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(54) **METHOD AND DEVICE FOR PROVIDING PLASMA**

VERFAHREN UND VORRICHTUNG ZUR PLASMAERZEUGUNG

PROCEDE ET APPAREIL DE FOURNITURE DE PLASMA

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(73) Proprietor: **VALTION TEKNILLINEN TUTKIMUSKESKUS**
02150 Espoo 15 (FI)

(72) Inventors:
- **ROINE, Johannes**
FIN-02044 VTT (FI)
- **ASIKAINEN, Matti**
FIN-01560 Maantiekylä (FI)

(74) Representative: **Simmelvuo, Markku Kalevi et al**
Papula Rein Lahtela Oy,
P.O. Box 981
00101 Helsinki (FI)

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Description

[0001] The present invention relates to a procedure as defined in the preamble of claim 1 and to a device as defined in the preamble of claim 7 for forming a plasma.

[0002] Elementary analyses of gas or aerosol samples are currently performed by subjecting a sample gas flow to a high temperature using external energy. Generally the sample gas is mixed with a gas that easily transforms into plasma, e.g. argon, helium or nitrogen, which may also be a component of the gas mixture under analysis. When the sample gas becomes sufficiently hot, the electrons in the atoms of the elements become excited, and the wavelength of the light quantum or photon produced when the electrons are de-excited is characteristic of each element and its electron ring. By examining the light quanta, it is possible to determine the elements and their amounts contained in the sample.

[0003] As is known, the external energy can be produced using various systems. Previously known is an induction heater, which uses magnetic flux to transfer energy into the gas to be heated. A problem with the use of magnetic flux is how to "ignite" the gas, i.e. how to achieve a sufficient degree of ionization to induce the plasma state of the gas. A small gas quantity cannot receive a sufficient amount of energy from the magnetic flux, and this leads to the need for large apparatus using a high volume of gas flow. On the other hand, if small amounts of gas are used, the magnetic field has to be generated using a very high frequency, typically a frequency of several gigahertz. Conventionally, this problem is solved by using a spark between two electrodes to "ignite" the gas. The spark is created in the area where plasma is to be developed and it is extinguished after a plasma flame has been set up. This is not an automatic system, because if the plasma decays in consequence of an external disturbance, such as a power failure, gas supply failure or the like, it has to be ignited again with a spark.

[0004] Another prior-art method is to use only a high-voltage spark to produce a plasma. In this case, a gas is ionized using an electric spark until a breakdown occurs and the gas is converted into plasma. However, the spark is not extinguished after a plasma has been generated, but the spark is used to transfer the energy required by the plasma to the gas. As the required high power is transferred by means of a spark, the spark discharge is very unstable and difficult to control, causing serious disturbances in the analysis of sample gases.

[0005] Patent publication EP-A-0602764 discloses an inductively coupled plasma spectrometer comprising a plasma induction coil, a power supply; a plasma forming space; an electric circuit electrically connected to the power supply to produce a magnetic field through the induction coil; and a torch, which is fed gas from a gas supply, for igniting the plasma. The electric circuit connected to the power supply and the induction coil comprises a resonant circuit consisting of a coil and a capacitor and is arranged to connect the power required for forming the plasma. The resonant circuit is supplied with an alternating current, whose frequency is set to the resonant frequency of the circuit and the induction coil. The plasma is maintained by the magnetic field. The induction coil is placed in the vicinity of the plasma forming space and the magnetic field is in the direction of the plasma.

[0006] Patent publication WO 93/12633 discloses a plasma torch comprising three tubular electrodes, through one of which plasma forming gas may be supplied. The other two electrodes are in conjunction with the plasma forming space. The plasma torch also comprises a coil causing a magnetic field within which the plasma is formed and maintained.

[0007] The object of the present invention is to eliminate the drawbacks mentioned above.

[0008] A specific object of the present invention is to produce a procedure and a device for forming a plasma which allow a stable and controlled plasma to be generated with flue gas samples for the purpose of determining the percentages of elements present in the flue gas samples.

[0009] Another object of the present invention is to produce a plasma forming device that works on a continuous principle, i.e. when the plasma reverts into gas, the device acts automatically so that the gas is again converted into plasma.

[0010] A further object of the present invention is to produce a procedure and a device which enable a plasma to be generated and maintained with a power demand significantly lower than in prior-art devices.

[0011] As for the features characteristic of the invention, reference is made to the claims.

[0012] In the procedure of the invention for forming a plasma, a magnetic field is set up in a plasma forming space, a spark discharge is produced in the plasma forming space and a gas flow is passed into the plasma forming space against the magnetic field. Preferably the gas flow is applied in a direction perpendicular to the magnetic field, permitting the most effective transfer of electric energy from the magnetic field to the gas. According to the invention, plasma is generated in the plasma forming space by means of the spark discharge and maintained by means of the magnetic field and spark discharge. In practice, however, the situation is such that when the power of the magnetic field is sufficient, the spark has only a slight significance for the plasma. However, since the spark discharge exists continuously, the procedure of the invention is automatic.

[0013] As compared with prior art, the present invention has the advantage that plasma is formed automatically both at the first "ignition" and during operation when the plasma has reverted back into gas due to a disturbance. Moreover, the arrangement of the invention allows a significant reduction in the energy consumption. This is because in the device of the invention the energy can be applied accurately to the plasma forming region and used for the generation of plasma. In addition, the circuit used in the device of the invention has a good efficiency.

[0014] Another advantage of the present invention as compared with prior art is that no high voltage or high power needs to be used in the amplifier which feeds the electric circuit producing the magnetic field and spark discharge.

[0015] A further advantage of the present invention as compared with prior art is that, in the device of the invention, no large quantities of gas or high frequencies need to be used.

[0016] In a preferred embodiment of the present invention, the magnetic field and the spark discharge are produced by means of substantially the same resonator circuit, consisting of a capacitor and a coil connected in series. The load of the circuit, connected in parallel with the coil, is the plasma forming space, which contains gas. As compared with the conventional parallel connection, the series connection has the advantage that, when the load impedance falls as the gas is converted into plasma, the amplifier feeding the resonator circuit sees an impedance - the impedance caused by the capacitor - independent of the load impedance.

[0017] The frequency of the resonator circuit - a series connection of a capacitor and a coil - is automatically so selected that the circuit works at the resonant frequency. In this case, the magnitudes of capacitance and reactance are equal, compensating each other. A suitable frequency is in the RF range, typically in the range of 100 kHz - 3 MHz. When frequencies higher than this are used, it is possible to use the normal transmission path matching, i.e. a parallel connection of a coil and a capacitor, which is used in prior-art devices.

