Nov. 17, 1970 ITIRO OMURA ET AL 3,541,372

MICROWAVE PLASMA LIGHT SOURCE

Filed Dec. 21, 1967 2 Sheets-Sheet 1

FIG. 1a

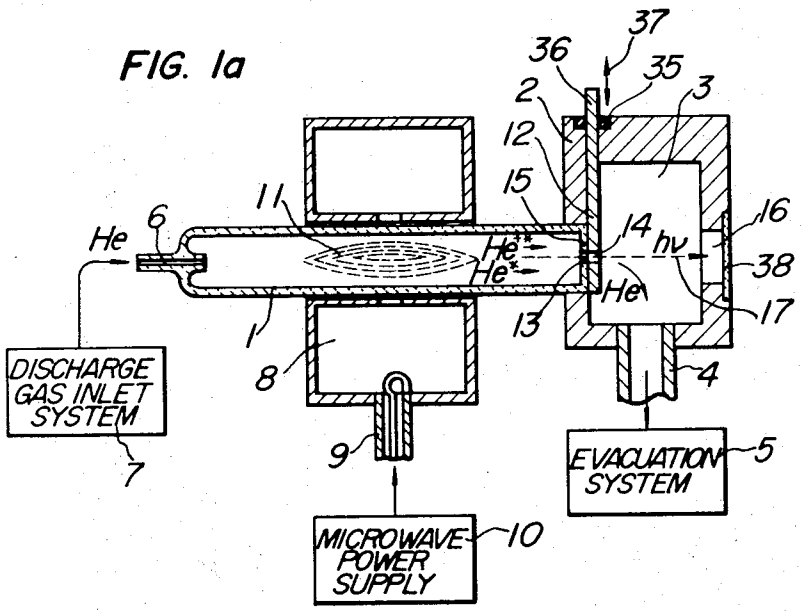


FIG. 1b

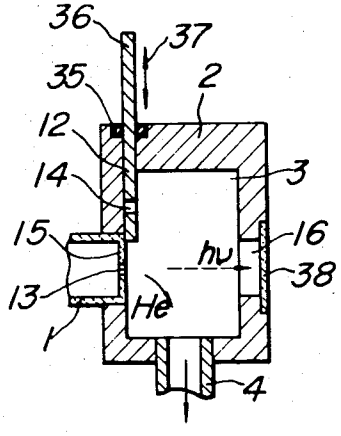
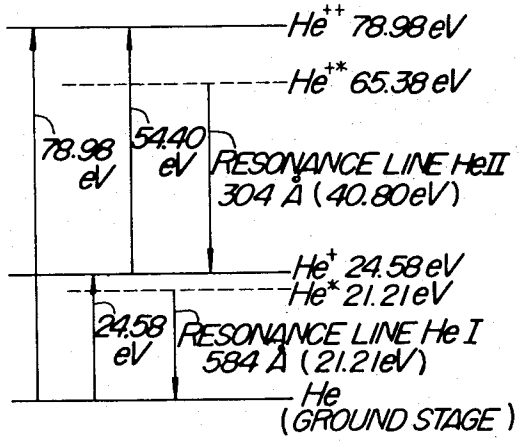


