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Mosharrafa

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[54] **AUTOMATIC GAIN METHOD AND CONTROLLER FOR MASS SPECTROMETER**

[75] Inventor: **Mostafa A. Mosharrafa,** Edina, Minn.

[73] Assignee: **Automated Medical Systems, Inc.,** Minneapolis, Minn.

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[58] **Field of Search** ..... 250/41.9 D, 41.95 R

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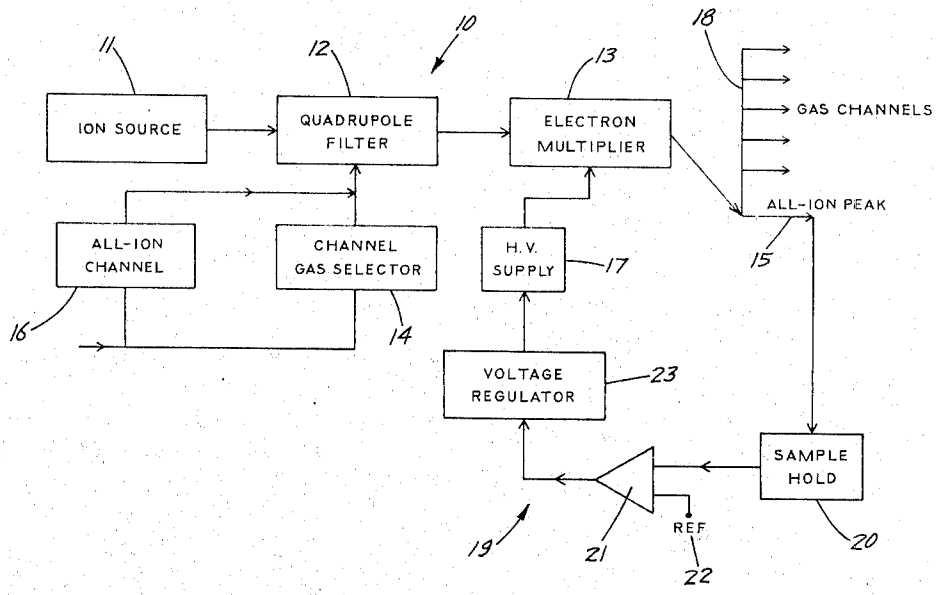
Primary Examiner—James W. Lawrence