[0018] In a preferred case, the form and characteristics of the plasma being generated are controlled by adjusting the power of the magnetic field and spark discharge and regulating the flow of the gas used. Furthermore, it is preferable to keep the power of the spark discharge constant and under control so that the discharge will not cause any extra disturbance in the process of determining the presence of elements.

[0019] The device of the invention for forming a plasma comprises a power supply for supplying the power required for the formation of plasma, a plasma forming space, which is open in relation to its environment, an electric circuit, which is electrically connected to the power supply to produce a magnetic field and a spark discharge in the plasma forming space, and a gas channel communicating with the plasma forming space for passing a gas into the plasma forming space and out of it via its open part. According to the invention, the electric circuit comprises a resonator circuit consisting of a series connection of a coil and a capacitor and arranged to connect the electric power needed for forming a plasma to the plasma forming space.

[0020] As for the advantages of the device of the invention, reference is made to the advantages of the procedure of the invention.

[0021] In a preferred embodiment, the device comprises a first electrode, which is electrically connected to a first potential of the electric circuit, and a second electrode, which is placed at a distance from the first electrode and electrically connected to a second potential in the electric circuit, said first and second potentials being substantially different in magnitude. Further, the electrodes are so disposed that a spark discharge takes place in the plasma forming space with the selected values of the first and second potentials. In a preferred embodiment, one of the potentials is the earth potential of the amplifier feeding the electric circuit. The first and second electrodes are needed especially when treating gases that are difficult to convert into plasma. Such gases include e.g. nitrogen. On the other hand, when treating gases that are easier to convert into plasma, the second electrode is not necessarily needed at all. Such gases include e.g. argon. In this case, the second potential consists in the surrounding space, and the spark discharge shoots from the tip of the first electrode out into space, e.g. through a coil placed in the direction of the tip. Resonance preferably prevails between the coil and the capacitor, and the spark jet can be directed through a torque tube with a magnetic field on it.

[0022] In a preferred embodiment, the coil is disposed in the vicinity of the plasma forming space in such a way that the magnetic field generated by the coil is in the direction of the gas flow. In this case, the coil may me be so disposed that the plasma forming space is inside the coil structure. On the other hand, the magnetic field produced by the coil is also present outside the coil, so it is possible to dispose the plasma forming space outside the coil. In practice, however, the fact is that the magnetic flux density is greatest inside the coil. The coil preferably comprises a specified number of successive spiral discs with crossed windings. In such a solution, the winding is arranged in a spiral pattern on a round disc, starting near the centre of the disc.

[0023] In the following, the invention is described by the aid of examples of its embodiments by referring to the attached drawing, in which

Fig. 1 presents a diagram representing a device as provided by the invention;

Fig. 2 presents a diagram representing a spiral disc forming part of the coil of the device in Fig. 1;

Fig. 3a presents a conventional circuit for generating a magnetic field;

Fig. 3b presents the circuit used in the device of Fig. 1 for generating a magnetic field and a spark discharge;

Fig. 4 -7 present simulation results for the circuits in Fig. 3a and Fig. 3b; and

Fig. 8 presents a diagram representing another device according to the invention, resembling the device in Fig. 1.

[0024] The device for generating a plasma as presented in Fig. 1 comprises a power supply 1, which preferably outputs a 200-V alternating voltage in the frequency range of 100 kHz - 3 MHz, and a plasma forming space 2 open to its environment, into which space a gas to be ionized is supplied. Furthermore, the device comprises an electric circuit 3, which according to the invention is a series connection of a coil 5 and a capacitor 6 and is electrically connected to the power supply 1 to generate a magnetic field and a spark discharge in the plasma forming space 2. As shown in Fig. 1, adjoined to the plasma forming space is a wall 7 which also functions as a first electrode, being electrically connected to the earth potential of the power supply 1. Further, the device comprises a gas channel 4 communicating with the plasma forming space 2 for passing gas into the plasma forming space and out of it via its open part. The device presented in Fig. 1 has a second bar-like electrode 8 attached to the frame and preferably made of an electrically conductive material. In Fig. 1, the plasma 12 being formed is represented by elliptic lines.

[0025] Fig. 2 presents a structure in which a conductor wire 12 is arranged in a spiral form on a disc-like body 11. The conductor wire 12 is wound alternately on either side of the disc 11. As the magnetic flux density in the circuit used in the device of the invention is proportional to the number of winding turns, the coil structure shown in Fig. 2 is very advantageous. Referring again to Fig. 1, the coil 5 comprises several spiral discs as shown in Fig. 2, connected in series. The cooling of such a coil structure is simple to implement and can be advantageously effected by blowing air into the gaps between the discs.

[0026] Referring to Figures 3a and 3b and to the curves shown in Figures 4 - 7, the series connection of the invention is compared with the conventional parallel connection used for matching the transfer path and generating a magnetic field. The action of the circuits was simulated using appropriate simulation software. The simulation results are presented in Fig. 4 - 7, in which the horizontal axis represents the frequency of the voltage supplied by the power supply and also the frequency of the resonator. In Fig. 4 and 5, the vertical axis represents the power, in Fig. 6 'the current and in Fig. 7 the voltage. In addition, the simulation program was given an external temperature value of 60°C.

[0027] The load impedance is represented in Fig. 3a and 3b by resistors R1 and R2, respectively. The load is connected in parallel with the coil producing the magnetic field, affecting the current that flows through the coil. When the gas is transformed into plasma, the electric conductivity of the gas is clearly improved, thus reducing the load impedance. In this case, the high-power amplifier in Fig. 3a sees the fall in the load impedance directly and tries to supply more and more current into the load, so the circuit becomes unstable and difficult to control. In Fig. 3b, the load impedance of the amplifier does not change, because it has a constant value depending on capacitor C2. Therefore, the circuit remains stable and under control.

[0028] When the simulation results are examined, it can be seen from Fig. 4 - 7 that there is a definite difference between the conventional circuit and the circuit of the invention. Fig. 4 presents the power supplied by the amplifier into the resonator and the power fed into the coil as functions of frequency. As is clearly manifest from the figure, the highest power both from the amplifier and across the coil is achieved at the resonant frequency. Fig. 5 also graphically illustrates the difference between the conventional circuit and the circuit of the invention regarding the power transferred by the coil. Fig. 6 shows the current flowing through the load resistances R1 and R2 (plasma) as a function of frequency. From this, too, one can draw the conclusion that the resonator of the invention is more effective than the conventional resonator.

