

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 862 198 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.09.1998 Bulletin 1998/36

(51) Int Cl.⁶: **H01J 25/58**, H01J 23/02,
H01J 23/075, H01F 7/02,
H01F 3/10

(21) Application number: **98301106.5**

(22) Date of filing: **16.02.1998**

(84) Designated Contracting States:
**AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC
NL PT SE**
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **28.02.1997 JP 46532/97**

(71) Applicant: **SHARP KABUSHIKI KAISHA**
Osaka-shi, Osaka-fu 545 (JP)

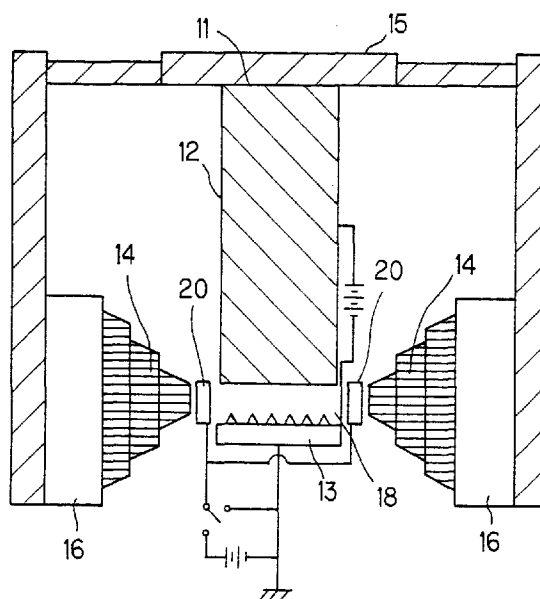
(72) Inventors:
• **Ide, Tetsuya**
Yokohama-shi, Kanagawa (JP)
• **Uda, Keiichiro**
Kashiwa-shi, Chiba (JP)
• **Yano, Seiki**
Yamatokoriyama-shi, Nara (JP)

(74) Representative: **Brown, Kenneth Richard et al**
R.G.C. Jenkins & Co.
26 Caxton Street
London SW1H 0RJ (GB)

(54) A plate-type magnetron

(57) A plate-type magnetron has a cathode (13) for emitting electrons and plate shaped anode (11) having a multiple number of vanes (12) arranged at regular intervals thereon, forming an interaction space (18). Provided on both sides of the interaction space are a pair of pole pieces (14) which are formed of bellows, and hence flexible in their length, and an adjustable magnet-

ic portion (16). A yoke (15) is provided, which is used to alter the distance between the magnets, so that the frequency of the microwaves can be changed. A pair of electrodes (20) arranged facing each other perpendicularly to the magnetic field on both sides of the interaction space (18) is also provided, and the applied voltage to the electrodes is changed to thereby change the output power of microwaves.

FIG.5

Description

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a plate-type magnetron applied to high-frequency heating devices such as microwave ovens etc., in particular, relating to a multi-purpose plate-type magnetron which efficiently provides microwaves having a desired power and frequency.

(2) Description of the Prior Art

A magnetron is a crossed-field device in which magnetic fields and electric fields are produced orthogonally to each other in the interaction space of an electron tube, and the oscillation modes are of two types, namely, the A-type oscillation and the B-type oscillation.

The A-type oscillation depends only on the magnetic field strength, and is produced by periodic rotating movement of electrons caused by the magnetic field. Because the wavelength of this oscillation is little affected by cavity resonators as external circuits, unlike the B-type oscillation mode (described later), it is determined only by the magnetic field and can be represented by the following relation:

$$\lambda = \alpha/H$$

where λ is the oscillation wavelength, H is the magnetic field strength and α is $2\pi mc/e$. Here, m is the mass of electron and e is the charge of an electron, hence the constant α is theoretically 10,650, but empirically, has a value from 10,000 to 13,000.

In this A-type oscillation, there are two kinds of electron orbits, one gaining energy from the alternating electric field and the other giving up energy to the alternating electric field, and it is necessary to remove the electrons in the former orbits.

Referring next to Fig. 1, the B-type oscillation will be described.