FIG. 2



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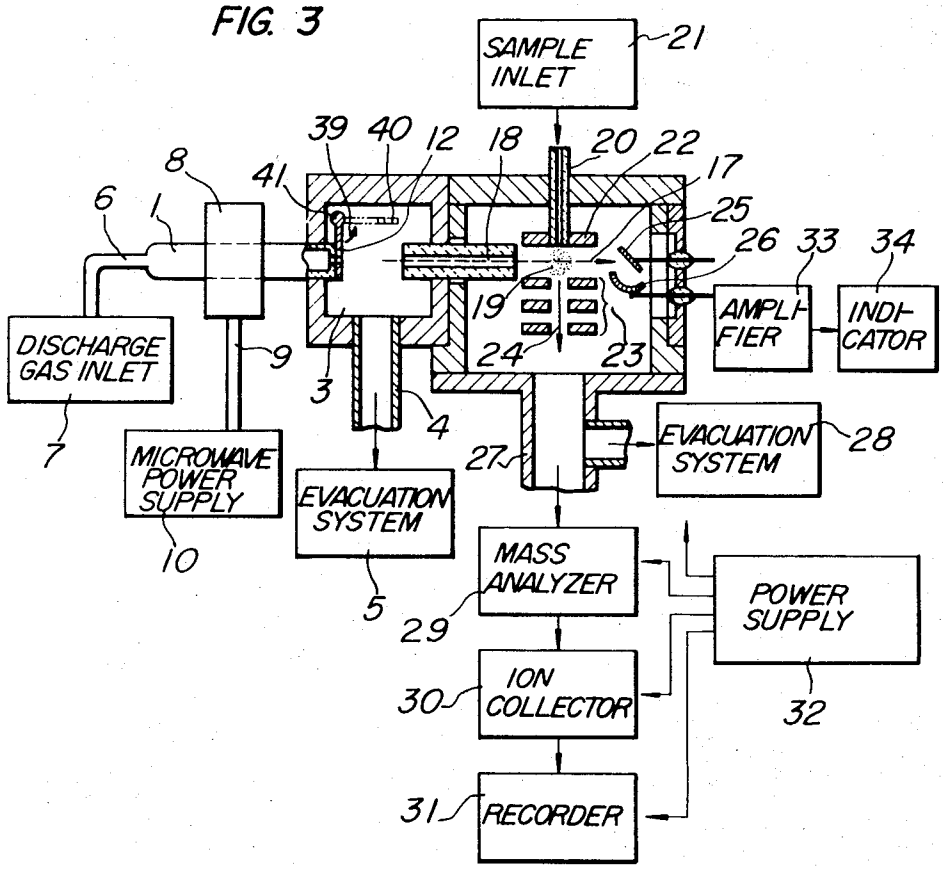
ATTORNEYS

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FIG. 3



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3,541,372

MICROWAVE PLASMA LIGHT SOURCE

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Claims priority, application Japan, Dec. 28, 1966, 42/85,334
Int. Cl. H01j 7/46, 39/34; H05h 1/00
U.S. Cl. 313—63 4 Claims

ABSTRACT OF THE DISCLOSURE

A microwave plasma light source, wherein microwave power is fed into a discharge vessel containing discharge gas (rare gas) to form a high frequency electromagnetic field in said vessel, a high frequency electrodeless discharge plasma is generated within said discharge vessel by said electromagnetic field, a microwave reflector is inserted in the propagation path of the electromagnetic wave propagating in said discharge vessel perpendicularly to the direction of propagation to generate an intense standing wave in said discharge vessel and thereby to increase the intensity of the high frequency electromagnetic field in the discharge vessel, the gas atoms in said plasma are excited to high energy levels, said excited gas atoms are made to undergo resonance transitions having large resonance potentials and a resonance line as short as possible is made to be radiated with a relatively small microwave power.

This invention relates to an improvement of a so-called microwave plasma light source or a device wherein a high frequency electromagnetic field is induced in a low pressure gaseous atmosphere to excite the atoms of said gas to higher energy levels and the resonance line (far ultraviolet light) radiated when said excited atoms undergo (resonance) transitions to the old ground state (stable level) is taken out.

In a general microwave plasma light source, a microwave power of several giga cycles per second in frequency is fed into a low pressure discharge gas (e.g., rare gas like helium, argon or neon) of about 0.1~5 mm. Hg, electrodeless gas discharge plasma is generated by forming an intense high frequency electromagnetic field in said discharge gas and thereby the atoms of said gas are excited and the resonance line radiated when said excited atoms return to the ground state is taken out.

The wavelength of the resonance line radiated from plasma is inversely proportional to the resonance potential (the difference in energy of the gas atom between the excited state and the ground state) corresponding to said resonance transition and, for example, when a helium (He) atom in the ground state is excited to the first excited state (the helium atom in this excited state will be denoted by He* hereafter) as shown in FIG. 2, the resonance potential becomes 21.21 ev. and the wavelength of the resonance line (denoted by HeI hereafter) emitted when said excited helium atom (He*) undergoes a transition to the ground state helium atom (He) is 584 A.