[0029] In Fig. 7, the voltage across the coil is presented as a function of frequency and compared with the amplifier output voltage. It can be seen from Fig. 7 that the voltage across the coil, about 4 kV, achieved by the procedure of the invention is clearly higher than the amplifier output voltage (200 VAC). By contrast, the voltage across the coil achieved using the conventional parallel connection, about 1.8 kV, remains below the amplifier output voltage (2 kV).

[0030] The device presented in Fig. 8 mainly corresponds to the device shown in Fig. 1. However, the device in Fig. 8 comprises only one electrode 8; the device has no separate electrode connected to the earth potential of the power supply 1. In the embodiment in Fig. 8, the plasma is formed in the plasma forming space 2 and shot into space through the torque tube formed by the coil 5, i.e. through the magnetic field generated by the coil. The device of Fig. 8 is particularly applicable in conjunction with treating gases convertible into the plasma state, such as argon.

[0031] As a summary, the following can be stated. Plasma generated by means of a spark and maintained by means of a spark and a magnetic field according to the invention becomes stabilized at the series resonance frequency because the net effect of the spark diminishes as the voltage rises and vice versa, and when the power transferred via the magnetic field to the plasma increases, the voltage falls and the effect of the magnetic field diminishes. Moreover, amplifier noise and other interference voltages in the series circuit are attenuated according to the proportion of the impedances.

Claims

1. Procedure for forming a plasma (12), in which procedure a magnetic field is set up in a plasma forming spacer (2), a spark discharge (14) is produced in the plasma forming space (2) and a gas flow is passed into the magnetic field in the plasma forming

space, and wherein the plasma is formed in the plasma forming space by means of the spark discharge and maintained by means of the magnetic field and spark discharge, **characterised** in that the magnetic field and the spark discharge are produced by means of the same resonator circuit (3), consisting of a series connection of a capacitor (6) and a coil (5).

2. Procedure as defined in claim 1, **characterised** in that the plasma is formed substantially within the coil (5).

3. Procedure as defined in claim 1 or 2, **characterised** in that the resonator circuit (3) is supplied with an alternating electric current, whose frequency is selected automatically so that the resonator circuit works at the resonant frequency.

4. Procedure as defined in any one of claims 1 - 3, **characterised** in that the plasma is controlled by adjusting the power of the alternating current.

5. Procedure as defined in any one of claims 1 - 4, **characterised** in that the plasma is controlled by adjusting the rate of the gas flow.

6. Procedure as defined in any one of claims 1 - 5, **characterised** in that the spark discharge is produced in the plasma forming space (2) by means of an electrode (8) placed in the gas flow and another electrode (7) placed in conjunction with the plasma forming space (2).

7. Procedure as defined in any one of claims 1 - 5, **characterised** in that the spark discharge is produced in the plasma forming space (2) by means of the electrode (8) placed in the gas flow by directing the spark discharge through the magnetic field generated by the coil (5) into the surrounding space, which constitutes the other electrode (7).

8. Device for forming a plasma (12), comprising

- a power supply (1) for supplying the power required for forming a plasma;
- a plasma forming space (2), which is open to the environment;
- an electric circuit (3), which is electrically connected to the power supply to produce a magnetic field and a spark discharge (14) in the plasma forming space; and
- a gas channel (4) communicating with the plasma forming space for passing a gas into the plasma forming space and out of it via its open part, **characterised** in that the electric circuit (3) is a resonator circuit consisting of a series connection of a coil (5) and a capacitor (6) and arranged to connect the electric power required for forming a plasma to the plasma forming space (2) so that the magnetic field and the spark discharge are produced by means of the said resonator circuit.

9. Device as defined in claim 8, **characterised** in that the device comprises a first electrode (7) , which is electrically connected to a first potential of the electric circuit (3), and a second electrode (8), which is placed at a distance from the first electrode and electrically connected to a second potential of the electric circuit, said first and second potentials being substantially different in magnitude; and that the electrodes are so disposed that a spark discharge takes place in the plasma forming space (2) with the selected values of the first and second potentials.

10. Device as defined in claim 8 or 9, **characterised** in that the coil (5) is disposed in the vicinity of the plasma forming space (2) in such a way that the magnetic field generated by the coil is in the direction of the gas flow.

11. Device as defined in any one of claims 8 - 10, **characterised** in that the plasma forming space (2) is disposed inside the coil (5).

12. Device as defined in any one of claims 8 - 11, **characterised** in that the coil (5) comprises a specific number of annular discs (11), spaced from each other in direction of the gas flow and arranged coaxially around the plasma forming space (2), wherein a winding is formed by winding a conductor wire (13) alternately on either side of the disc (11) in a spiral form.

Patentansprüche

1. Verfahren zum Bilden eines Plasmas (12), wobei in welchem Verfahren ein Magnetfeld in einem Plasmabildungsraum (2) aufgebaut wird, wobei eine Funkenentladung (14) in dem Plasmabildungsraum (2) hergestellt wird und ein Gasfluss in das Magnetfeld in dem Plasmabildungsraum eingeleitet wird, und wobei das Plasma in dem Plasmabildungsraum mittels der Funkenentladung gebildet wird und mittels des Magnetfeldes und der Funkenentladung aufrechterhalten wird, dadurch gekennzeichnet, dass das Magnetfeld und die Funkenentladung mittels derselben Resonatorschaltung (3) hergestellt werden, der aus einer Reihenschaltung aus einem Kondensator (6) und einer Spule (5) besteht.

2. Verfahren gemäß Anspruch 1, dadurch gekennzeichnet, dass das Plasma im Wesentlichen innerhalb der Spule (5) gebildet wird.

3. Verfahren gemäß Anspruch 1 oder 2, dadurch gekennzeichnet, dass die Resonatorschaltung (3) durch einen elektrischen Wechselstrom versorgt wird, dessen Frequenz automatisch ausgewählt wird, so dass die Resonatorschaltung an der Resonatorfrequenz arbeitet.

4. Verfahren gemäß einem der Ansprüche 1-3, dadurch gekennzeichnet, dass das Plasma durch Einstellen der Leistung des Wechselstroms gesteuert wird.

5. Verfahren gemäß einem der Ansprüche 1-4, dadurch gekennzeichnet, dass das Plasma durch Anpassen der Rate des Gasflusses gesteuert wird.

6. Verfahren gemäß einem der Ansprüche 1-5, dadurch gekennzeichnet, dass die Funkenentladung in dem Plasmabildungsraum (2) mittels einer in dem Gasfluss angebrachten Elektrode (8) und einer anderen in der Verbindung mit dem Plasmabildungsraum (2) angebrachten Elektrode (7) hergestellt wird.

