CLAIMS

1. An ion source for a mass spectrometer, the mass spectrometer having a mass filter, the ion source comprising:

an ionization volume configured to be evacuated by a vacuum pump;

a gas source configured to deliver gas to the evacuated ionization volume, the gas source being at a substantially higher pressure than that of the evacuated ionization volume;

a nozzle between the gas source and the evacuated ionization volume,

wherein the ion source does not have a restricted-conductance ionization chamber to hold gas at an elevated pressure,

wherein the nozzle is configured to pass gas freely, which expands through an ionization region of the evacuated ionization volume;

an electron source configured to emit electrons, the electrons passing the nozzle through the expanding gas ionization region to ionize at least a portion of the expanding gas; and

electrodes configured to create electrical fields for ion flow from the ionization region to the mass filter, the electrodes being located at distances from the nozzle and oriented to limit exposure of the electrodes to the gas.

2. The ion source of claim 1 wherein the nozzle is a tube.

3. The ion source of claim 1 or 2 wherein the nozzle is configured to pass at least twenty percent of the gas molecules through the ionization region.

4. The ion source of any preceding claim wherein the electron source is a heated filament.

5. The ion source of any preceding claim wherein:

wherein the electron source is configured to produce electrons which travel through an aperture of a first electrode and toward the ionization region, resulting in an electron beam traveling through the expanding gas in the ionization region.

6. The ion source of claim 5 further including a second electrode arranged opposite the first electrode and including an aperture, wherein the electron source is configured to produce electrons which travel through the aperture of the second electrode.

7. The ion source of claim 5 or 6 further including a trap electrode arranged opposite the first electrode with respect to the ionization region.

8. The ion source of any preceding claim wherein the electrodes include first and second electrodes arranged on opposite sides of the ionization region, surfaces of the first and second electrodes being substantially parallel to a primary direction of gas flow from the nozzle through the ionization region.

9. The ion source of claim 8 further comprising a repelling electrode configured to repel ions from the ionization region toward the mass filter.

10. The ion source of claim 8 further comprising a ion exit electrode having an aperture configured to direct the ion flow from the ionization region to the mass filter.

11. The ion source of claim 1 wherein:

the electrodes include:

first and second electrodes arranged on opposite sides of the ionization region, the surfaces of the first and second electrodes being substantially parallel to a primary direction of gas flow from the nozzle through the ionization region;

a trap electrode arranged opposite the first electrode and outside the second electrode with respect to the ionization region;

a repelling electrode configured to repel ions from the ionization region toward the mass filter; and

an ion exit electrode having an aperture to direct the ion flow from the ionization region to the mass filter;

the electron source includes a filament arranged on an opposite side, with respect to the ionization region, of the first electrode; wherein the filament is configured to produce electrons which travel through an aperture of the first electrode, through the ionization region, and through an aperture of the second electrode, resulting in an electron beam traveling between the first and second electrodes and through the expanding gas in the ionization region.

12. The ion source of claim 11 wherein the electrodes are configured to have independently controllable voltages.

13. The ion source of claim 1 wherein an outlet opening of the nozzle has an area of less than five square millimeters, a cross-sectional area of the emitted electrons in the ionization region is less than five times the area of the outlet opening of the nozzle, and the electrodes are located at least five millimeters from a center of the outlet opening.

14. The ion source of claim 1 wherein the electron source is configured to pass the electrons to within five millimeters of the nozzle.

15. A mass spectrometer system comprising:

a vacuum pump;

a mass filter;

a detector; and

an ion source including:

an ionization volume, wherein the vacuum pump is configured to evacuate the ionization volume to create an evacuated ionization volume;

a gas source configured to deliver gas to the evacuated ionization volume, the gas source being at a substantially higher pressure than that of the evacuated ionization volume;

a nozzle between the gas source and the ionization volume, wherein the ion source does not have a restricted-conductance ionization chamber to hold gas

at an elevated pressure , and wherein the nozzle is configured to pass gas freely, which expands through an ionization region of the ionization volume;

an electron source configured to emit electrons, the electrons passing the nozzle through the expanding gas in the ionization region to ionize at least a portion of the expanding gas; and

electrodes configured to create electrical fields for ion flow from the ionization region to the mass filter, the electrodes being located at distances from the nozzle and oriented to limit exposure of the electrodes to the gas.

