[0023] The present method provides a relatively good mobility resolution of $R_{mob} \geqq 100$ because, in initial experiments without a Laval nozzle and without a field barrier of uniform height, mobility resolutions of more than $R_{mob}=40$ have already been achieved.

[0024] These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of preferred embodiments thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. **1** is a flow diagram of a method for generating mobility spectra of sample ions;

[0026] FIG. **2**A schematically illustrates an apparatus for dividing ions as a function of ion mobility;

[0027] FIG. **2**B graphically illustrates a potential profile P through an axis of the apparatus in FIG. **2**A;

[0028] FIG. **2**C graphically illustrates a characteristic of strength of an opposing electric field E;

[0029] FIG. **3** diagrammatically illustrates an ion mobility spectrometer that includes the apparatus in FIG. **2**A;

[0030] FIG. **4** diagrammatically illustrates another embodiment of an ion mobility spectrometer that includes the apparatus in FIG. **2**A;

[0031] FIG. **5** diagrammatically illustrates a system that includes a time-of-flight mass spectrometer with orthogonal ion injection coupled to the ion mobility spectrometer in FIG. **4**;

[0032] FIG. **6** graphically illustrates (i) an integral curve of a total ion current I_{tot} of a mobility measurement as a function of voltage V (i.e., a field barrier height), and (ii) a mobility spectrum of a mixture of ions obtained by differentiating the integral curve I_{tot} with respect to the voltage V;

[0033] FIG. **7** graphically illustrates an acquisition of a mass-resolved mobility spectra of a similar ion mixture with a mass spectrometer coupled to the mobility spectrometer;

[0034] FIG. **8** graphically illustrates a measured mobility spectrum acquired using a combination of an ion mobility spectrometer and a mass spectrometer that does not include a Laval nozzle or a field barrier with a uniform height;

[0035] FIG. **9** graphically illustrates an "outflow diagram" for compressible gases (e.g., air) from a region with pressure p_0, density ρ_0 and temperature T_0; and

[0036] FIG. **10** diagrammatically illustrates another embodiment of an apparatus for dividing ions as a function of ion mobility.

DETAILED DESCRIPTION OF THE INVENTION

[0037] The present invention includes methods and devices for generating a gas jet having molecules and ions with substantially equal velocities, and erecting a field barrier having a substantially uniform height across a cross-section of the gas jet. Ions in gases may be sorted according to their mobility with a high sorting limit resolution. The gas jet is used to push ions with mobilities below a mobility threshold over the field barrier. The field barrier is used to sharply reject those ions with mobilities above the mobility threshold. The field barrier, as indicated above, is the steepest rise of an electric potential barrier.

[0038] Referring to FIG. **1**, in step **100** the gas jet is formed by a sharply focused supersonic gas jet of molecules and ions with substantially equal velocities, which is generated by a suitably shaped Laval nozzle. The supersonic gas jet has a relatively low temperature (e.g., a few Kelvin) and a low pressure. The velocities of the molecules have relatively small statistical variances as a result of the low temperature. Where the Laval nozzle is correctly shaped (i.e., shaped in such a manner as to generate a jet of molecules and ions with substantially equal velocities), the supersonic gas jet has a substantially constant cross-section over a length of at least a few centimeters, and the molecules fly in parallel. The optimum form of the Laval nozzle can be constructed using, for example, a method of characteristics known from gas dynamics. For air, the molecules can achieve a maximum velocity of v equal to $792\sqrt{(T_0/293K)}$ m/s, which are only slightly lower in practice.

[0039] Referring to FIGS. **1** and **2**A, in step **102** the field barrier of uniform height is generated by a potential distribution across three or more apertured diaphragms. Where, for example, three thin apertured diaphragms R_2, R_3 and R_4 (i) have identical aperture radii r_2, r_3, and r_4, (ii) are respectively separated by distances d_2 and d_3, and (iii) have the potentials U_2, U_3 and U_4 respectively applied thereto, a field barrier with uniform height can be generated across the entire central apertured diaphragm R_3 when $(U_4-U_3)/(U_3-U_2)=d_3/d_2$. The height of the field barrier is proportional to the voltage V equal to (U_4-U_2). Where the apertured diaphragms are relatively thick, or have different diameters, or where the external fields effect stronger asymmetrical field penetrations through the outer apertured diaphragms, the condition should be correspondingly corrected. In the simplest case of three equally separated identical apertured diaphragms **2**, **3** and **4**, $U_3=(U_4-U_2)/2=V/2$. The apertured diaphragms are formed from a mechanically thin, electrically conductive material such as, but not limited to, sheet metal.

[0040] Referring still to FIG. **2**A, the Laval nozzle is disposed in a wall **1** between chambers having different pressures. The Laval nozzle, when appropriately shaped, generates a supersonic gas jet **7** having molecules with substantially equal velocities. The shape of the Laval nozzle may be designed or calculated using the method of characteristics, or by any other suitable methods of gas dynamics. In the interest of ease of illustration, the Laval nozzle is depicted larger than it really is for reasons of clarity. The potential of the Laval nozzle is designated hereinafter as U_1.

[0041] The three apertured diaphragms **2**, **3** and **4** generate opposing electric fields with suitably applied potentials U_2 to U_4. In the apertured diaphragm **2**, the above-mentioned voltage condition $U_3=(U_4-U_2)/2=V/2$ generates a field barrier having a substantially uniform height in a direction transverse to the supersonic jet. The height of the field barrier is proportional to the voltage V. The potential distribution is shown in FIG. **2**A by thin equipotential lines. Several possible ion trajectories for ions of a given low mobility are shown via lines **6**. The ion trajectories **6** illustrate that the ions are initially focused between the nozzle in the wall **1** and the apertured diaphragm **2** and then defocused, as far as their mobility allows. The ions are further defocused between the apertured diaphragms **2** and **3**, and refocused between the apertured diaphragms **3** and **4**. The voltage (U_2-U_1) is selected such that the ions are focused, when possible, within the Laval nozzle, and do not hit the wall as a result of Coulomb repulsion when the mobility of the ions increases due to a fall in temperature and pressure. The focusing and defocusing are effective insofar as the mobility of the ions in the supersonic gas jet allows. The apertured diaphragm **5** makes the external field penetrations through the diaphragms **2** and **4** approximately sym-