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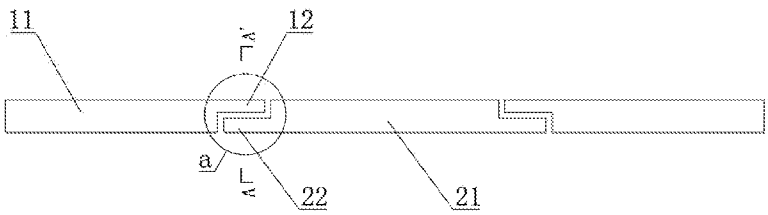

Figure 2

(57) Abstract: The invention discloses a connection method and device for two or more groups of quadrupole electrode systems, including at least two groups of quadrupole electrode systems placed adjacently: the first quadrupole electrode system and the second quadrupole electrode system; The characteristic is that the first quadrupole electrode system is composed of 4 identical electrodes, and the second quadrupole electrode system is composed of 4 identical electrodes. The first electrode in first quadrupole electrode system and the adjacent second electrode in second quadrupole electrode system are arranged coaxially; the first electrode and the corresponding second electrode form partly overlapping by the first and second electrode extensions, a gap is provided between the first extension part and the second extension part. The invention has the advantages of avoiding the fringe field effect between the two groups of quadrupole electrode systems due to the arrangement of a planar electrode between two quadrupole electrode systems, preventing the loss of ions during the transmission between the two quadrupole electrode systems, and improving ion transmission efficiency.

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Connection between multistage quadrupole electrode system and its method

Technical Field

[0001]

The invention relates to the technical field of a mass spectrometry, in particular to a multistage quadrupole electrode system for improving the ion transmission efficiency in quadrupole mass spectrometer and its connection method.

Background

[0002] Mass spectrometer is widely used in chemical and biological analysis and molecular composition identification. It has the advantages of being fast, accurate, molecular specification and it can perform high sensitivity analysis of chemical composition. The basic principle and procedure of mass analysis include: firstly, the detected material is ionized into ions, and then different ions of mass to charge ratio (m/z) are separated through electric field or magnetic field or both. Then, these separated ions are detected by ion detector to obtain mass spectroscopy. By analyzing the mass spectroscopy, the chemical species, composition, structure and content of the detected substance can be revealed. In a mass spectrometer, the part that ionizes the sample is called the ion source, and the part that measure the mass of the ions is called the mass analyzer. Ion source and ion mass analyzer are two key components of a mass spectrometer.

[0003] Mass spectrometry has the characteristics of speediness, high sensitivity and high mass resolution. And it has become one of the most widely used analytical instruments in the world today, which play an increasingly important role in lots fields such as the environmental science, food safety, athletes' illicit drugs, pharmaceutical, disease diagnosis and treatment, proteomics, genomics and material sciences. Moreover, the research and development of mass spectrometry has important implications for basic scientific research, technology development and for national security areas such as the detection and maintenance of national defense, space, biological and chemical weapons.

[0004] At present, the research and development of mass spectrometry technology has been quite mature, and a variety of new mass spectrometers are emerging. The common method of all mass spectrometers is to ionize neutral matter and then separate ions according to their mass to charge ratios. However, different types of mass spectrometers use different mass analyzers, and these mass analyzers implement ion mass charge ratio separation in different ways. According to different mass analyzers, mass spectrometers can be divided into the following categories: Magnetic sector mass spectrometer (using magnetic mass analyzer, magnetic sector), the time-of-flight mass spectrometer (using time-of-flight mass analyzer, TOF), quadrupole mass spectrometer (using quadrupole mass analyzers, QMF), Ion trap mass spectrometer (using Ion trap mass analyzer, Ion trap), Fourier transform Ion cyclotron resonance mass spectrometer (using Fourier transform mass analyzer, FT - ICR), orbital Ion trap mass spectrometer (use rail Ion trap mass analyzer, Orbitrap), etc. Different types of mass spectrometers have different characteristics and applications.

[0005] Mass spectrometry does not only obtain the information of the type and content of the molecules in the sample, but also obtain the information of the molecular structure, such as the amino acid sequence in the protein molecule, the binding position and the binding mode between each atom or group in the organic macromolecule. This method of mass spectrometry for the analysis of molecular structure is called tandem mass spectrometry. The triple quadrupole mass spectrometer is one of the most commonly used instruments for tandem mass spectrometry. Triple quadrupole mass spectrometry is composed of three groups of quadrupole electrode systems, which are successively connected in series, as shown in Figure 1. During the experiment, the first set of quadrupole mass analyzers selected the parent (precursor) ions from a large kind of ions from the ion source. The parent ions from the first quadrupole mass analyzer enter the second quadrupole electrode system, it is so-called quadrupole ion collision pool, where the accelerated parent ions are dissociated by colliding with buffer gas molecules such as argon or helium and produce daughter ions. All of the daughter ions from the parent ion dissociation in the collision pool were transferred into the third quadrupole mass system, the third quadrupole mass system is quadrupole mass analyzers, all of the fragment ions are mass analyzed by the third quadrupole mass system, then the sample molecular structure can be deduced according to the fragment ions information. This method is called tandem mass analysis. Using tandem mass analysis method to identify parent ions is more reliable than the single mass analyzer.