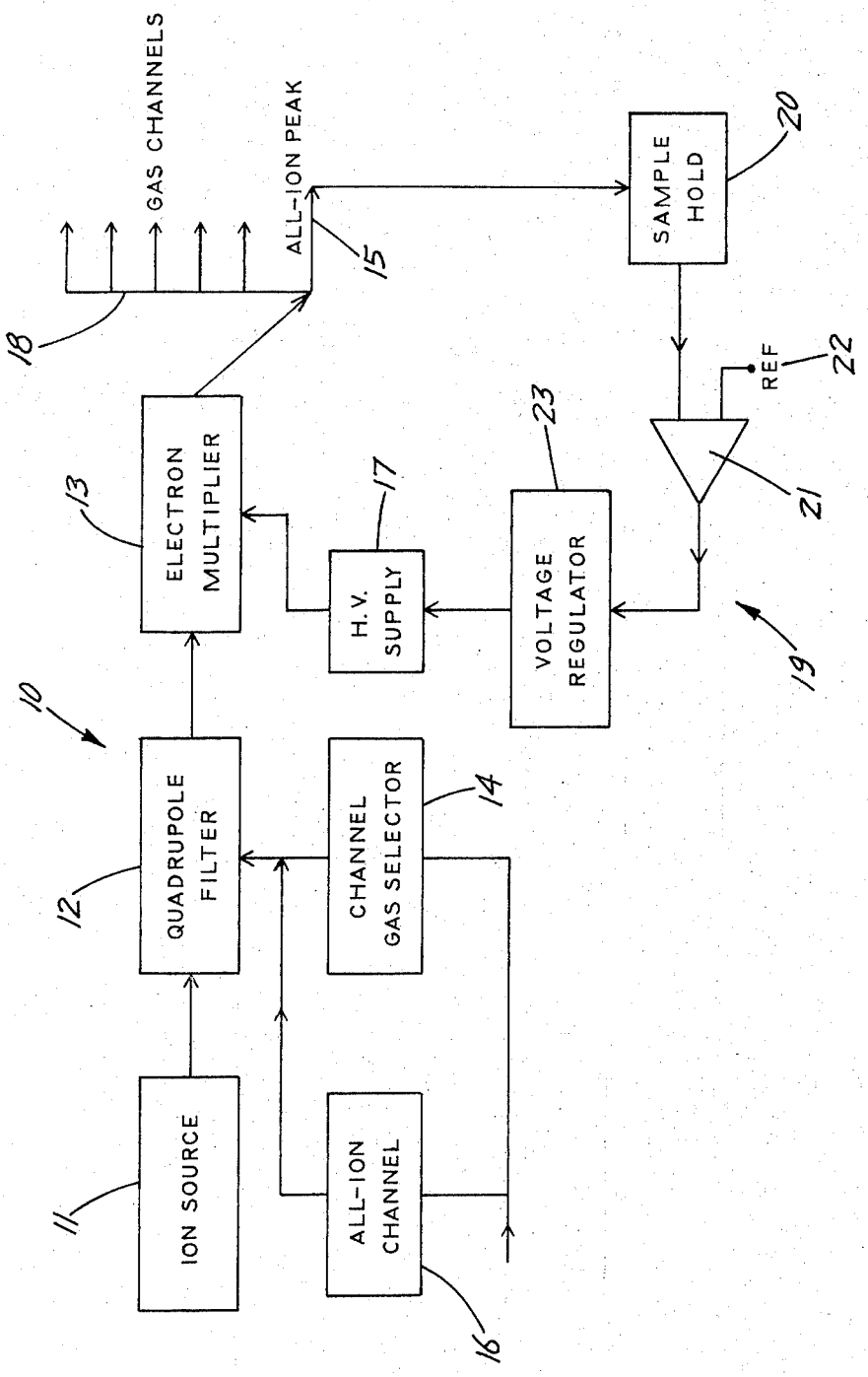
Assistant Examiner—C. E. Church

[57] **ABSTRACT**

A method and apparatus for analyzing relative abundance of the composition of a sample with a mass spectrometer having an electron multiplier controlled with a high voltage supply. When the sample is a gas mixture, the volume per cent of a gas is analyzed. The all-ion peak signal is repetitively sampled and held to produce an analog output voltage. This output voltage is compared with a reference voltage via an error amplifier in a feedback loop to control the high voltage applied to the electron multiplier so that the all-ion peak signal of the mass spectrometer is maintained a constant.

13 Claims, 1 Drawing Figure




GAS CHANNELS
ALL-ION PEAK
SAMPLE HOLD
REF
ELECTRON MULTIPLIER
H.V. SUPPLY
VOLTAGE REGULATOR
QUADRUPOLE FILTER
CHANNEL GAS SELECTOR
ION SOURCE
ALL-ION CHANNEL
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AUTOMATIC GAIN METHOD AND CONTROLLER FOR MASS SPECTROMETER

BACKGROUND OF THE INVENTION

A common non-magnetic mass spectrometer employs a quadrupole radio frequency filter for mass analysis of ions. This instrument is capable of scanning the mass spectrum in a few milliseconds and can provide a convenient visual real time observation of the mass spectrum on an oscilloscope. The instrument is sensitive to ion source pressure fluctuations, ion beam density fluctuations, and electronic gas signal drifts and fluctuations. The instrument does not measure directly relative abundance of the composition of a sample, as gas, and accordingly is not a volume per cent analyzer.

SUMMARY OF THE INVENTION

The invention is directed to a method and apparatus for analyzing relative abundance of the composition of a sample, as a gas, with a mass spectrometer system using an electron multiplier and having a signal proportional to the total ion density available for control. The all-ion peak of a sample is held and averaged with a time constant to produce an output signal. The output signal of the sample is compared with a constant reference voltage applied to an error amplifier. The output of the error amplifier is used to control the high voltage applied to the electron multiplier whereby the all-ion peak of the spectrometer is maintained a constant. This technique transforms the mass spectrometer from a partial pressure analyzer to a volume per cent analyzer. In other words, the mass spectrometer no longer measures partial pressure, but relative abundance of a composition of a sample, as a gas. In addition, the technique greatly improves the overall stability of the mass spectrometer.

IN THE DRAWINGS

FIG. 1 is a schematic block diagram of a mass spectrometer and the means and method of the invention whereby the spectrometer operates to analyze the volume per cent of a gas.

Referring to FIG. 1, there is shown a mass spectrometer indicated generally at **10** usable to provide output information concerning the relative abundance of a gas in a mixture of gases. Spectrometer **10** is a non-magnetic instrument that has an ion source **11** and employs a quadrupole radio frequency filter **12.** Filter **12** is coupled to an electron multiplier **13.** A multichannel gas selector **14** controls the operation of the filter **12** for repetitive sampling of the selected gases. An additional channel **16** is added to sample repetitively the all-ion peak output signal. The all-ion output peak signal is the total ion current after amplification of the electron multiplier when no filtering is made by the analyzer or filter. Gas selector **14** has one or more channels connected to the filter. For example, selector **14** has five channels.

The electron multiplier **13** is controlled with a high voltage supply **17.** The power input to the high voltage supply **17** is controlled with a voltage regulator circuit **23.** A plurality of gas channels **18** are connected to the electron multiplier **13.**

A ion peak output signal **15** as the all-ion peak output signal, of the electron multiplier **13** is used in conjunction with a feedback loop indicated generally at **19** to control the gain of the electron multiplier **13** thereby transforming the mass spectrometer from a partial pressure analyzer to a volume per cent analyzer when the sample is a gas. The mass spectrometer **10** with feedback loop **19** analyzes relative abundance of the composition of a sample. Feedback loop **19** includes the all-ion signal sample-and-hold circuit **20,** with or without filtering. The output of the sample-and-hold circuit **20** is a voltage signal proportional to the all-ion peak intensity. Circuit **20** is a means to measure the all-ion peak of a sample. This means can be a pressure gauge, ionization gauge, the output of a chromatograph, the all-ion peak of a quadrupole gas chromatograph or like instruments to measure the all-ion peak. The output signal of circuit **20** is applied to an error amplifier **21** together with a reference voltage **22.** The sample signal is compared with the constant reference voltage **22** by the error amplifier **21.** The output signal of the error amplifier **22** drives the voltage regulator circuit **23,** thereby controlling the power input to the high voltage power supply **17,** which in turn controls the high voltage applied to the ion multiplier **13.** The result is that the mass peak heights of the spectrometer **10** become independent of the pressure in the ion source and the spectrometer no longer measures partial pressures but relative abundances of the components of a sample, as a gas, introduced into the ion source of the mass spectrometer.

In terms of a method of analyzing relative abundance of the composition of a sample, as the volume per cent of a gas, the feedback loop **19** is used in conjunction with the mass spectrometer or instrument **10** having an electron multiplier **13** and a high voltage supply **17** controlling the electron multiplier. The method comprises repetitively sampling the all-ion or selected ion peak output signal of the electron multiplier **13** of the gas. A sample of the all-ion peak output signals is held and averaged with a time constant producing a sample output signal. The output signal proportional to the all-ion peak is compared with a constant reference voltage with the use of an error amplifier **21.** The output of the amplifier is used to control the high voltage applied to the electron multiplier whereby the all-ion peak output signals of the spectrometer are maintained constant. The output of the amplifier can control voltage regulator circuit **23** which controls the power input to high voltage supply **17.** This transforms the mass spectrometer from a partial pressure analyzer to a volume per cent analyzer. The method can be applied to any mass spectrometer system using an electron multiplier and a signal proportional to the total ion density. The total ion density signals may be derived from an ionization gauge or a gas chromatograph detector.