Such a short wavelength resonance line belongs to a particularly short wavelength region of far ultraviolet lines. Accordingly, a device generating such a short wavelength resonance line can be utilized not only for a light source of a vacuum ultraviolet monochromator indispensable for the study of far ultraviolet waves, but also for a far ultraviolet light source of various devices which make use of the intense photo-electric effect, photo-ionization effect, sterilization effect or the like of the far ultraviolet light.

As to said photo-ionization effect (the effect to ionize atoms or molecules by irradiation of light), as the wavelength of the irradiated light becomes smaller or the resonance potential becomes larger when said resonance line is used as the irradiating light, it becomes possible to ionize the atoms (or molecules) having a higher ionization voltage. In this respect, a light source generating a resonance line having a wavelength as short as possible has recently been desired. However, in order to provide such a device, an excited state having a larger resonance potential must be prepared in a plasma. On the other hand, as the potential of the required excited state becomes higher or as the atoms are to be excited to a higher level, it becomes necessary to increase the microwave power to be fed to the discharge gas plasma and to form a more intense high frequency electromagnetic field in the plasma space.

More specifically, as shown in FIG. 2, when a helium atom is excited from a monovalent helium ion (He^+) state to a second excited state (this excited helium atom will be denoted by He^{+*} hereafter), the resonance potential corresponding to the transition from said second excited state (He^{+*}) to said monovalent helium ion state (He^+) becomes 40.80 ev. and a resonance line (denoted by HeII hereafter) of 304 A. in wavelength can be generated. However, the helium atom must be excited from a ground state to quite a high energy level of 65.38 ev. and correspondingly, an intense electromagnetic field must be formed in the discharge gas plasma to excite the gas atom to such a high energy level. Now, it is impossible to excite a helium gas atom to a high energy level of 65.38 ev. necessary to obtain said resonance line (HeII) of 304 A. in wavelength with a conventional microwave plasma light source comprising a microwave power supply of the order of several hundred watts in output, and in order to obtain said resonance line (HeII) of 304 A. in wavelength, a large output microwave power supply of at least several to several tens of kilo-watts is required. However, such a method of feeding a large microwave power into plasma is impractical not only because the microwave power supply becomes large and expensive, but also because discharge tubes cause troubles like overheating, etc., due to the large microwave power. Accordingly, a device which provides a resonance line (HeII, 304 A.) of a helium atom by feeding a large microwave power of several kilo-watts to helium gas has not been put into practical use.

Therefore, the shortest wavelength of the resonance line obtained up to now with a microwave plasma light source having a practical microwave power supply of several hundred watts in output is 584 A. (HeI) and the resonance potential corresponding thereto is only 21.21 ev.

The invention is intended to improve said situation and a primary object of this invention is to provide a microwave plasma light source comprising said relatively small microwave power supply of several hundred watts in output, wherein the discharge gas can be excited to a higher energy level without increasing the supply power and said excited gas atom is made to undergo a large resonance potential transition to radiate a shorter wavelength resonance line.

In order to achieve siad object, the present inventors discovered after various experiments and discussions that a short wavelength resonance line can be generated by introducing microwave power into a discharge vessel containing discharge gas to form a high frequency electromagnetic field in said discharge vessel and to generate a high frequency electrodeless discharge plasma within said discharge vessel, inserting a body like a metal plate which highly reflects a microwave in a direction perpendicular to the traveling direction of the electromagnetic wave propagating in the discharge vessel and reflecting an incident electromagnetic wave at the surface

of said metal plate to form a standing wave consisting of an incident wave and a reflected wave in said plasma; thereby forming an intense high frequency electromagnetic field with a relatively small feed power; and exciting the gas atoms in the plasma to a higher energy level.

A second object of this invention is to provide a microwave plasma light source comprising a relatively low power excitation microwave power supply similar to a conventional one, wherein a resonance transition having a higher resonance potential can be induced by exciting a gas atom to a relatively high energy level with an excitation power nearly equal to the power conventionally used when generating a resonance line of a relatively long wavelength by exciting the gas atom to a relatively low energy level, and which accordingly can also generate a resonance line of a yet shorter wavelength and thus can produce at least two kinds of resonance lines having different wavelengths in turn.