[0006] As shown in Figure 1, in the usual triple quadrupole mass spectrometry system, three different quadrupole system are installed in the different vacuum chambers, and two adjacent quadrupole electrode systems are separated by a plate electrode. This plate electrode has two basic functions, to isolate two vacuum chambers with different pressure and to let the ion beam enters the next quadrupole electrode system from previous quadrupole electrode system by passing through the small hole in the plate electrode. Some voltage can be applied to it if necessary. The reason for installing three different quadrupole system in the different vacuum chambers is that the first quadrupole electrode system and the third quadrupole electrode system are mass analyzers which need higher vacuum, and the second quadrupole electrode system is a collision cell which needs lower vacuum or higher gas pressure, so the mass selected parent ions can have more collision with buffer gas molecules in the second quadrupole electrode system and dissociation. However, the plate electrode between the two quadrupole electrodes also has two disadvantages. First, the small hole in the plate electrode will limit the transmission of the ion beam, resulting in ion loss; Second, the presence of the plate electrode between two quadrupole electrode systems will cause the change of the distribution of the quadrupole electric field generated by the RF power supply, and produces the so-called "fringing field effect". Since the movement of ions can be deviated by the distribution of the electric field, the distribution of the "fringe field" will break the restraint of the quadrupole electric field on the ions and cause the ions to move apart after leaving the quadrupole electrode system diverges, resulting in the loss of a large number of ions, and finally affects the sensitivity of mass spectrometry.

[0007] That is to say, in almost all existing commercial quadrupole mass spectrometers, since high-frequency alternating current is applied to the quadrupole and direct current is applied to the plate electrode, coupling occurs between the RF signal at the end of the quadrupole electrode and the DC signal on the plate electrode, forming a fringe electric field between the quadrupole electrode and the plate electrode. During the ion transmission of the existing tandem mass spectrometer, due to the influence of the fringing field effect, part of the ions will deviate from the axial travel trajectory and cause losses, reducing the ion transmission efficiency and sample detection sensitivity.

Contents of the invention

[0008] In order to solve the deficiencies in the above existing technologies, the invention provides a connection method among multistage quadrupole electrode systems, which can avoid fringing field effect and prevent ion loss and improve ion transmission efficiency.

[0009] The technical solution adopted by the invention to solve the above technical problems is: A multiple sections of quadrupole electrode system, that improve the efficiency of ion transport in quadrupole mass spectrometry of, include at least two groups of longitudinally adjacent placed quadrupole electrodes system: the first quadrupole electrode system and the second quadrupole electrode system. The first quadrupole electrode system made up of four identical first electrodes, and the second quadrupole electrode system consists of four identical second electrodes. Each of the first electrode in the first quadrupole electrode system and each of the corresponding adjacent second electrode in the second quadrupole electrode system is successively aligned; There are not plate electrode between two adjacent electrodes. A transition part is created between the first quadrupole electrode set and the second quadrupole electrode set. This transition part may be formed by extension of each first quadrupole electrode towards the respective second quadrupole electrode, as well as an extension of each second quadrupole electrodes towards the respective first quadrupole electrode. Both extension part of the first and the second quadrupole electrodes overlap each other, with gaps between them or with insulation material filling the gaps. The transition part may also be formed by a scale down quadruple which is inserted into the first quadrupole rods and the second quadrupole rods set, and longitudinally overlaps with the first quadrupole rods set and the second quadrupole rods set. The radio frequency voltage applied on the scaled down quadrupole electrodes is also scaled down from the first or the second quadrupole electrodes by a factor of square of the scale down ratio between the inscribe radii of the first or second quadrupole system and the transition quadrupole.

[0010] In some embodiments, the extension part of each of the first electrodes is stepped, and the extension part of each of the second electrodes is inverted stepped; or each extension part of the first electrodes is a bevel type, and the extension part of each of the second electrodes is a bevel type. Such an extension structure does not require a plate electrode with holes, they can generate a continuous quadrupole electric field distribution, avoiding the fringe field effect caused by the existing structures, and they can prevent the ion from running out and causing ion loss. The two adjacent quadrupole electrode system can be either installed in one vacuum chamber or installed in two separated vacuum chambers as required.

[0011] In some embodiments, the gap between each of the first extensions and the corresponding second extensions ranges from 0.5 mm to 3 mm. In this way, it is possible to better prevent the ion loss from causing ion loss, while not affecting the performance of the adjacent electrode system.

[0012] In some embodiments, each electrode in the first quadrupole electrode system and each electrode in the second quadrupole electrode system have the same cross-section, and the cross-sectional shapes are hyperboloid, round or rectangular.