16. The mass spectrometer system of claim 15 wherein the nozzle is configured to direct the gas toward the vacuum pump.

17. The mass spectrometer system of claim 15 wherein the electron source is a heated filament.

18. The mass spectrometer system of claim 15 wherein:

the electron source is arranged on an opposite side, with respect to the ionization region, of a first electrode;

the electron source is configured to produce electrons traveling through an aperture of the first electrode and toward the ionization region, resulting in an electron beam traveling through the expanding gas in the ionization region; and

a second electrode is arranged opposite the first electrode and includes an aperture, the electron source is configured to produce electrons traveling through the ionization region and through the aperture of the second electrode.

19. The mass spectrometer system of claim 15 wherein the electrodes include first and second electrodes arranged on opposite sides of the ionization region, the surfaces of the first and second electrodes being configured to be substantially parallel to a primary direction of gas flow from the nozzle through the ionization region.

20. The mass spectrometer system of claim 19 further comprising a repelling electrode configured to repel ions from the ionization region toward the mass filter.

21. The mass spectrometer system of claim 19 further comprising an ion exit electrode having an aperture configured to direct the ion flow from the ionization region to the mass filter.

22. The mass spectrometer system of claim 15 wherein:

the electrodes include:

first and second electrodes arranged on opposite sides of the ionization region, the surfaces of the first and second electrodes being substantially parallel to a primary direction of gas flow from the nozzle through the ionization region;

a trap electrode arranged opposite the first electrode and outside the second electrode with respect to the ionization region;

a repelling electrode configured to repel ions from the ionization region toward the mass filter; and

an ion exit electrode having an aperture to direct the ion flow from the ionization region to the mass filter;

the electron source includes a filament arranged on an opposite side, with respect to the ionization region, of the first electrode; and

electrons produced by the filament travel through an aperture of the first electrode, toward the ionization region, and through an aperture of the second electrode, resulting in an electron beam traveling between the first and second electrodes and through the expanding gas in the ionization region.

23. The mass spectrometer system of claim 22 wherein the electrodes are configured to have independently controllable voltages.

24. A method of producing ions for a mass spectrometer using an ion source, the mass spectrometer having a mass filter, the method comprising:

evacuating gas from an ionization volume to create an evacuated ionization volume;

delivering substantially higher pressure gas to the evacuated ionization volume through a nozzle, and wherein the ion source does not have a restricted-conductance ionization chamber to hold gas at an elevated pressure

passing the gas freely through the nozzle, wherein the gas freely expands through an ionization region of the ionization volume;

emitting electrons, the electrons passing the nozzle through the expanding gas in the ionization region to ionize at least a portion of the expanding gas; and

directing ions formed in the ionization region to the mass filter.

25. The method of claim 24 wherein directing the ions includes directing the ions using electric field using electrodes, and the gas is delivered at a distance from the electrodes to limit exposure of the electrodes to the gas.

26. The method of claim 24 wherein the electrons are emitted from a heated filament.

27. The method of claim 24 wherein electrons are emitted through an aperture of a first electrode and through the expanding gas in the ionization region.

28. The method of claim 27 wherein the electrons are emitted through an aperture of a second electrode, wherein the second electrode arranged on an opposite side of the ionization region to the first electrode.

29. The method of claim 24 further comprising repelling the ions from the ionization region toward the mass filter.

30. The method of claim 24 wherein further comprising focusing the ions from the ionization region through an aperture to the mass filter.