In order to achieve said object, said metal plate placed on the propagation path of the electromagnetic wave propagating within the discharge vessel in a perpendicular relation to the traveling direction of the wave is so constructed that the metal plate may be removed from the propagation path when necessary.

Other object features and advantages of this invention will become more apparent from the following detailed description of some embodiments of the invention, when taken in conjunction with the acompanying drawings, wherein

FIG. 1*a* is a longitudinal sectional diagram showing the principle of a microwave plasma light source embodying this invention,

FIG. 1*b* is a fragmentary longitudinal sectional diagram wherein the metal plate is removed,

FIG. 2 is a diagram showing the excited energy levels of a helium atom presented for the illustration of the principle of resonance line radiation of a microwave plasma light source according to this invention, and

FIG. 3 is a fragmentary longitudinal sectional diagram showing an example wherein a microwave plasma light source of this invention is supplied for an ion source of a mass spectrometer.

In FIGS. 1*a* and 1*b* indicates a discharge vessel containing discharge gas, **2** indicates a vacuum wall forming a vacuum chamber **3** communicating with the discharge vessel **1**, **4** designates an evacuation tube, and **5** designates an evacuation system comprising a vacuum pump. The discharge vessel **1** is a cylindrical tube (inner diameter 8 mm., length 200–300 mm.) made of heat-resisting and electrically insulating material like quartz, wherein one end thereof penetrates through the vacuum wall **2** into the vacuum chamber **3** and the space of said vessel communicates with the vacuum chamber **3** by way of a small hole **13** of about 1 mm. in diameter provided at the end wall **15** of the discharge vessel **1**. The inner part of this vacuum chamber **3** is continuously evacuated with the evacuation system **5** through the evacuation tube **4** and maintained at a low pressure of the order of $10^{-3}\sim10^{-5}$ mm. Hg. At the other end of the discharge vessel **1**, a discharge gas inlet **6** is provided and through said inlet **6** discharge gas (rare gas) like helium is continuously introduced from a discharge gas inlet system **7** into the vessel **1**. The desired amount of gas to be introduced should be such that the gas pressure in the vessel **1** becomes 0.1~5 mm. Hg. Further, **8** indicates a cavity resonator provided around the discharge vessel **1**, **9** indicates a wave guide, and **10** designates a microwave power supply comprising a microwave oscillator like a magnetron. As the microwave power supply **10**, a power supply of several gHz. in frequency and several hundred watts in output is used. When microwave power of the order of a few hundred watts is fed from said power supply **10** into the cavity resonator **8** by way of the waveguide **9**, a high frequency electromagnetic field is formed within the discharge vessel **1**, the gas atoms in the vessel absorb the microwave power under the intense electric field effect and are excited to high energy levels and cause so-called high frequency electrodeless discharge and thus discharge plasma **11** is generated.

At the outer side of the end wall **15** of the discharge vessel **1** comprising the small hole **13**, a metal plate **12** comprising a small hole **14** of about 1 mm. in diameter to be communicated with said small hole **13** is inserted in a perpendicular relation with the central axis of the vessel **1** and is used as a microwave reflector. Said metal plate **12** comprises a stick part **36** inserted inwards from the outside of the vacuum wall **2** through a Wilson seal **35**, etc. and the metal plate can be moved therewith from outside in a direction indicated by arrow **37**. Namely, by moving said metal plate **12** in the direction indicated by arrow **37**, the outer surface of the end wall **15** of the discharge vessel **1**, i.e., the path of the electromagnetic wave propagating within the vessel **1** in an axial direction, can be covered with the metal plate **12** in the state where the small holes **13**, **14** communicate with each other as shown in FIG. 1*a*; in other words, the metal plate **12** on can be removed completely from the outer surface of the end wall **15**, i.e., the path of the electromagnetic wave propagating within the discharge vessel **1** in axial direction, as shown in FIG. 1*b*. It is to be noted that the moving mechanism of the metal plate **12** is by no means restricted to the one described hereinabove, but various modifications are possible.