[0013] In some embodiments, the first quadrupole electrode system is selected from one of a quadrupole ion guidance and a quadrupole mass analyzer; the second quadrupole electrode system is selected from one of a quadrupole ion guidance, a quadrupole mass analyzer or a quadrupole ion collision cell. Usually, the quadrupole ion guide, the quadrupole mass analyzer and the quadrupole ion collision cell are installed in different vacuum chambers because they work on different vacuum conditions or different pressures.

[0014] A connection method of a multi-stage quadrupole electrode system includes the following steps:

1) In two or more quadrupole electrode systems, randomly select the two groups placed next to each other as the first quadrupole electrode group and the second quadrupole electrode group, A first extension portion is provided at the end of each electrode on the first quadrupole electrode group, and a second extension portion having a matching shape is provided at the front end of each electrode on the second quadrupole electrode group;

2) The first quadrupole electrode group and the second quadrupole electrode group are connected in series, each first extension set and the corresponding second extension set are partially overlapped and the position is kept symmetrical, and a gap is left or an insulating material is filled between the first extension set and the second extension set.

[0015] In three or more quadrupole electrode systems, an extension structure is set between one or more adjacent quadrupole electrode rod groups, and the shapes of the multiple extension structures are the same or different.

[0016] Compared with the prior art, the present invention has the advantage that by providing a specific quadrupole electrode end structure between two adjacent sets of quadrupole electrodes, there is not plate electrode between two adjacent sets of quadrupole electrodes, so a continuous quadrupole electric field distribution can be generated to avoid fringing fields effect which prevents ions from running out and causing ion loss by the existing structure, so that the ions can be completely passed along the axial direction during the ion transmission, collision dissociation and mass analysis, and the ion transmission efficiency and detection sensitivity can be significantly improved.

Instruction with Pictures

[0017] Figure 1 is a schematic diagram of the structure of the existing triple quadrupole mass spectrometer;

Figure 2 is a partial structural schematic diagram of a multi-stage quadrupole electrode system in an embodiment of the invention;

Figure 3 is an enlarged schematic view of part a in Figure 2;

Figure 4 is a cross-sectional view of the structure of the extension of the multi-stage quadrupole electrode system in the A-A' plane;

Figure 5 is a partial structural schematic diagram of a multi-stage quadrupole electrode system in another embodiment of the invention;

Figure 6 is an enlarged schematic view of part b in Figure 5.

Figure 7 is another embodiment of the invention, where a scaled down quadrupole is used for the transition part of multistage quadrupoles

Figure 8 shows the structure of the scaled down quadrupole

Figure 9 is a modified structure of the scaled down quadrupole

specific implementation mode

[0018] The multi-stage quadrupole electrode system of the present invention and its tandem method will be further described in detail below with reference to the drawings, but it is not intended to limit the present invention.

[0019] Embodiment example 1

As shown in the figure, a multi-stage quadrupole electrode system for improving ion transmission efficiency in quadrupole mass spectrometry of the present invention includes at least two sets of quadrupole electrode systems placed adjacent to each other: a first quadrupole electrode system 1 and the second quadrupole electrode system 2, the first quadrupole electrode system 1 is composed of four identical first electrodes 11, and the second quadrupole electrode system 2 is composed of four identical second electrodes 21. Each first electrode 11 of the first quadrupole electrode system 1 is arranged coaxially with each second electrode 21 of the adjacent corresponding second quadrupole electrode system 2, and the first quadrupole electrode system 1 and the second quadrupole electrode system 2 are installed in two separated vacuum chambers.

[0020]

Each of the first electrode 11 on one end of the second electrode 21 and its corresponding adjacent, extension set is the first 12, each second electrodes 21 and its corresponding adjacent first electrode 11, at the end of the extension set has shape and the first match of the second extension of 22, the first extension 12 and second extension 22 overlap, There is a gap 3 or insulating materials between the first extension 12 and the second extension 22. and the first quadrupole electrode system 11 and the second quadrupole electrode system 21 are installed in two separated vacuum chambers.

[0021] In this embodiment, as shown in Figure 2, the first extension 12 of each first electrode 11 and the second extension 22 of the corresponding second electrode 21 are in the form of step and reverse step with a certain gap between them. The ends of each electrode on each quadrupole electrode set are of the same shape, and the electrical ends between adjacent quadrupole electrode sets are of the same shape. and the first quadrupole electrode system 11 and the second quadrupole electrode system 21 are installed in two separated vacuum chambers.

[0022] The range of clearance size d between each of the first extension 12 and its corresponding second extension 22 is preferably 0.5 mm to 3 mm.

[0023] Each electrode in the first quadrupole system 1 and each electrode in the second quadrupole system 2 have the same cross section, which may be hyperboloid, circular or rectangular.

[0024] The first quadrupole electrode system 1 can be selected from one of the quadrupole ion guidance and quadrupole mass analyzer. The second quadrupole electrode system 2 can be selected from either a quadrupole ion guide, quadrupole mass analyzer, or quadrupole ion collision pool.