7. Verfahren gemäß einem der Ansprüche 1-5, dadurch gekennzeichnet, dass die Funkenentladung in dem Plasmabildungsraum (2) hergestellt wird mittels einer in dem Gasfluss angebrachten Elektrode (8) durch Leiten der Funkenentladung durch das durch die Spule (5) erzeugte Magnetfeld in den Umgebungsraum, der die andere Elektrode (7) ausmacht.

8. Vorrichtung zum Bilden eines Plasmas (12) umfassend:

- eine Leistungsversorgung (1) zum Versorgen der für das Bilden des Plasmas notwendigen Leistung;
- einen Plasmabildungsraum (2), der zu der Umgebung hin offen ist;
- eine elektrische Schaltung (3), die elektrisch mit der Leistungsversorgung verbunden ist, um ein Magnetfeld und eine Funkenentladung (14) in dem Plasmabildungsraum herzustellen; und
- einen Gaskanal (4), der mit dem Plasmabildungsraum in Verbindung steht, um ein Gas in den Plasmabildungsraum durch seinen offenen Teil hineineinzuleiten und hinauszuleiten, dadurch gekennzeichnet, dass die elektrische Schaltung (3) eine Resonatorschaltung ist, der aus einer Reihenschaltung aus einer Spule (5) und einem Kondensator (6) besteht und die so angeordnet ist, dass die benötigte elektrische Leistung zur Bildung eines Plasmas mit dem Plasmabildungsraum (2) verbunden ist, so dass das Magnetfeld und die Funkenentladung mittels der Resonatorschaltung hergestellt wird.

9. Vorrichtung gemäß Anspruch 8, dadurch gekennzeichnet, dass die Vorrichtung eine erste Elektrode (7), die elektrisch mit einem ersten Potential der elektrischen Schaltung (3) verbunden ist, und eine zweite Elektrode (8), die mit einem Abstand von der ersten Elektrode angeordnet ist und elektrisch mit einem zweiten Potential der elektrischen Schaltung verbunden ist, umfasst, wobei die ersten und zweiten Potentiale sich in der Größe wesentlich unterscheiden; und, dass die Elektroden so angeordnet sind, dass eine Funkenentladung in dem Plasmabildungsraum (2) mit den ausgewählten Werten des ersten und zweiten Potentials stattfindet.

10. Vorrichtung gemäß Anspruch 8 oder 9, dadurch gekennzeichnet, dass die Spule (5) in der Nähe des Plasmabildungsraums (2) auf so eine Art und Weise angeordnet ist, dass das durch die Spule erzeugte Magnetfeld in Richtung des Gasflusses verläuft.

11. Vorrichtung gemäß einem der Ansprüche 8-10, dadurch gekennzeichnet, dass der Plasmabildungsraum (2) innerhalb der Spule (5) angeordnet ist.

12. Vorrichtung gemäß einem der Ansprüche 8-11, dadurch gekennzeichnet, dass die Spule (5) eine spezifische Anzahl an Ringscheiben (11) aufweist, die voneinander in die Richtung des Gasflusses beabstandet sind und koaxial um den Plasmabildungsraum (2) angeordnet sind, wobei eine Wicklung durch Wickeln eines Leiterdrahtes (13) wechselweise auf beiden Seiten der Scheibe (11) spiralförmig gebildet wird.

Revendications

1. Procédure pour former un plasma (12), procédure dans laquelle un champ magnétique est établi dans un espace de formation de plasma (2), une décharge par étincelles (14) est produite dans l'espace de formation de plasma (2) et on fait passer un courant gazeux dans le champ magnétique dans l'espace de formation de plasma, et dans laquelle le plasma est formé dans l'espace de formation de plasma au moyen de la décharge par étincelles et maintenu au moyen du champ magnétique et de la décharge par étincelles, caractérisée en ce que le champ magnétique et la décharge par étincelles sont produits au moyen du même circuit résonateur (3), constitué d'un montage en série d'un condensateur (6) et d'une bobine (5).

2. Procédure selon la revendication 1, caractérisée en ce que le plasma est formé essentiellement à l'intérieur de la bobine (5).

3. Procédure selon la revendication 1 ou 2, caractérisée en ce que le circuit résonateur (3) est alimenté avec un courant électrique alternatif, dont la fréquence est choisie automatiquement pour que le circuit résonateur fonctionne à la fréquence de résonance.

4. Procédure selon l'une quelconque des revendications 1 à 3, caractérisée en ce que le plasma est contrôlé en ajustant la puissance du courant alternatif.

5. Procédure selon l'une quelconque des revendications 1 à 4, caractérisée en ce que le plasma est contrôlé en ajustant le débit du courant gazeux.

6. Procédure selon l'une quelconque des revendications 1 à 5, caractérisée en ce que la décharge par étincelles est produite dans l'espace de formation de plasma (2) au moyen d'une électrode (8) placée dans le courant gazeux et d'une autre électrode (7) placée en conjonction avec l'espace de formation de plasma (2).

7. Procédure selon l'une quelconque des revendications 1 à 5, caractérisée en ce que la décharge par étincelles est produite dans l'espace de formation de plasma (2) au moyen de l'électrode (8) placée dans le courant gazeux en dirigeant la décharge par étincelles à travers le champ magnétique produit par la bobine (5) dans l'espace environnant, qui constitue l'autre électrode (7).

8. Dispositif pour former un plasma (12), comportant

- une alimentation en énergie (1) pour fournir l'énergie requise pour former un plasma ;
- un espace de formation de plasma (2), qui est ouvert sur l'environnement ;
- un circuit électrique (3), qui est relié électriquement à l'alimentation en énergie pour produire un champ magnétique et une décharge par étincelles (14) dans l'espace de formation de plasma ; et
- un canal pour gaz (4) communiquant avec l'espace de formation de plasma pour faire passer un gaz dans l'espace de formation de plasma et à l'en faire sortir via sa partie ouverte, caractérisé en ce que le circuit électrique (3) est un circuit résonateur constitué d'un montage en série d'une bobine (5) et d'un condensateur (6) et disposé de manière à relier l'énergie électrique requise pour former un plasma à l'espace de formation de plasma (2) pour que le champ magnétique et la décharge par étincelles soient produites au moyen dudit circuit résonateur.