Fig. 1 is a diagram showing a conventional cylinder type magnetron configuration. As shown in this figure, a cylindrical anode 21 has a plurality of vanes 22 extending radially toward its center, forming cavity resonators. A cathode 23 is provided on the central axis of the cylindrical anode thus defining the interaction space between cathode 23 and vanes 22.

Provided on the top and bottom ends of anode 21 are pole pieces 24, each being attached in close contact with a magnet 26 having a yoke 25. Provided between anode 21 and yoke 25 are radiating plates 27 for releasing heat generated by anode dissipation. This anode dissipation will arise when the electrons emitted from cathode 23 and accelerated by the anode voltage collide with anode 21.

A pair of electrodes (end hats) 30 are provided across, or at right angles with the direction of the magnetic field, sandwiching this interaction space. A negative voltage is applied to these end hats 30, so that the electrons are confined within the interaction space.

In this arrangement, the space inside the anode 21 is decompressed to a vacuum. When, with a magnetic field formed in the interaction space by magnets 26, a high voltage is applied to cathode 23 and vanes 22 using a power supply input portion 28, electrons are emitted from cathode 23 toward vane 22.

The thus emitted electrons travel under the influence of the magnetic field from magnets 26 toward vanes 22 following a spiral or cycloidal path. As a result, these electrons give up energy to the cavity resonators, generating high-frequency electric fields, which are output as microwaves through a microwave output portion 29.

As the electron source of the magnetron, a thermionic cathode is predominantly used at present. A thermionic cathode is a cathode in which thermionic emission provides the source of electrons. Thermionic emission is the mechanism for emitting electrons over the potential barrier at the material surface by heating the material up to a temperature from 1500 to 2500°K so as to impart energy equal to or greater than the work function of the material to the free electrons in the conduction band. Thermionic cathode is formed of a pure metal, or a metallic oxide, etc., but currently, a sintered type which is obtained by mixing a Ba compound (5BaO-2Al₂O₃-CaO etc.) and a W powder and press-sintering the mixture, an impregnation type which is obtained by impregnating Ba compound in a molten state into porous W, are mainly used. Either of these has a high emission density of electrons and additionally has advantages that gases are emitted less during evacuation and it can be reactivated if it is exposed to the air because of the effect of barium aluminates used.

Another type of electron source is a cold cathode. A cold cathode is a cathode which emits electrons based on field emission, instead of thermionic emission. Field emission is a method of electron emission wherein a high electric field is applied at and in proximity to the material surface to lower the potential barrier at the surface so as to emit electrons, using the tunnel effect. This cathode is called a cold cathode since it does not need to be heated, unlike the thermionic cathode. The current-voltage characteristics can be approximated by the Fowler-Nordheim formula. Fig. 2 shows a sectional view of the configuration of a cold cathode. Emitter portions 90 made up of a metal or semiconductor such as Si etc. are made to have a pointed structure so as to form a high voltage gradient therearound and are covered with a metallic film forming a gate 70 with an insulating layer 80 such as SiO₂ film in between. When a voltage is applied to gate 70, a strong electric field is generated at the pointed ends of the emitter, thereby causing emission of electrons. The cold cathode has advantages

over the thermionic cathode in that the operating temperature is lower than that of the thermionic cathode and a high current density can be obtained by providing them in an arrayed form.

The prevailing type of magnetrons currently used in high-frequency heating appliances such as microwave ovens are of a cylindrical type. But there are some which use a plate-type magnetron. Figs.3 and 4 are sectional and perspective views respectively, showing a plate-type magnetron employing a cold cathode.

A plate-type anode 41 shown in Fig.3 has a number of vanes 42 which are provided on and perpendicularly to a cathode 43 and a sole portion 51, defining cavity resonators. Here, sole portion 51 is at equi-potential with cathode 43, but indicates the portion which will not contribute to emission of electrons unlike the cathode 43. Cathode 43 is arranged in the lower left portion of anode 41. The space between anode 41 and sole 51-vanes 42 forms an interaction space. A pole piece for forming a uniform magnetic field in the interaction space is attached to the magnet of the yoke, on either side of anode 41. This yoke has radiating plates 47 for releasing heat generated due to anode dissipation.