[0025] Embodiment example 2

A multistage quadrupole electrode system for improving ion transport efficiency in quadrupole mass spectrometry has the same structure as embodiment example 1 except that in this embodiment, each first extension is inclined plane 12 and each second extension is inclined plane 22 as shown in Figure 5. The end face of the first extension part 12 is parallel to the end face of the adjacent second extension part 22, with a gap d between them. and the first quadrupole electrode system and the second quadrupole electrode system are installed in two separated vacuum chambers.

[0026] Embodiment example 3

A series of sections of quadrupole electrodes method, including the following steps:

1) In the two or more quadrupole electrode systems, two groups of adjacent quadrupole electrodes are randomly selected as the first and second quadrupole electrodes. A first extension set is arranged at the end of each electrode on the first quadrupole electrode set, and a second extension set with a shape matching is arranged at the front end of each electrode on the second quadrupole electrode rod set; and the each quadrupole electrode is installed in one separated vacuum chambers.

2) The first quadrupole electrode set and the second quadrupole electrode set are connected in series. Each first extension set shall be overlapped with the corresponding second extension set and the position shall be symmetrical. A gap is left between the first extension set and the second extension set or an insulating material fills between the first extension set and the second extension set.

[0027] Embodiment example 4

This is yet another way to join multiple stages of quadrupole system to improve the transmission efficiency. As seen in figure 7, the multiple quadrupole system consists the first quadrupole set 11 and the second quadrupole set 21. The transition part between the first and the second quadrupole sets is formed by a scale down quadrupole 71, which is mounted on the insulator plate 72. There are many cases where gas pressure needs to be different between the quadrupole sections. For example, the first quadrupole set may be within the collision cell where the pressure can be as high as 10^{-2} mbar. When the second quadrupole is the mass filter, the pressure in mass analyzing area need to be around 10^{-4} mbar. Such a pressure difference usually established using differential pumping where the orifice plate electrode is needed. By removing the orifice plate which limits the transmission, we now use this scaled down quadrupole and its mounting ceramic plate to limit the gas flow from the high pressure first quadrupole set to the low pressure second quadrupole set region. The inscribe radius of the transition quadrupole may be 5% to 20% of the original 2 quadrupoles. It may be firstly mounted on a ceramic disc and the disc is then installed to the separation wall between two vacuum chambers, so the conductance of gas can be largely reduced.

The ends of the scaled sown quadrupole need to be inserted into the first and the second quadrupole sets as shown in figure 7. In theory, the scale down quadrupole should create the quadrupole field exactly the same as if the original quadrupole would produce in its place. The ideal shape of the scale down quadrupole is therefore to follow the hyperbolic surface. As shown in figure 8, one of the preferred embodiments of this scale down quadrupole is made of 4 thin sheet electrodes 71 bent into the hyperbolic shape, and mounted on a ceramic disc 72. If the scale down ratio (ratio of radius of small quadrupole to the original quadrupole) is R, an rf voltage on the transition quadrupole should be scale down by factor R^2. This can be done by using voltage dividing capacitor circuit or using taps of radio frequency oscillator coil. With such a condition, ions passing from the first quadrupole to the second quadrupole will subject a continued RF field, so the fringing field effect can be minimized.

It may be difficult to manufacture the electrodes in hyperbolic sheet structure and mount them to the ceramic holder. Figure 9 gives a more practical way of making these electrodes. The transition small quadrupole may be initially formed as four rods 71 which can be mounted onto the ceramic holder with a way as normal quadrupole. Only the ends of the rods 73 were thinned down to such approximate hyperbolic shape by milling or spark eroding. There may be some fringing field near the solid rod part 71 and the ceramic plate, but ions will enter the transition quadrupole from the tip so the fringing field outside will have no effect to them. Only part overlapping the first quadrupole rods set was drawn in figure 9 while the other side overlapping with the second quadrupole rods set was omitted. There are many ways to shape the tip at the end of transition rods to make the quadrupole field smooth at the entrance. It can be thin down, or can be sharpened to knife edges, or the tip profile is made into a cone shape.

[0028] In a quadrupole electrode system of three or more groups, the transition structure can be arranged between one or more adjacent quadrupole electrode groups, with the same or different styles between multiple transition structures. For example, in the three groups of quadrupole electrode system, one transition structure or two transition structures can be set. When two transition structures are used, their structures can be the same or different. This may depend on whether the quadrupole sets are installed in the same or separated vacuum chambers.

[0029] In the present invention of multiple stage quadrupole electrode system in tandem arrangement, by using specific transition electrode structure between the adjacent two groups of electrode rods set continuous quadrupole electric field distribution can be produced. By avoiding the fringing field effect caused by the existing structure, it prevents the loss of ions, so it can make ion traveling along the axis of the quadrupoles in 2 or more stages of tandem mass analysis, and improve the transmission efficiency of ions.

The description of the invention of the multiple section quadrupole structure uses example of the triple quadrupole mass spectrometer. However, the multiple section quadrupole structure may be used in other type of mass spectrometers as well. For example, it can be used in the Q-ToF mass spectrometer for quadrupole ion guide, quadrupole mass analyzer and the collision cell based on quadrupole field. It can also be used as a series of quadrupole sections in the hybrid mass spectrometers like quadrupole-ion trap, the quadrupole-Orbitrap (or other electrostatic ion trap for Fourier Transform mass analysis) mass spectrometer. Often there is need to join several quadrupoles for ion guiding or mass analysis, where the gas pressure needs to be step down (or step up) several orders of magnitude.