When the metal plate **12** is positioned as shown in FIG. 1*b*, i.e., when the metal plate is absent from the outer surface of the end wall **15** of the discharge vessel **1**, loss of microwave power fed into the discharge vessel **1** due to leakage out of the vessel **1** is large as in a conventional device not comprising the metal plate **12** and thus the high frequency electromagnetic field formed in the vessel **1** cannot be made sufficiently intense. Accordingly, the supply power from the microwave power supply **10** must be made large to obtain an intense high frequency electromagnetic field necessary and sufficient to generate plasma.

An example of this case follows. Helium gas of 1 mm. Hg in pressure is introduced into the vessel **1** as discharge gas and a microwave power of 250 w. is fed to the resonator **8** from a microwave power supply of 2450 mHz. in frequency and 250 w. in output. Then only a resonance line (HeI) of 584 A. in wavelength is emitted from the plasma **11** and a resonance line (HeII) of 304 A. in wavelength is not radiated at all. In other words, the upper limit of the excitation energy of the gas atoms in the plasma **11** is at most 22~23 ev.

The present inventors have verified after various experiments and discussions that an excitation energy sufficient to emit a resonance line (HeII) of 304 A. in wavelength cannot be obtained in the above case because the microwave power fed into the discharge vessel **1** is lost from the vessel through the end wall **15** of the discharge vessel **1** and a sufficiently intense electric field is not formed in the vessel **1**.

When the metal plate **12** of this invention is inserted along the outer surface of the end wall **15** of the discharge vessel **1** in a perpendicular relation to the central axis of the vessel **1** so that the metal plate **12** may cover the outer surface of the end wall **15** as shown in FIG. 1*a*, the electromagnetic wave propagating within the discharge vessel **1** along the axis of the vessel tries to leak out of the vessel through the end wall **15**, but is reflected by the metal plate provided outside of the end wall **15** and returns to the vessel **1**. In this case, an intense standing wave is formed of the incident wave and the reflected wave within the discharge vessel **1** and the electric field intensity in the plasma **11** is remarkably increased.

Under the effect of said strengthened electric field, the electrons in the plasma **11** are excited to quite high energy levels and thus a helium atom (He) is ionized to become

a monovalent helium ion (He^+) and further excited to the excited state (He^{+*}) of said monovalent helium ion. In this case, an emission line (HeII) of 304 A. in wavelength caused by the transition from the excited state of the monovalent helium ion (He^{+*}) to the monovalent helium ion (He^+) is obtained from the plasma **11**. In this case, the amount of the resonance line (HeI) of 584 A. in wavelength due to the transition from the first excited state of a helium atom (He^*) to the ground state (He) is negligible compared with the amount of generation of said resonance line (HeII) of 304 A. in wavelength.

An example of this case is described hereinbelow. Helium gas (pressure in the vessel **1** is 1 mm. Hg) is used as discharge gas and the gas is excited with a microwave power supply of 2450 mHz. in frequency and 50 w. in output. Then, the excitation energy in the plasma **11** exceeds 80 ev. and an intense emission line of 304 A. in wavelength is radiated from the plasma. In this case, it is verified that the resonance line (HeI) of 584 A. in wavelength is scarcely emitted.

The emission line **17** radiated from the plasma **11** is radiated into the vacuum chamber **3** through the small holes **13** and **14**. When a desired irradiation material (not shown in the figure) is inserted into the vacuum chamber **3**, said irradiation material can be irradiated with the emission line **17**.

When the emission line **17** is to be taken out of the vacuum chamber **3**, the following means are employed. When only the resonance line (HeI) of 584 A. in wavelength is to be taken out, a window plate **38** made, for example, of lithium fluoride (LiF) film is provided at a lead out window **16** and the resonance line (HeI) is taken out through said window plate. The emission line of wavelength 304 A. (HeII) cannot penetrate through said window plate **38** and so when said emission line is to be taken out, the window plate **38** is removed and a slit (not shown) having a suitable aperture is provided and another vacuum chamber (not shown in the figure) is set outside of said slit. Thus, the emission line is introduced into said chamber and used for irradiation.