9. Dispositif selon la revendication 8, caractérisé en ce que le dispositif comporte une première électrode (7), qui est électriquement reliée à un premier potentiel du circuit électrique (3), et une seconde électrode (8), qui est placée à une certaine distance de la première électrode et électriquement reliée à un second potentiel du circuit électrique, lesdits premier et second potentiels étant sensiblement différents en grandeur ; et que les électrodes sont disposées de telle manière qu'une décharge par étincelles se produit dans l'espace de formation de plasma (2) avec les valeurs choisies des premier et second potentiels.

10. Dispositif selon la revendication 8 ou 9, caractérisé en ce que la bobine (5) est disposée à proximité de l'espace de formation de plasma (2) d'une façon telle que le champ magnétique produit par la bobine est dans la direction du courant gazeux.

11. Dispositif selon l'une quelconque des revendications 8 à 10, caractérisé en ce que l'espace de formation de plasma (2) est disposé à l'intérieur de la bobine (5).

12. Dispositif selon l'une quelconque des revendications 8 à 11, caractérisé en ce que la bobine (5) comporte un nombre spécifique de disques annulaires (11), espacés les uns des autres en direction du courant gazeux et arrangés coaxialement autour de l'espace de formation de plasma (2), dans lequel un bobinage est formé en enroulant un fil conducteur (13) alternativement de part et d'autre du disque (11) sous une forme en spirale.