[0030] It is worth noting that the above is only a few preferred embodiments of the invention and does not therefore limit the scope of patent protection of the invention. The invention can further improve the structure of the above-mentioned parts and components, or replace them with technical equivalents. Therefore, any equivalent structural change made in the specification and diagram contents of the present invention, directly or indirectly applied to other related technical fields, is likewise included within the scope of the present invention.

1. A multi-stage quadrupole rods system for improving ion transmission efficiency in a mass spectrometer, comprising,

   At least two segments of quadruple rods set disposed longitudinally next to another, wherein, the first segment of the quadrupole rods set consists of 4 identical electrode rods, nominated as the first electrodes; the second segment of the quadrupole rods set consists of 4 identical electrode rods, nominated as the second electrodes; each of the first electrodes in the first quadrupole electrode rods set is aligned longitudinally with the respective second electrode in the second quadrupole electrode rods set;

   A transition part between the first quadrupole electrode rods set and the second quadrupole electrode rods set, wherein the quadrupole field along the ion path in the transition part during the operation matches the quadrupole field in the first quadrupole electrode rods set and the quadrupole field in the second quadrupole electrode rods set.
2. A multi-stage quadrupole rods system as claimed in claim 1, wherein the transition part is formed by an extension of the first quadrupole rods set towards the second quadrupole rods set, and an extension of the second quadrupole rods set towards the first quadrupole rods set, while both extensions of the first and the second quadrupole rods overlap in longitudinally, with insulation gaps between respective first and second electrodes.
3. According to the multi-stage quadrupole electrode system mentioned in claim 1, its characteristic is that the first transition set of each of the first electrodes is stepped, and the second transition set of each of the second electrodes is inverted stepped; or each of the first electrodes the first transition set of the is a bevel type, and the second transition set of each of the second electrodes is a bevel type. And the gap between each of the first transition set and the corresponding second transition set ranges from 0.5 mm to 3 mm. When the first transition set and the second transition set are inclined plane type, the range of inclination angle is 0 ~ 75°.
4. According to the multi-stage quadrupole electrode system mentioned in claim 1 or 2, its characteristic is that each electrode in the first quadrupole electrode system and each electrode in the second quadrupole electrode system have the same cross-section, and the cross-sectional shapes are hyperboloid, round or rectangular.
5. A multi- stage quadrupole rods system as claimed in claim 1, wherein the transition part is formed by a scale down quadruple set which is partially inserted into the first quadrupole rods set and partially inserted into the second quadrupole rods set, with longitudinal overlaps with the first quadrupole rods set and the second quadrupole rods set, wherein the applied radio frequency voltage on the scaled down quadrupole electrodes has its value scaled down

from that of the first or the second quadrupole electrodes set by factor of square of the ratio of inscribe radii between the transition quadrupole set and the first or the second quadrupole set.

6. A multi- stage quadrupole rods system as claimed in claim 5, wherein the scaled down quadrupole electrode set is mounted on a insulator plate between the first and the second quadrupole rods set and the gas pressure difference is established between the two sides of the insulator plate.

7. According to the connection method of multi-stage quadrupole electrode system mentioned in Claim 1, its characteristic is by the following steps:

 1) In two or more quadrupole electrode systems, randomly select the two groups placed next to each other as the first quadrupole electrode group and the second quadrupole electrode group, A first transition portion is provided at the end of each electrode on the first quadrupole electrode group, and a second transition portion having a matching shape is provided at the front end of each electrode on the second quadrupole electrode group;

 2) The first quadrupole electrode group and the second quadrupole electrode group are connected in series, each first transition set and the corresponding second transition set are partially overlapped and the position is kept symmetrical, and a gap is left or an insulating material is filled between the first extension set and the second extension set.

8. According to the multi-stage quadrupole electrode system mentioned in claim 1 and 2, its characteristic is that the first quadrupole electrode system is selected from one of a quadrupole ion guidance and a quadrupole mass analyzer; the second quadrupole electrode system is selected from one of a quadrupole ion guidance, a quadrupole mass analyzer or a quadrupole ion collision cell. And the third quadrupole electrode system is selected from one of a quadrupole ion guidance, a quadrupole mass analyzer or a quadrupole ion collision cell, and so on. A transition structure is set between one or more adjacent quadrupole electrode rod groups, and the shapes of the multiple transition structures are the same or different.

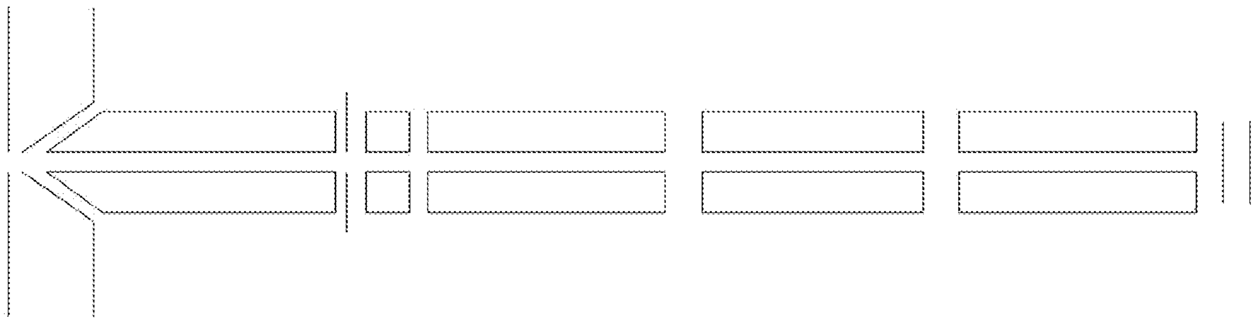

Figure 1

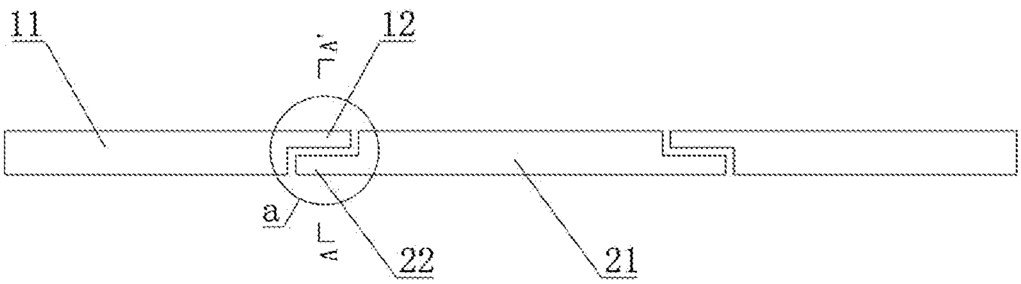

Figure 2

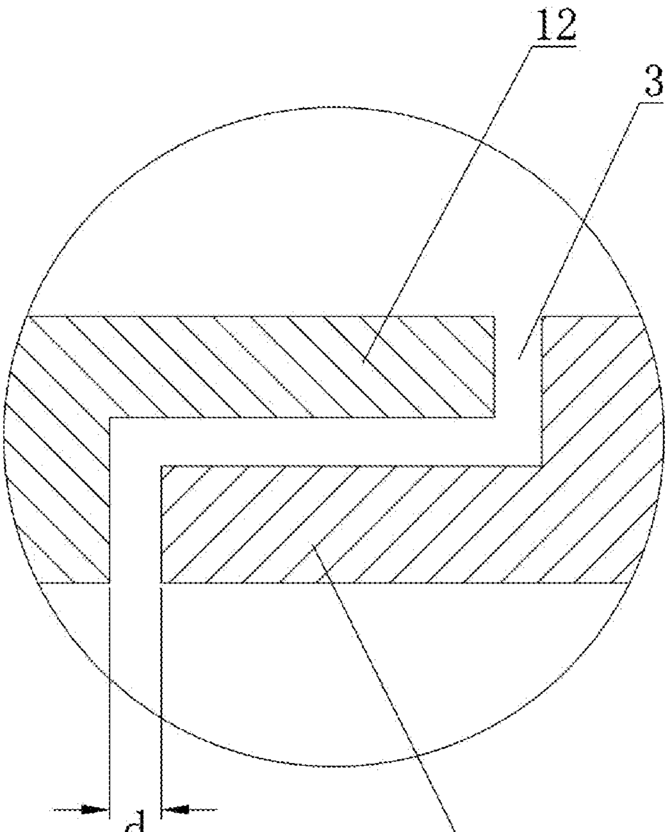

Figure 3

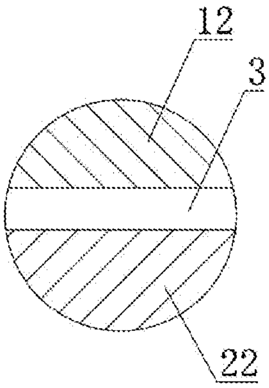

Figure 4

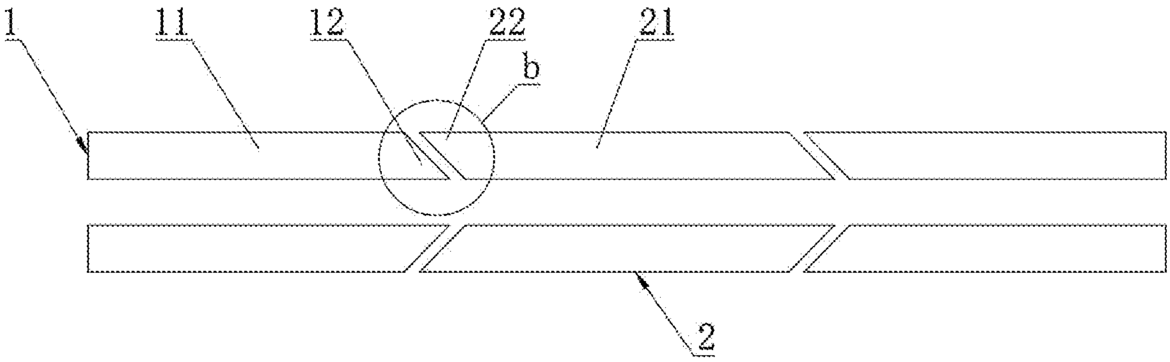

Figure 5

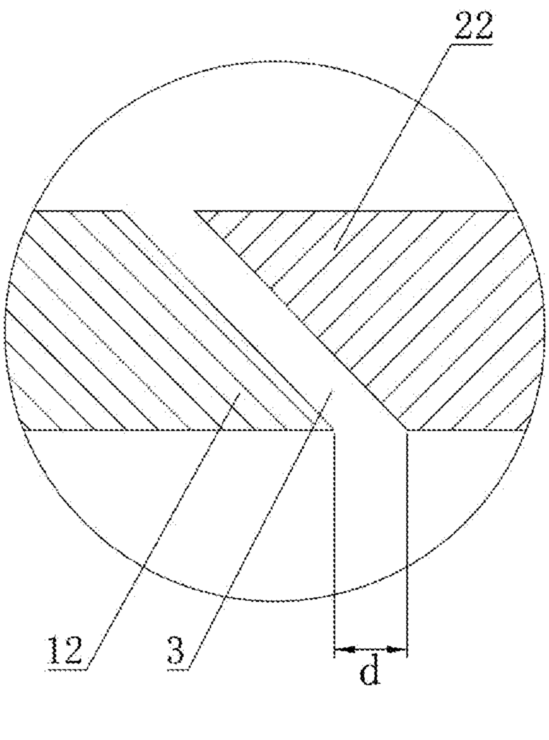

Figure 6

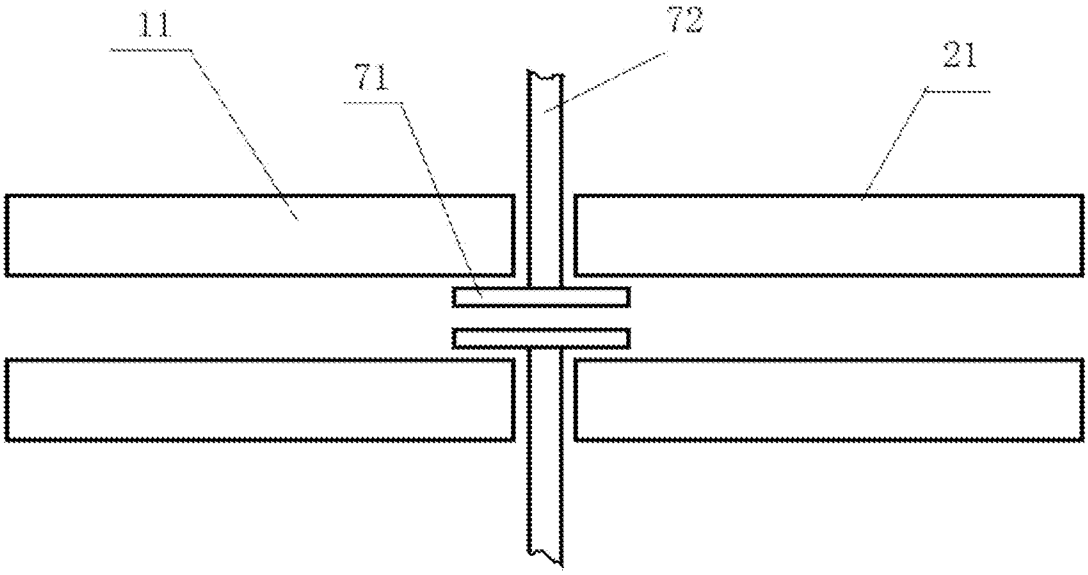

Figure 7

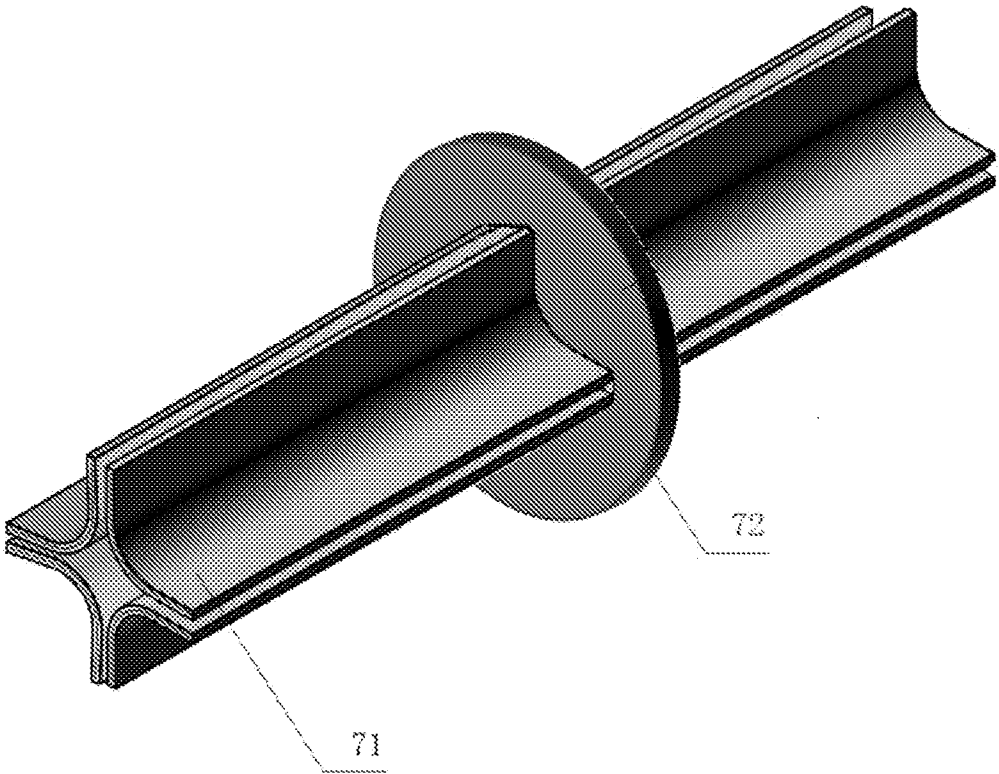

Figure 8

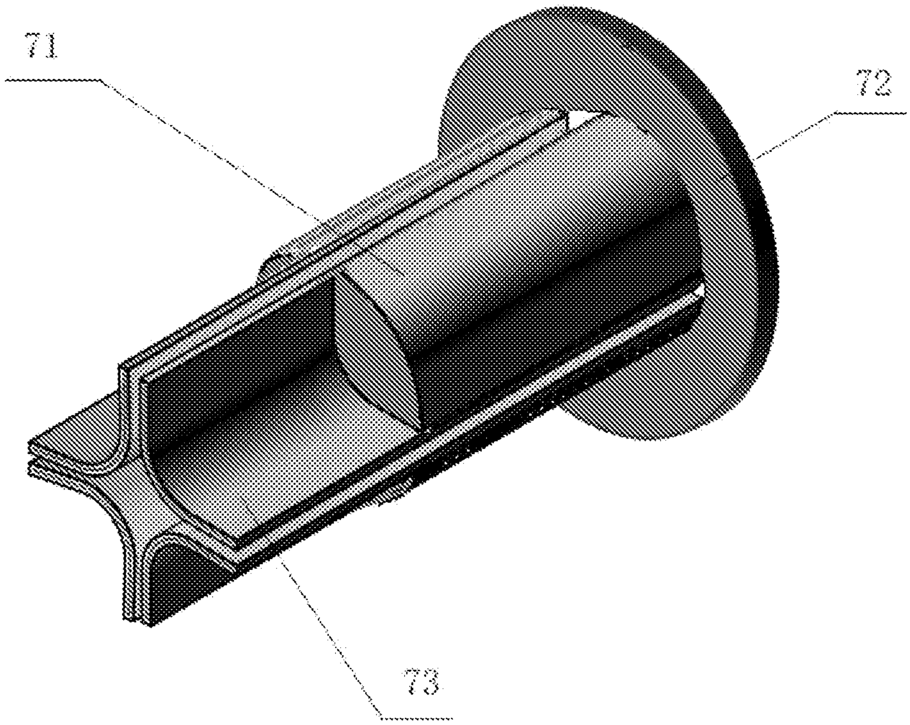

Figure 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/110948

A. CLASSIFICATION OF SUBJECT MATTER

H01J 49/42(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNTXT, CNKI, SIPOABS, DWPI: multi-stage, section, in series, quadrupole rod, electrode, gap, insulate, mass spectrometer, ion, guidance, guide, fringe field effect

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 109686647 A (SHANGHAI YUDA IND CO LTD) 26 April 2019 (2019-04-26) description, paragraphs [0037]-[0050] and figures 2-4	1, 4, 8
PX	CN 110571128 A (UNIV NINGBO) 13 December 2019 (2019-12-13) description, paragraphs [0019]-[0028] and figures 1-6	1-4, 7, 8
PX	CN 210668276 U (UNIV NINGBO) 02 June 2020 (2020-06-02) description, paragraphs [0022]-[0036] and figures 1-6	1-4, 7, 8
A	CN 206584892 U (SHANGHAI ZHIKE INSTR EQUIP CO LTD) 24 October 2017 (2017-10-24) the whole document	1-8

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 November 2020	**01 December 2020**

Name and mailing address of the ISA/CN	Authorized officer
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Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62412106**

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN	109686647	A	26 April 2019	None	
CN	110571128	A	13 December 2019	None	
CN	210668276	U	02 June 2020	None	
CN	206584892	U	24 October 2017	None	