The helium atoms in the discharge vessel **1** are exhausted in the vacuum chamber **3** through the small holes **13, 14** and further exhausted with the evacuation system **5** and then fresh helium gas is introduced into the vessel **1** from the gas inlet **6.**

Thus, in a device according to this invention, the emission line (HeII) of 304 A. in wavelength unobtainable with conventional devices can be generated with a relatively small microwave power of less than a few hundred watts by inserting the metal plate **12** along the outer surface of the end wall **15** of the discharge vessel **1**. Further, by moving said metal plate **12** as shown in FIG. 1*b* according to the purpose, the device of this invention can be used also as a light source for the resonance line (HeI) of 584 A. in wavelength like the conventional one. Thus, the device comprising the movable metal plate **12** can produce two lines different in wavelength with a relatively small microwave power of the order of several hundred watts.

As has been fully described hereinabove, an intense standing wave can be generated within the discharge vessel and the high frequency electromagnetic field can be strengthened by inserting a metal plate perpendicularly to the traveling direction of the electromagnetic wave propagating in the discharge vessel, and the excitation energy of the discharge gas atoms in the vessel can be raised from about 20 ev. obtained with conventional devices to a few hundred ev. with a microwave power of the order of several hundred watts. Accordingly, it becomes possible to induce various resonance transitions from high excitation energy levels and thereby to take out various resonance lines different in wavelength which is inversely proportional to the energy difference corresponding to said transition or resonance potential.

In particular, the resonance line (HeII) of 304 A. in wavelength is smaller in wavelength than the resonance line (HeI) having the shortest wavelength (584 A.) obtained with conventional devices and the resonance potential 40.80 ev. of the former (HeII) is about twice higher than the potential 21.21 ev. of the latter (HeI). This fact further causes the following effects.

In ionizing the gas atoms (or molecules) by using the photo-ionization effect of the resonance lines of this kind, since the energy difference between the levels or the resonance potential is 21.21 ev. and small in the case of the resonance line (HeI) of 584 A. in wavelength, the atoms (or molecules) which can be ionized with said resonance line (HeI) of 584 A. in wavelength are limited to those having the ionization voltage smaller than said resonance potential 21.21 ev. On the other hand, when the resonance line (HeII) of 304 A. in wavelength is used, the resonance potential thereof is 40.80 ev. and large. Thus, the number of atoms (or molecules) to be ionized therewith increases remarkably.

An example of the experimental results indicating the possibility or impossibility of ionization of representative gas atoms or molecules with various resonance lines are tabulated hereinbelow.

	Gas to be ionized		
	Ne	CH_4	C_3H_6
Ionization voltage	21.57	13.04	9.73
Resonance line:			
HeII 304 A. 40.80 iv	o	o	o
HeI 584 A. 21.21 ev	x	o	o
Ar 871 A. 14.25 ev	x	o	o
Ar 1046 A. 11.84 ev	x	x	o

Note.—o: ionization possible, x: ionization impossible.

As is evident from the above table, neon atom (Ne) can be ionized only with the resonance line (HeII) of 304 A. in wavelength. Also, a monovalent helium ion (He^+) (ionization voltage 24.58 ev.) can be obtained only with the irradiation of the resonance line (HeII) of 304 A. in wavelength and not with the irradiation of the other resonance linese having a longer wavelength.

Since a resonance line having a short wavelength unobtainable with conventional devices can be radiated according to this invention by exciting the discharge gas atoms to high energy levels in plasma as described hereinabove, it becomes possible to ionize gas atoms or molecules having a higher ionization voltage with said short wavelength resonance lines. Accordingly, the plasma light source according to this invention can be used for example, as a photo-ionization type ion source in a mass spectrometer which ionizes the samples.