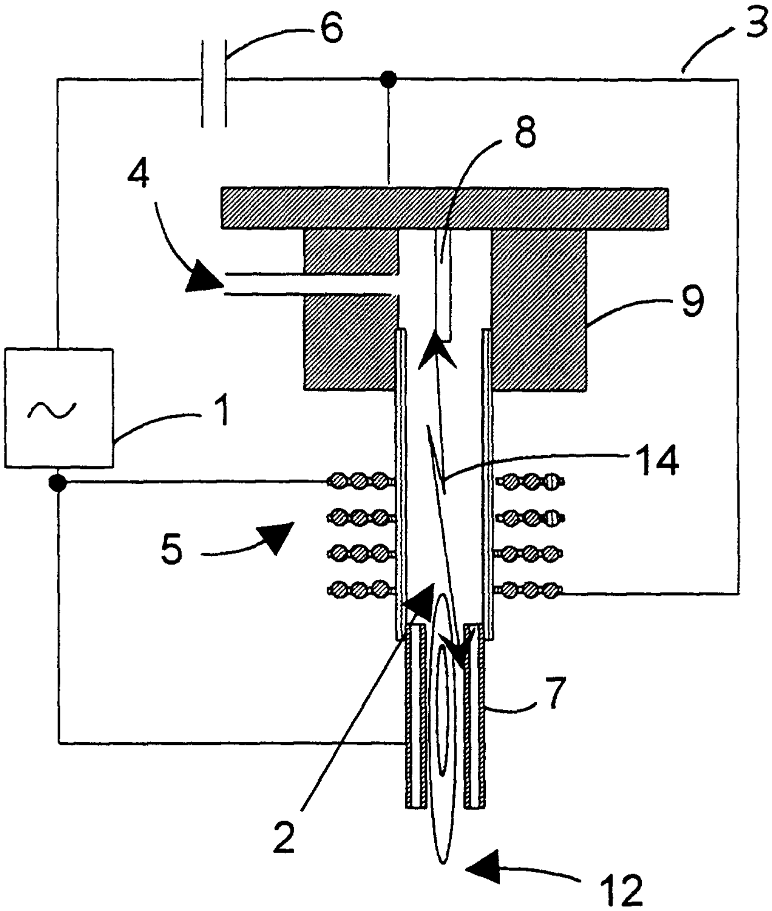

Fig 1

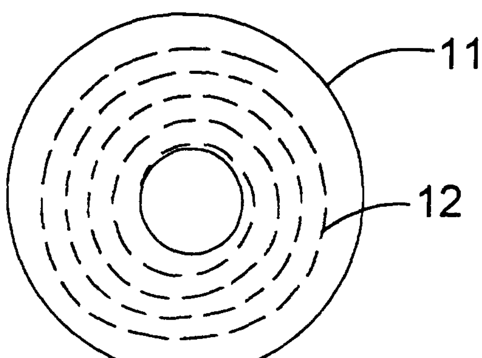

Fig 2

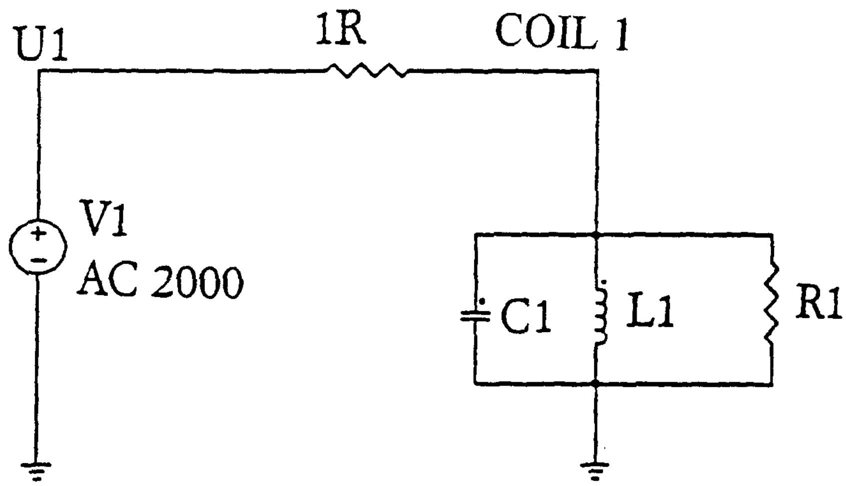

Fig 3a

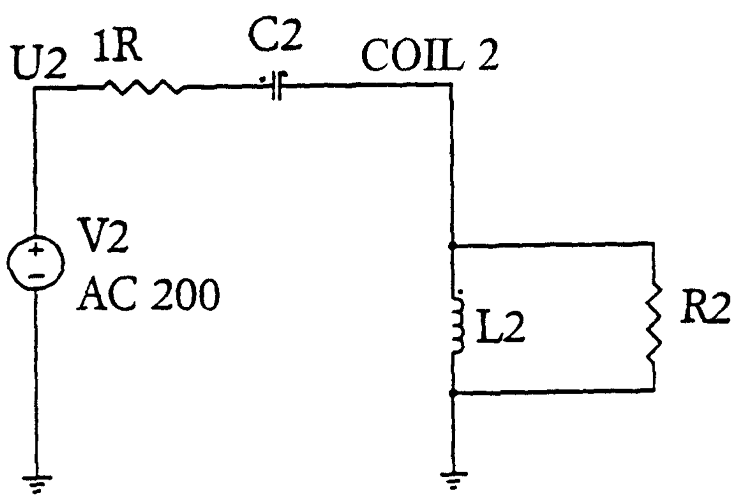

Fig 3b

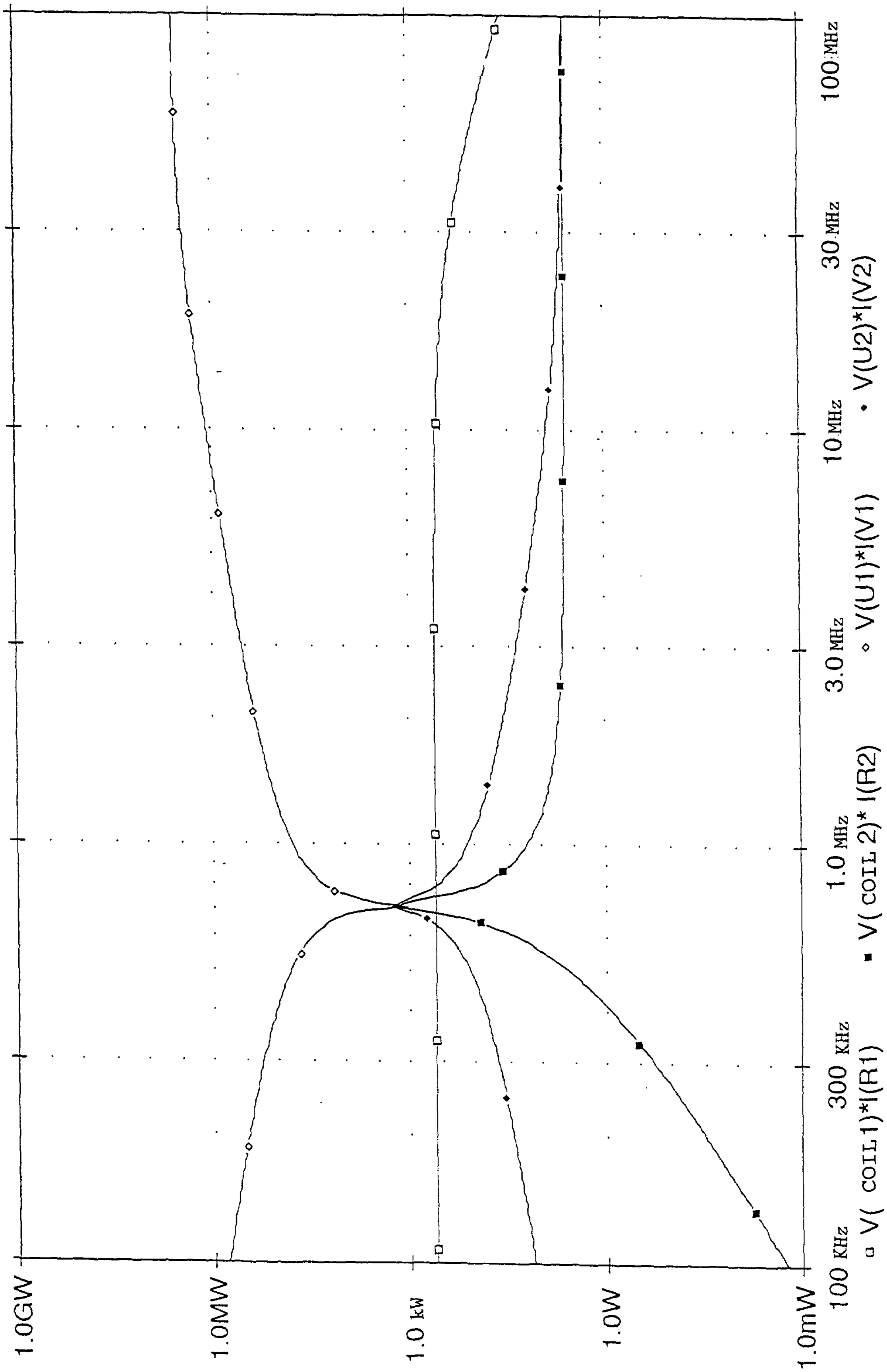
1.0GW
1.0MW
1.0 kW
1.0W
1.0mW
100 KHz
300 KHz
1.0 MHz
3.0 MHz
10 MHz
30 MHz
100 MHz
V(COIL1)*I(R1)
V(COIL 2)* I(R2)
V(U1)*I(V1)
V(U2)*I(V2)