The measurement of the relative abundance of the gas in accordance with the structure and method of the invention eliminates the effects of ion source pressure fluctuations due to outgassing, variations in sample size, and differences in pumping speeds. Also, there is an elimination of pressure regime changes in continuous sampling inlet systems for gases due to changes in viscosity of the gas sample, changes in pressure gradient due to condensable vapors and changes in flow regime, i.e., transonic flow and capillary tubing and the like. In addition, the effects of ion beam density fluctuations are eliminated. These fluctuations are due to emission current changes, ion source changes, ion

source sensitivity degradation due to contamination and ion source thermal nonequilibrium. Furthermore, electronic gas signal drifts and fluctuations are eliminated. These fluctuations are due to changes in electron multiplier gain and drifts in the electrometer amplifier.

While there have been shown and described a preferred method and apparatus for analyzing relative abundance of the composition of a sample, as the volume per cent of a gas, it is understood that changes and modifications in the method and apparatus can be made by those skilled in the art without departing from the spirit of the invention. The invention is defined in the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of controlling the sensitivity of a mass spectrometer having an electron multiplier producing ion output signals and a high voltage supply controlling the electron multiplier comprising: measuring a selected ion peak with the electron multiplier to provide an output signal, averaging a sample of said output signal with a time constant representative of the period during which said selected ion peak is measured to provide a sample output signal, comparing the sample output signal with a constant reference voltage by applying said output signal and said reference voltage, to an error amplifier, and controlling the high voltage applied to the electron multiplier with the output of the error amplifier so that the selected ion peak sample output signals of the spectrometer are maintained constant.

2. The method of claim **1** wherein: the output of the amplifier drives a voltage regulator circuit that controls the power input to the high voltage power supply.

3. The method of claim **1** wherein: the selected ion peak output signal is the all-ion peak output signal of the electron multiplier.

4. A means for controlling the sensitivity of a mass spectrometer having an ion source, filter means, an electron multiplier receiving ions from said source, and high voltage power supply means for controlling said electron multiplier, the improvement comprising means for holding and averaging over a period of time a sample of a selected ion peak output signal of the electron multiplier so as to produce a sample output signal, and error amplifier means for receiving the sample output signal and a reference voltage, said amplifier means having an output controlling the high voltage applied to the electron multiplier such that the sample ion output signals of the spectrometer are maintained constant.

5. The means of claim **4** including: circuit means for controlling the power input to the high voltage power supply means thereby controlling the high voltage applied to the electron multiplier.

6. A means for improving the stability of a mass spectrometer having an ion source, electron multiplier producing ion output signals, and high voltage source means supplying high voltage to the electron multiplier comprising: first means for sampling a selected ion output signal of the electron multiplier to provide a sample output signal, and a second means for comparing said sample output signal with a constant reference signal and applying the difference between the sample output signal and reference signal to a closed feedback loop to control the gain of the electron multiplier by controlling the high voltage source means to vary the high voltage applied to said electron multiplier.

7. The means of claim **6** wherein: said first means is an instrument to sample the all-ion peak of a substance.

8. The means of claim **6** wherein: said second means includes an error amplifier.

9. The means of claim **6** wherein: said second means includes circuit means for controlling the power input of the mass spectrometer.

10. The means of claim **6** wherein: said second means includes an error amplifier and circuit means connected to the error amplifier for controlling a high voltage supply for the mass spectrometer.

11. A mass spectrometer for analyzing relative abundance of the composition of a sample comprising: an ion source, filter means for receiving ions from said ion source, electron multiplier means for receiving ions from said filter means, a high voltage supply for controlling the electron multiplier means, means for holding and averaging over a period of time a sample of a selected ion peak output signal of the electron multiplier means thereby producing a sample output signal, and error amplifier means for receiving the sample output signal and a reference voltage, said amplifier means having an output controlling the high voltage supply to vary the high voltage applied to the electron multiplier means so that the sample output signals of the spectrometer are maintained constant.

12. The mass spectrometer of claim **11** including: circuit means for controlling the power input to the high voltage supply thereby controlling the high voltage applied to the electron multiplier means.

13. The mass spectrometer of claim **11** wherein: the filter means is a quadrupole filter.

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