FIG. 3 shows a photo-ionization type mass spectrometry ion source composed of a plasma light source embodying this invention. In the figure, the same reference numerals as used in FIG. 1*a* indicate the same parts as in FIG. 1*a*. The vacuum chamber **3** and an ionization chamber **19** of the ion source are communicated by a thin tube **18** and the resonance lines **17** generated in the discharge vessel **1** are introduced through said thin tube into the ionization chamber **19.** On the other hand, sample gas (or vapor) is introduced from a sample inlet system **21** into the ionization chamber **19** through the sample inlet **20.** The pressure of said sample gas is of the order of 10^{-4} mm. Hg. In this case, it is desirable to choose the tube resistance of the thin tube **18** and the evacuation speed of the evacuation system **5** in a way to prevent the discharge gas (helium gas) in the vacuum chamber **3** from flowing into the ionization chamber **19** and disturbing the sample gas pressure and the sample composition even when the gas pressure in the vacuum chamber **3** ($10^{-3}\sim10^{-5}$ mm. Hg) exceeds the sample gas pressure (10^{-4} mm. Hg) in the ionization chamber **19.** For example, for thin tube **18** an inner diameter of about 1 mm. is preferable.

The sample gas introduced into the ionization chamber **19** is irradiated with the resonance line **17** from the light source and ionized by the known photo-ionization effect. Component atoms (or molecules) of the ionized sample are accelerated with a positive potential applied to a known repeller plate **22**, focused with a focusing electrode system **23** to form an ion beam and the ion beam **24** is injected into an analyzer tube **27**. Then, the ion beam **24** is separated in a mass analyzer **29** according to the mass to charge ratio (m/e value) of the ions and only the fragment ions having a specific m/e value are detected with a ion collector **30** and recorded with a recorder **31**. Thus, by scanning the m/e values of the fragment ions reaching the ion collector **30** at the mass analyzer **29**, the recorder **31** can record the current peaks (mass spectra) of the fragment ions having different m/e values in sequence. The analyzer tube **27** is evacuated with the evacuation system **28** to a low pressure (high vacuum) of less than 10^{-6} mm. Hg. The power supply **32** is provided to feed the accelerating voltage to the repeller plate **22**, the voltage to each electrode of the focusing electrode system **23**, the scanning current to the mass analyzer **29** and the operating power to the ion collector **30** and the recorder **31**.

Thus, with the current peak of each fragment ion recorded with the recorder **31**, composition analysis of the sample can be performed.

In a device shown in FIG. 3, when helium gas is used as discharge gas to be introduced into the discharge vessel **1**, the gas pressure in the vessel is made to be 1 mm. Hg and microwave power of 2450 mHz. and 50 w. is supplied, an intense resonance line (HeII, 304 A.) of $10^{11\sim12}$ photons/sec. in photon number can be injected into the ionization chamber **19** through the small holes of 1 mm. in diameter provided at the end wall of the discharge vessel **1** and the metal plate **12**, and then through the thin tube **18** of 1 mm. in diameter. The intensity of said resonance line can be measured by projecting the resonance line (emission line) **17** onto the gold target **25**, collecting electrons emitted from said target surface with the collector electrode **26** and measuring and displaying said electrons with an amplifier **33** and an indicator **34**.

The resonance line **17** of 304 A. in wavelength obtained in this way irradiates the sample gas (e.g., Ne) of the order of 10^{-4} mm. Hg in pressure introduced into the ionization chamber **19** and a measurable ion beam of the order of $10^{-12}\sim10^{-13}$ A. can be derived therefrom.

When the metal plate **12** is rotated about the rotation axis **41** in a direction indicated by the arrow **39** and placed at a position **40** separated from the end wall of the discharge vessel **1** as shown by a double chain line in the figure, a resonance line (HeI, 584 A.) of about 10^{12} photons/sec. in photon number is obtained with a microwave power of 50 w. In this latter case, it is verified that the resonance line of 304 A. in wavelength (HeII) is not emitted.

