four elongated seals
between two of the conductive elements so as to seal the transport tunnel over
its length.
- 15 23. An ion collision cell substantially as hereinbefore described with reference to and
as illustrated by Figures 2 to 5.
24. An ion collision cell assembly substantially as hereinbefore described with
reference to and as illustrated by Figures 2 to 5.
- 20 25. A mass spectrometer substantially as hereinbefore described with reference to
and as illustrated by Figures 2 to 5.
26. A method for fabricating an ion collision cell assembly substantially as
hereinbefore described with reference to and as illustrated by Figures 2 to 5.