Fig 4

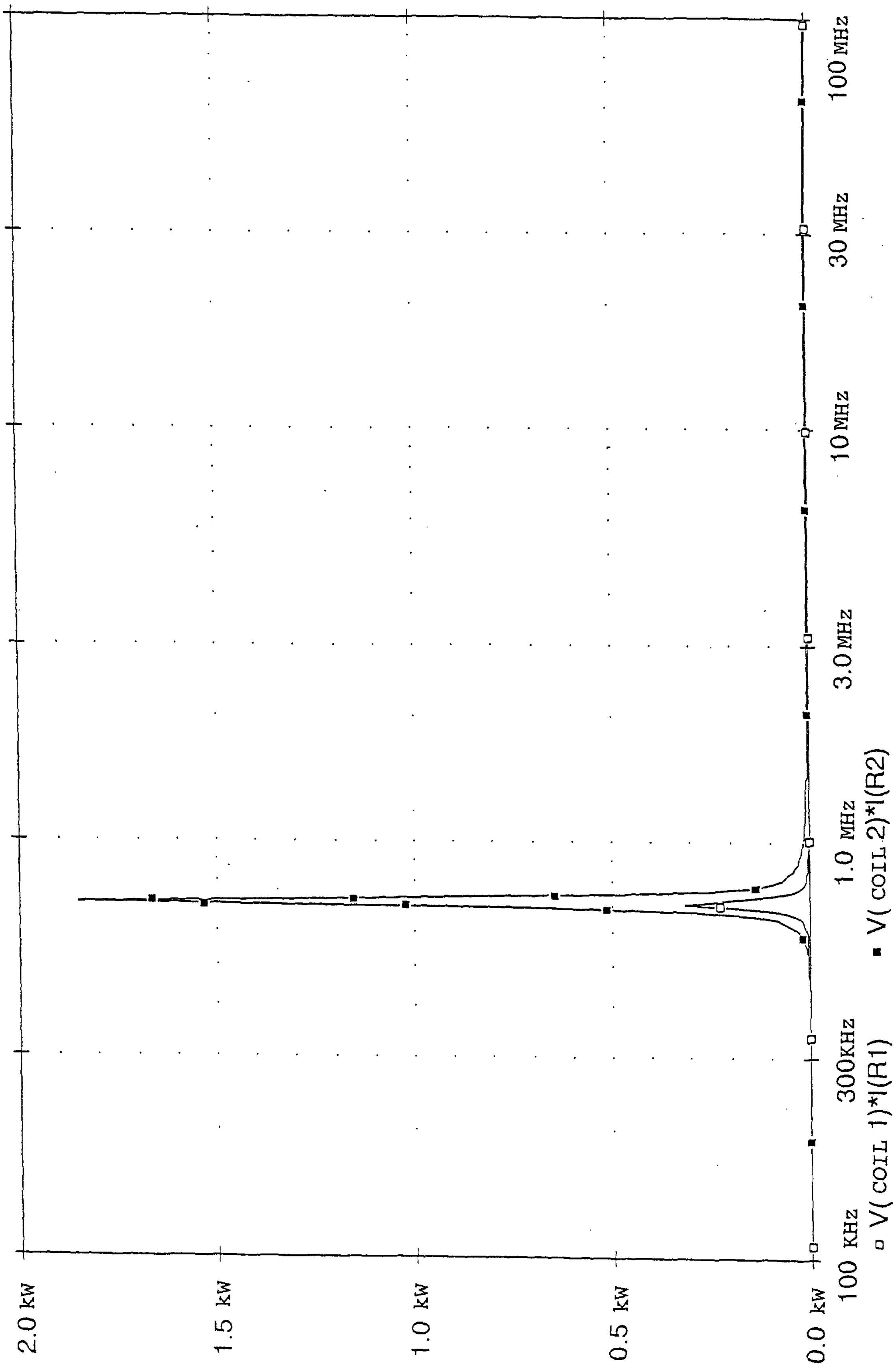
2.0 kW
1.5 kW
1.0 kW
0.5 kW
0.0 kW
100 KHz
300KHz
1.0 MHz
3.0 MHz
10 MHz
30 MHz
100 MHz
V(COIL 1)*I(R1)
V(COIL 2)*I(R2)

Fig 5

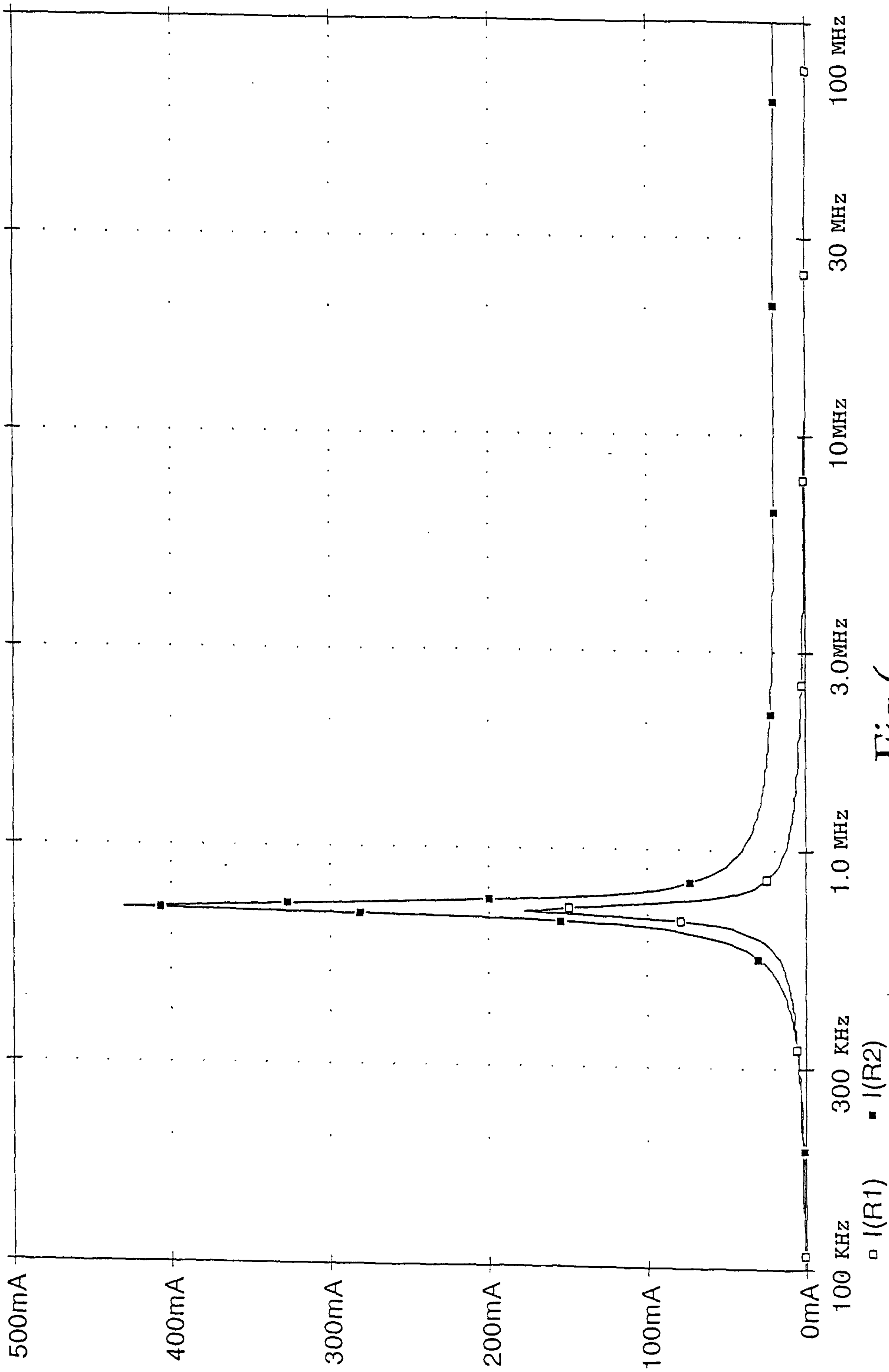
500mA
400mA
300mA
200mA
100mA
0mA
100 KHz
300 KHz
1.0 MHz
3.0MHz
10MHz
30 MHz
100 MHz
I(R1)
I(R2)