As has been fully described hereinabove, the microwave plasma light source according to this invention can produce the resonance line (HeII, 40.80 ev.) of 304 A. in wavelength with a relatively low power microwave power supply of less than several hundred watts and the device can further produce other resonance lines having a relatively long wavelength like the one of 584 A. in wavelength when the metal plate **12** is removed from the outer surface of the end wall **15** of the discharge vessel **1**. Accordingly, said photo-ionization type ion source comprising the light source of this invention can ionize elements having a high ionization voltage like a neon atom (Ne) which cannot be ionized with the conventional resonance line (HeII) of 584 A. in wavelength and further it can ionize the samples by choosing a resonance line having the most suitable wavelength according to the composition of the sample to be ionized. Further, when the photo-ionization type ion source including the light source of this invention is used as a mass spectrometry

ion source as shown in FIG. 3, it is possible to refer to the accumulated data obtained with a conventional electron impulse type ion source in ascribing the ion current peaks (mass spectra) indicated with the recorder to the composition of the sample. Namely, in a conventional electron bombarding type ion source, data are available wherein the energy of the electron beam used to ionize the sample is 50 ev. and 70 ev., but no data are available wherein a low energy electron beam corresponding to a wavelength of 584 A. (21.21 ev.) is used. On the other hand, since the ionization can be done with the resonance line (HeII, 40.80 ev.) of 304 A. in wavelength in the light source of this invention, conventional data wherein the electron beam of 50 ev. is used can be utilized.

The photo-ionization type ion source of this invention can produce a stable ion beam compared with the conventional electron bombarding type ion source. In particular, it is difficult to obtain a stable electron beam of about 20 ev. and below in energy with the electron bombarding type ion source and only electron beams of more than 50 ev. can be obtained stably. On the other hand, with the photo-ionization type ion source of this invention, resonance lines having an energy of less than about 20 ev. [e.g., HeI 584 A. (21.21 ev.), Ar 1046 A. (11.58 ev.) etc.] can be obtained stably and thus said device is quite effective for studying the molecular structure of the organic material by using the results of mass spectrometry.

Though the case where the light source of this invention is used as a mass spectrometry ion source has been described hereinabove the light source of this invention is also effective as a light source for a vacuum monochromator and in this case, the resonance line (HeII) of 304 A. in wavelength contributes to extend the range of application of the monochromator.

As has been described in detail hereinabove, since the microwave plasma light source of this invention can produce the resonance line (HeII) of 304 A. in wavelength unobtainable with conventional devices, said device can be used as a light source for a vacuum monochromator in the far short wave region and the device can further be used to construct a mass spectrometry ion source which utilizes the photo-ionization effect. Thus, the device according to this invention contributes greatly to the extension of the range of application for a spectrometer and the range of ionization. Further, since the device of this invention has such a simple structure that a movable metal plate is inserted into the conventional device, the device of this invention is also advantageous from an economic point of view.

What is claimed is:

1. A microwave plasma light source comprising a hollow discharge vessel having an inlet port at one end wall and an exhaust port at the other end wall, a vacuum chamber communicating with said discharge vessel through said exhaust port, means for introducing a discharge gas into said vessel through said inlet port, an evacuation system connected with said vacuum chamber, means for introducing microwave power into said vessel and producing an electrodeless gas discharge plasma therein, and a microwave reflector plate disposed along the outer surface of said other end wall of said vessel and having a small hole formed in said plate in a position aligned with said exhaust port, whereby a resonance line emitted from said plasma is derived through said exhaust port in said small hole into said vacuum chamber.

2. A microwave plasma light source according to claim **1**, wherein said discharge gas is helium, and said resonance line is a helium resonance line of 304 A.

3. A microwave plasma light source according to claim **1**, wherein said microwave reflector plate is removable from said position.

4. A photo-ionization type ion source for mass spectrometry comprising a sample gas, and a microwave plasma light source according to claim **2** for directing said

helium resonance line of 304 A. to said sample gas to ionize said sample gas.

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JAMES W. LAWRENCE, Primary Examiner

P. C. DEMEO, Assistant Examiner

U.S. Cl. X.R.

240—41.9; 313—231; 315—39

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,541,372 Dated November 17, 1970

Inventor(s) Itiro Omura and Hiroshi Doi

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 8, Priority Document Number should read

-- 41/85334 -- .

Signed and sealed this 31st day of August 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER, JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents