ION STORAGE DEVICE

BACKGROUND OF THE INVENTION

This invention relates to an ion storage device (alternatively termed an ion buncher) and it relates particularly, though not exclusively, to an ion storage device suitable for use in a time-of-flight mass spectrometry system.

In order that a time-of-flight mass spectrometry system may have an acceptable mass resolving power, ions should enter the flight path of the spectrometer in bursts of short duration, of typically 1 to 10 nsec. If, as is often the case, the ions are extracted from a continuous ion beam the sensitivity of the spectrometer tends to be rather low since only a small proportion of the total number of ions in the beam can be utilised for analysis. This can be particularly problematical if the system is being used to analyse samples (such as biological or biochemical samples) that are only available in relatively small volumes, especially when such samples are delivered over a relatively short time scale (typically of the order of a few seconds) using a conventional inlet system, such as a liquid chromatograph.

With a view to alleviating this problem, a technique described by R. Grux et al in Int. J. Mass Spectrom Ion.Proc.93(1989) p.323–330 involves using an electron impact ion source to produce ions by electron bombardment, storing the ions for a substantial period of time in a confined space defined by a potential well, and then extracting the stored ions by applying an accelerating voltage thereto whereby to form a burst of ions of relatively short duration. In this way, it is possible to utilise a relatively high proportion of the total number of available ions.

However, this technique suffers from several drawbacks. The technique requires an electron-impact type ion source, and this may be unsuitable for many applications. The ions are subjected to space-charge effects in the confined space and this limits the number of ions that can be stored. Also, the ions tend to oscillate in the confined space and so they have a finite 'turn-around' time which limits the minimum duration of each ion burst.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided an ion storage device for storing ions moving along a path, comprising field generating means for subjecting ions to an electrostatic retarding field during an initial part only of a preset time interval, the electrostatic retarding field having a spatial variation such that ions which have the same mass-to-charge ratio and enter the ion storage device during said initial part of the preset time interval are all brought to a time focus during the remaining part of that preset time interval.

Ions entering the ion storage device are slowed down progressively by the electrostatic retarding field and are caused to bunch together. In this way, the ions are stored in the device during said initial part of the preset time interval and the stored ions all exit the device during the remaining part of that time interval.

By this means it becomes possible to extract and utilise a relatively high proportion of the ions in a continuous beam, or in a pulsed beam of relatively long duration, giving improved sensitivity. Furthermore, the stored ions do not suffer to the same extent from space-charge effects, nor are they subject to a 'turn-around' time.

The spatial variation of the electrostatic retarding field is such that the velocity of an ion during said initial part of the preset time interval is related linearly to its separation along the path from the point at which that ion is brought to said time focus.

An electrostatic retarding field satisfying this condition is an electrostatic quadrupole field, and, preferably, the field generating means for generating an electrostatic quadrupole field comprises an electrode structure having rotational symmetry about the longitudinal axis of the device.

In a preferred embodiment, the electrode structure comprises a plurality of electrodes spaced at intervals along the longitudinal axis of the ion storage device, each electrode in the plurality substantially conforming to a respective equipotential surface in the electrostatic quadrupole field and being maintained at a respective retarding voltage during the initial part of the or each said preset time interval, and having a respective aperture for enabling the ions to travel through the ion storage device.

According to another aspect of the invention, there is provided a time-of-flight mass spectrometer comprising an ion source for generating ions which move along a path, an ion storage device in accordance with said first aspect of the invention, and means for detecting the ions which exit the defined region of the ion storage device.

BRIEF DESCRIPTION OF THE DRAWINGS

Ion storage devices in accordance with the invention are now described, by way of example only, with reference to the accompanying drawings in which:

FIG. **1** illustrates diagramatically a time-of-flight mass spectrometer incorporating an ion storage device in accordance with the invention;

FIG. **2** illustrates a defined region in the ion storage device of FIG. **1**; and

FIGS. *3a* to *3f* show alternative forms of electrode structure used to generate the electrostatic retarding field in the ion storage device.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** illustrates diagramatically a time-of-flight mass spectrometer comprising an ion source **1** for generating a beam of ions, an ion storage device **2** in accordance with the invention and a detector **3** for detecting ions emergent from the ion storage device.

The ion storage device **2** comprises an electrostatic field generator.

Ions produced by the ion source **1** are constrained by suitable extraction electrodes and source optics (not shown) to travel along a path P, extending along the longitudinal X-axis, and the electrostatic field generator subjects ions occupying a defined region R of the path to an electrostatic retarding field.

As is shown schematically in FIG. **2**, ions enter region R at a position P_1 on the path and they exit the region at a position P_2, having travelled a distance x_T along the path.

In operation, the electrostatic field generator is energised during an initial part only of a preset time interval (referred to hereinafter as the 'ion-storage' period) and is de-energised during the remaining part of that time interval (referred to hereinafter as the 'listening' period). The electrostatic field generator may be