Fig 6

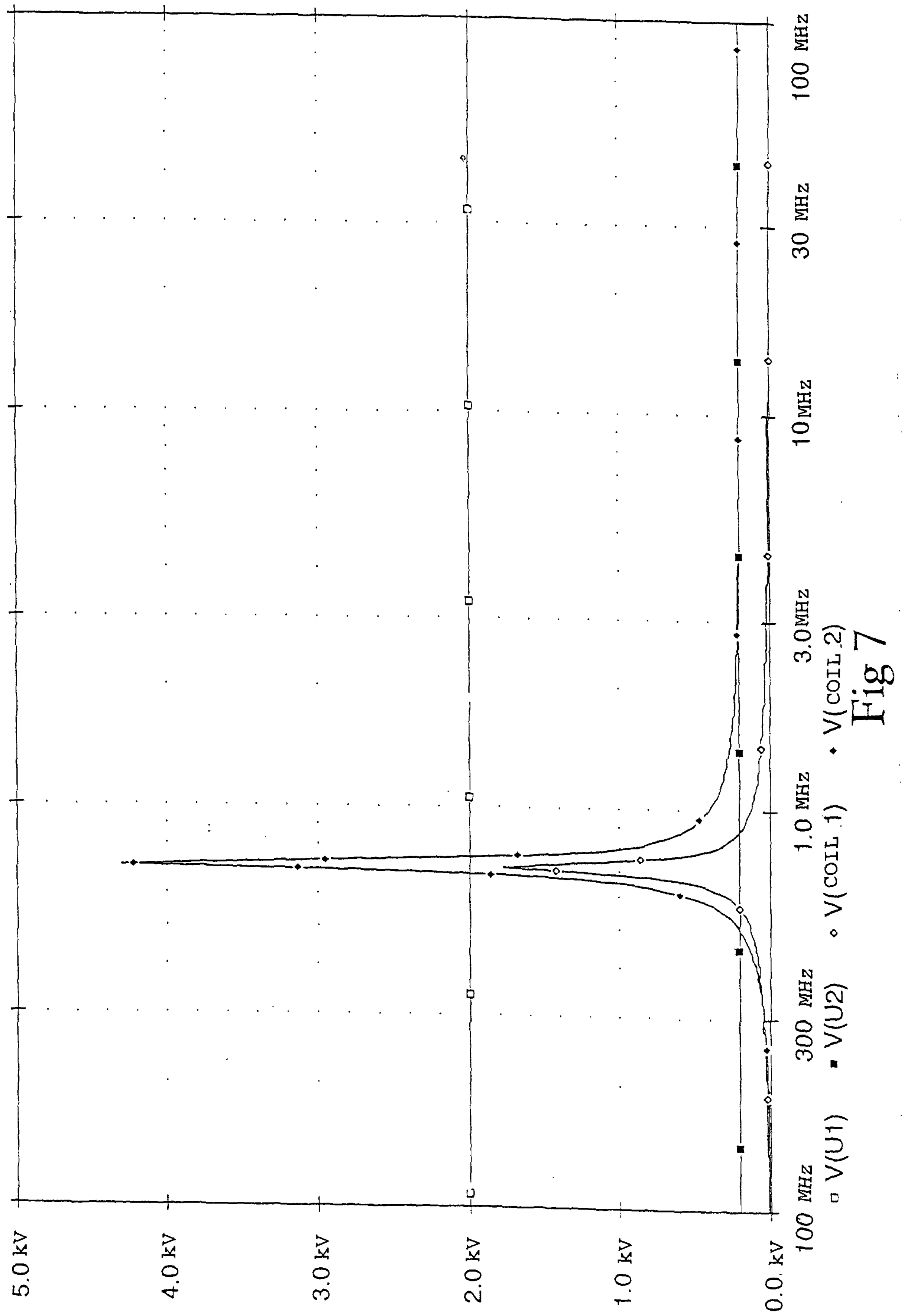
5.0 kV
4.0 kV
3.0 kV
2.0 kV
1.0 kV
0.0 kV
100 MHz
300 MHz
1.0 MHz
3.0 MHz
10 MHz
30 MHz
100 MHz
V(U1)
V(U2)
V(COIL 1)
V(COIL 2)

Fig 7

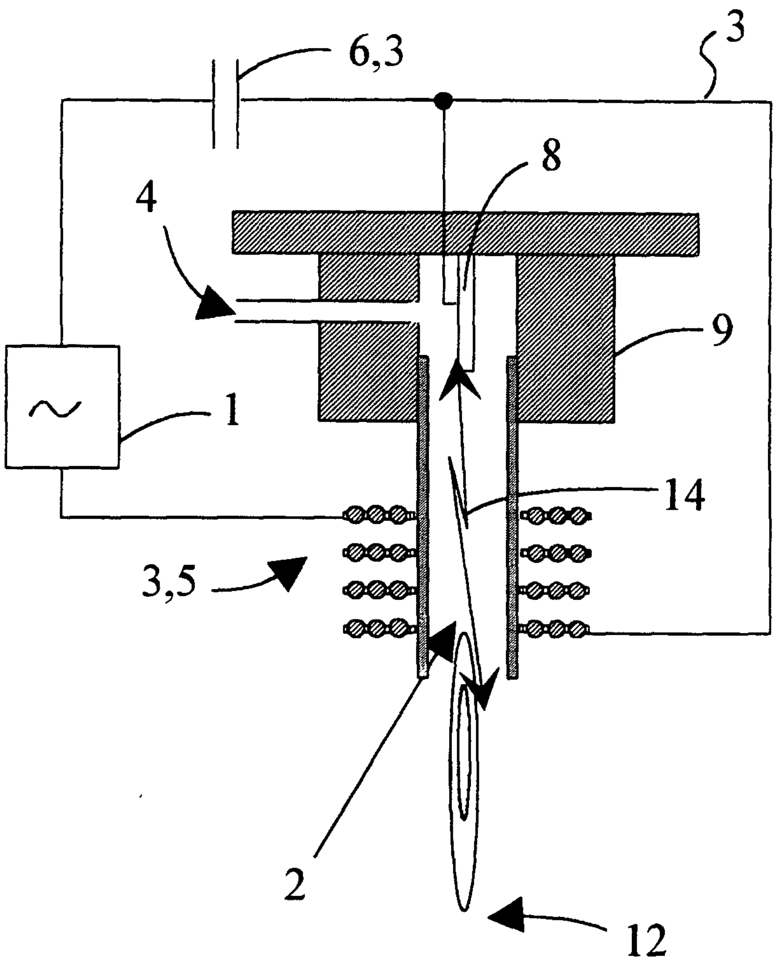

Fig 8