In this configuration, the space inside the anode 41 is decompressed to a vacuum. When, with a magnetic field formed in the interaction space by magnets 46, voltages are applied between gate 60 and sole 51-vanes 42 and between anode 41 and sole 51-vanes 42 from the power supply input portion, electrons are emitted from cathode 43 toward vanes 42, as illustrated using Fig.2.

The thus emitted electrons travels under the influence of the magnetic field from magnets 46 towards the right in Fig.2, in the interaction space, following a cycloidal path in a similar manner as in a cylindrical magnetron. During travel these electrons give up energy to the cavity resonators, generating high-frequency electric fields, which are output as microwaves through a microwave output portion 49.

In the case of a magnetron using anode segments, it is possible to cause various modes of operation depending upon the number of the segments. The mode mainly used in the B-type oscillation called π -mode, in which the phase difference between successive resonators is π radian and the interaction therebetween is the strongest.

However, in the oscillations of a magnetron, if there is another mode which has an oscillating frequency close to that in this π -mode, mode jumping from the π -mode to the other mode occurs triggered by a slight change in the operating conditions. As a result, the oscillating frequency and output power change abruptly. Therefore, it is necessary to make resonant frequencies of modes as discreet as possible by making the couplings between the resonators compact as close as possible.

In conventional magnetrons, alternate anode segments and vanes are connected through a conductor

forming an equalized ring, so as to separate one mode from another. Since this equalized ring forces the alternate anode segments to have an oscillation of voltage in phase, it is possible to limit the possible modes of oscillation to the π -mode and 0-mode (in which all the anode segments and vanes oscillate in phase).

In this way, conventional magnetrons are constructed such that the application of a fixed magnetic field to the interaction space by the magnets attached to the yoke is used to generate microwaves having a fixed frequency and fixed output power. Accordingly, the output power and frequency obtained could not be varied in accordance with its usage.

Since magnetrons have extremely useful characteristics, i.e., very high oscillation efficiency, high power and low cost, there is a demand that magnetrons be applied to a variety of technical fields other than microwave ovens. Accordingly, there has been an important theme of how a multi-purpose magnetron can be realized which can be applied to these broadened fields, such as communications, radar, electronic devices etc.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to solve the above problems and provide a plate-type magnetron which can be used for multiple purposes and can efficiently produce microwaves having a desired power and frequency.

In order to achieve the above object, the present invention is configured as follows:

In accordance with the first aspect of the invention, a plate-type magnetron comprises:

- a cathode for emitting electrons;
- an anode having a plurality of vanes arranged at regular intervals thereon;
- a magnetic portion for producing a uniform magnetic field in an interaction space sandwiched between the cathode and the anode; and
- a pair of electrodes arranged facing each other, perpendicularly to the uniform magnetic field, on both sides of the interaction space, and is characterized in that the magnetic portion is adjustable to vary the magnetic field strength produced in the interaction space.

The second aspect of the invention resides in the plate-type magnetron having the above first feature, wherein the magnetic portion comprises: a pair of pole pieces arranged facing each other on both sides of the interaction space; and a pair of magnets which each are attached to the pole piece and are set in close contact with the yoke to form a magnetic coupling, wherein the magnets are adapted to move.

The third aspect of the invention resides in the plate-type magnetron having the above first feature, wherein the magnetic portion comprises: a pair of pole pieces

arranged facing each other on both sides of the interaction space; and a pair of magnets which each are attached to the pole piece and are set in close contact with the yoke to form a magnetic coupling, and the pole pieces can be varied in length.

The fourth aspect of the invention resides in the plate-type magnetron having the above first feature, wherein the magnetic portion comprises: a pair of pole pieces arranged facing each other on both sides of the interaction space; and a pair of magnets which each are attached to the pole piece and are set in close contact with the yoke to form a magnetic coupling, and the yoke can be varied in length.

In accordance with the fifth aspect of the invention, a plate-type magnetron includes:

a cathode for emitting electrons;
 an anode having a plurality of vanes arranged at regular intervals thereon;
 a magnetic portion producing a uniform magnetic field in an interaction space sandwiched between the cathode and the anode; and
 a pair of electrodes arranged facing each other, perpendicularly to the uniform magnetic field, on both sides of the interaction space, and is characterized in that a positive or negative voltage can be selectively applied to the electrodes.

In the above way, the output power can be varied in accordance with change in the potential of the electrodes while the frequency can be varied in accordance with the distance between the magnets. Further, when a positive voltage is applied to the electrodes, it is possible to remove the electrons, which can disturb the oscillation, from the interaction space.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a constructional view showing a conventional cylindrical magnetron;
 Fig. 2 is a sectional view showing the configuration of a conventional cold cathode;
 Fig. 3 is a sectional view showing a conventional plate-type magnetron;
 Fig. 4 is a perspective view showing a conventional plate-type magnetron; and
 Fig. 5 is a sectional view showing a plate-type magnetron in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiment of the invention will hereinafter be described with reference to the accompanying drawings.

Fig. 5 is a sectional view showing a plate-type magnetron in accordance with the present invention. As shown in Fig. 5, this plate-type magnetron is composed

of an anode 11, vanes 12, a cathode 13, pole pieces 14, a yoke 15, magnets 16 and end hats 20.

The space sandwiched between anode 11 and cathode 13, which are arranged vertically, defines an interaction space 18. Provided on both sides in the horizontal direction of interaction space 18 are a pair of electrodes or end hats 20 facing each other, to which positive and negative potentials are applied. A pair of pole pieces 14 for generating a required magnetic field in interaction space 18 are arranged facing each other, on the outer sides of end hats 20. A pair of magnets 16 are provided on the outer sides of pole pieces 14. Magnets 16 have a yoke 15, which is disposed in contact with anode 11. The elements which contribute to forming the magnetic field in interaction space 18 are magnets 16, pole pieces 14 and yoke 15, which are magnetically coupled with one another. These elements are called, as a whole, a magnetic portion.

Here, magnets 16 are of a ferrite type and are affixed to the side walls of the housing. Since yoke 15 also serves as a radiating plate for releasing heat generated from anode dissipation, it is made of a galvanized iron material.

In this plate-type magnetron, the gap of the magnetic portion (the gap-distance in the magnetic portion) affecting the magnetic field strength in interaction space 18 can be varied by providing pole pieces 14 and yoke 15 in the form of bellows so that a variation of 20 mm in the gap-distance in the magnetic portion can be achieved. Magnets 16 can also be moved with the change in this distance.

Anode 11 is one which is produced by the fabrication method of a plate-type magnetron anode disclosed in Japanese Patent Application Laid-Open Hei 8 No. 315,742.

Next, the operation scheme of this plate-type magnetron will be described.

First, the gap-distance in the magnetic portion is set as desired by operating the bellows of pole pieces 14 and yoke 15 so that a desired magnetic field is formed in interaction space 18. When a voltage is applied in a similar manner as described for the conventional magnetron with reference to Fig. 3, electrons are emitted from cathode 13 and travel in interaction space 18 under the influence of this magnetic field, following a cycloidal path. As a result, these electrons give up energy to the cavity resonators, generating high-frequency electric fields. Accordingly, microwaves having a frequency and output power associated with the distance between the magnets or the adjusted amount of pole pieces 14 and yoke 15 will be extracted.

In the plate-type magnetron shown in Fig. 5, a positive or negative voltage can be selectively applied to end hats 20, and magnets 16 are adapted to move and so the yoke length and the pole-piece length can be varied so as to provide microwaves having a desired output power and frequency. In other words, this plate-type magnetron is constructed such that the electrons which

will disturb the oscillation are removed from the interaction space by the application of a positive voltage to end hats 20 and this voltage is changed so as to control the output power.

Magnets 16 are adapted to be movable and bellows-like pole pieces 14 and yoke 15 are adjusted to change the yoke length and the pole piece length, whereby the gap-distance in the magnetic portion is altered, thus controlling the frequency.

Illustratively, when the anode voltage is set at 100 V, the anode-sole distance set at 0.5 mm, the magnetic field strength set at 1,360 Gauss (the distance between the magnets set at 30 mm), the end hats set a voltage of -10V, then an emission current of 2.1A flows and an output power of oscillation of 160 W (2.5 GHz) can be obtained.

When the magnetic field strength is altered to 1,090 Gauss, microwaves having a frequency of 3.1 to 5.1 GHz with an output power of oscillation of 3 to 7 W can be obtained. Additionally, when a voltage of +10 V is applied to end hats 20, microwaves having a frequency 3.1 to 5.1 GHz with an output power of oscillation of 10 to 20 W, about the three times of the output power under the former conditions, can be produced.

As described above, in accordance with the first to fourth features of the invention, since the magnetic portion can be constructed so as to vary the magnetic field strength generated in the interaction space, it is possible to alter the oscillating frequency by changing the magnetic field strength. In particular, the magnets, the length of the pole pieces, and the yoke length are adjusted so as to alter the magnetic field strength in accordance with the gap-distance in the magnetic portion, thus making it possible to change the frequency.

In accordance with the fifth feature, since electrodes which can be applied with a positive or negative voltage are provided, when a positive voltage is applied to these electrodes, it is possible to remove the electrons which will disturb the oscillation, from the interaction space.

Although an embodiment using a cold cathode has been described, it is also possible to use a thermionic cathode.

Claims

1. A plate-type magnetron comprising:

a cathode for emitting electrons;
an anode having a plurality of vanes arranged at regular intervals thereon;
a magnetic portion for producing a uniform magnetic field in an interaction space sandwiched between the cathode and the anode; and
a pair of electrodes arranged facing each other, perpendicularly to the uniform magnetic field,

on both sides of the interaction space,

wherein the magnetic portion is adjustable to vary the magnetic field strength produced in the interaction space.

2. The plate-type magnetron according to Claim 1, wherein the magnetic portion comprises: a pair of pole pieces arranged facing each other on both sides of the interaction space; and a pair of magnets which each are attached to the pole piece and are set in close contact with the yoke to form a magnetic coupling, wherein the magnets are adapted to move.

3. The plate-type magnetron according to Claim 1, wherein the magnetic portion comprises: a pair of pole pieces arranged facing each other on both sides of the interaction space; and a pair of magnets which each are attached to the pole piece and are set in close contact with the yoke to form a magnetic coupling, and the pole pieces can be varied in length.

4. The plate-type magnetron according to Claim 1, wherein the magnetic portion comprises: a pair of pole pieces arranged facing each other on both sides of the interaction space; and a pair of magnets which each are attached to the pole piece and are set in close contact with the yoke to form a magnetic coupling, and the yoke can be varied in length.

5. A plate-type magnetron comprising:

a cathode for emitting electrons;
an anode having a plurality of vanes arranged at regular intervals thereon;
a magnetic portion producing a uniform magnetic field in an interaction space sandwiched between the cathode and the anode; and
a pair of electrodes arranged facing each other, perpendicularly to the uniform magnetic field, on both sides of the interaction space,

wherein a positive or negative voltage can be selectively applied to the electrodes.

6. A magnetron in which the magnetic field strength of a substantially uniform magnetic field, produced in an interaction space formed between a cathode and an anode is variable.

7. A magnetron according to claim 6, in the form of a plate-type magnetron in which the interaction space extends longitudinally, wherein there is provided a magnetic portion for producing said magnetic field, said magnetic portion including a pair of pole pieces which face one another laterally across said inter-

action space with a magnetic gap therebetween, and wherein to provide the variation of the magnetic field strength the magnetic portion is adjustable so as to change the width of said magnetic gap.

5

8. A magnetron according to claim 7 wherein said magnetic portion forms a magnetic circuit which includes said magnetic gap and said pole pieces, and which further includes one or more magnets and a magnetic yoke.

10

9. A magnetron according to any of claims 6 to 8 wherein a portion of said anode facing the cathode is formed with a row of vanes, said row extending along said interaction space.

15

10. A magnetron according to claim 7 or any claim dependent thereon, wherein said cathode includes an electron emitting portion at an end region of said longitudinal interaction space, and an elongate non-emitting sole portion extending longitudinally from said electron emitting portion.

20

11. A magnetron according to any of claims 6 to 10, further including a pair of end hat electrodes spaced apart in a direction transverse to the interaction space and arranged one on each side of said space.

25

12. A magnetron according to claim 11 when dependent on claim 7 or any claim dependent thereon, wherein each said electrode is disposed between a respective one of said pole pieces and the interaction space.

30

13. A magnetron according to claim 11 or claim 12, including means for applying a changeable voltage to said electrodes to vary the magnetron power output.

35

40

45

50

55

FIG.1 PRIOR ART

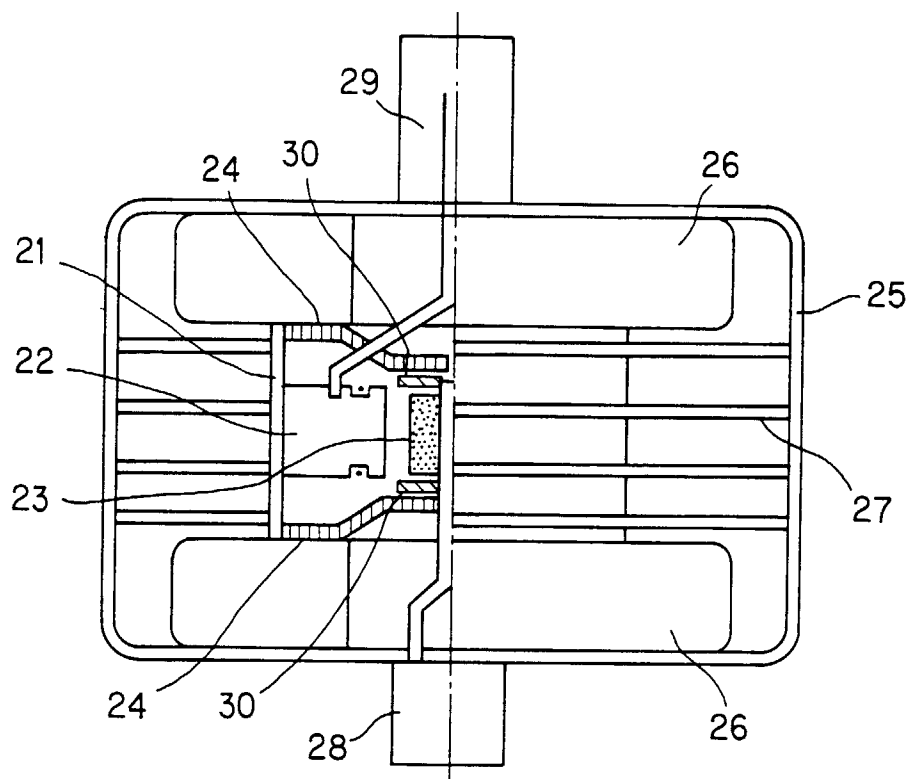


FIG.2 PRIOR ART

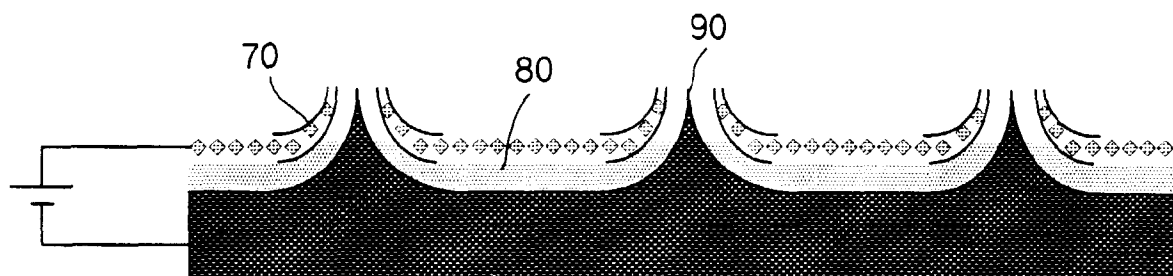


FIG.3 PRIOR ART

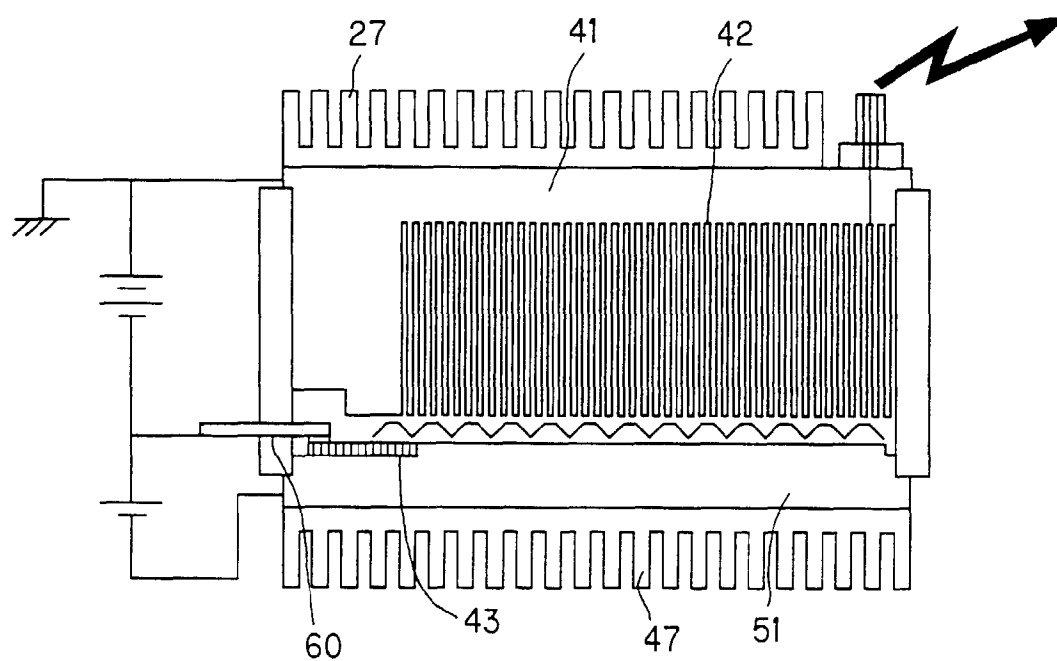


FIG.4 PRIOR ART

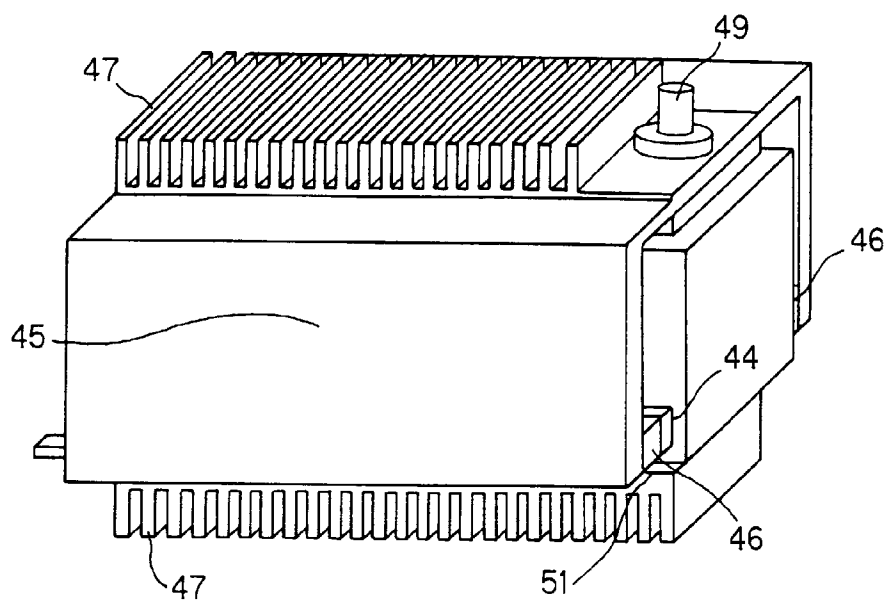


FIG. 5

