# United States Patent [19]

**Oguro et al.**

[11] **3,732,459**

[45] **May 8, 1973**


[54] **MAGNETRONS**


[75] Inventors: **Tomokatsu Oguro,** Mobara; **Mitsuru Watanabe,** Koganei; **Hideo Takatsuki,** Hitachi; **Kunihiko Okamoto,** Takasuzumachi; **Teruo Suda,** Matsudo, all of Japan

[73] Assignee: **Hitachi, Ltd.,** Tokyo, Japan



[22] Filed: **May 20, 1971**

[21] Appl. No.: **145,320**

[30] **Foreign Application Priority Data**

May 20, 1970 Japan.....45/42462

[52] **U.S. Cl.** .....**315/39.51,** 333/79 R, 333/96 R, 315/39.53

[51] **Int. Cl.**.....**H01j 25/50**

[58] **Field of Search**.....315/39.51, 39.53; 333/79, 84, 96; 174/36



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,782,342 | 2/1957 | Kilgore | 315/39.53 X |
| 3,573,676 | 4/1971 | Mayer | 333/84 |
| 3,456,151 | 7/1969 | Staats | 315/39.53 X |
| 3,543,082 | 11/1970 | Boehm | 315/39.53 X |
| 3,191,132 | 6/1965 | Mayer | 333/79 |
| 3,541,473 | 11/1970 | Schlicke et al. | 333/96 X |
| 3,551,858 | 12/1970 | Cielo | 333/79 |



*Primary Examiner*—Rudolph V. Rolinec
*Assistant Examiner*—Saxfield Chatmon, Jr.
*Attorney*—Craig, Antonelli and Hill



[57] **ABSTRACT**

In a magnetron having lead wires for passing heating current to the cathode filament, each of the lead wires comprises a coaxial cable including a core conductor for passing the filament heating current, at least one insulator layer having a large microwave loss surrounding the core conductor, and an outer conductor surrounding the insulator layer.


**4 Claims, 6 Drawing Figures**

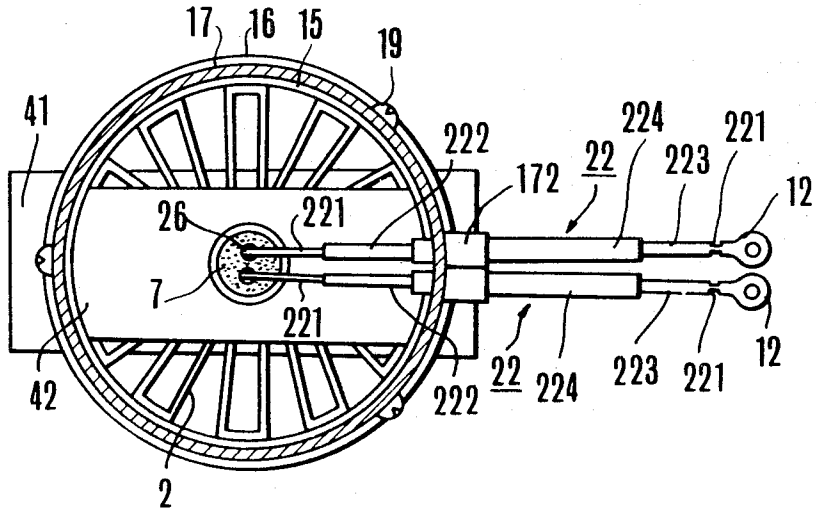


FIG. 1

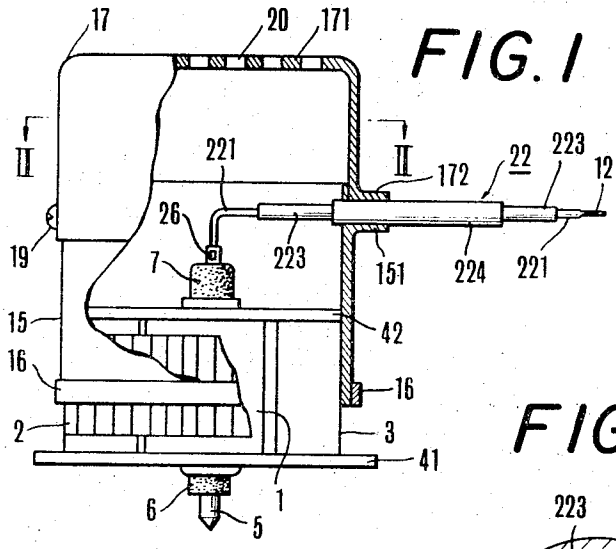



FIG. 3

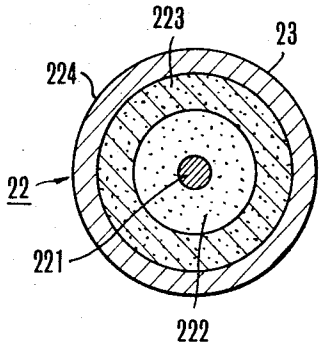
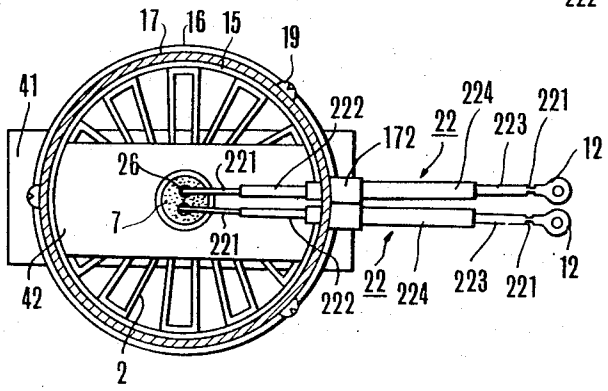



FIG. 2




INVENTORS

TOMOKATSU OGURO, MITSURU WATANABE, HIDEO TAKATSUKI, KUNIHIKO OKAMOTO AND TERUO SUDA

BY Craig, Antonelli & Hill

ATTORNEYS

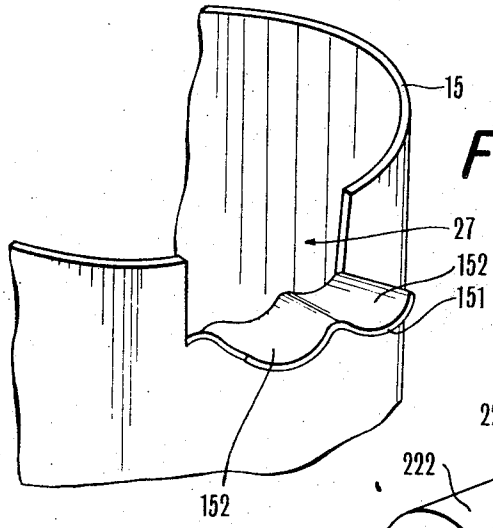
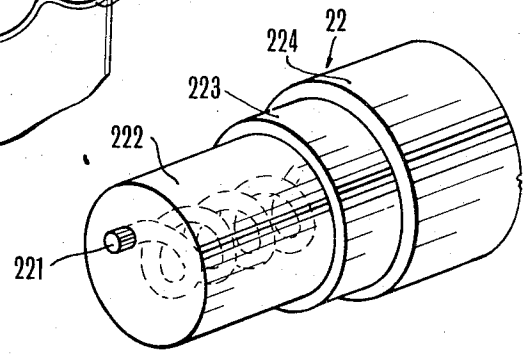



FIG. 4

FIG. 5



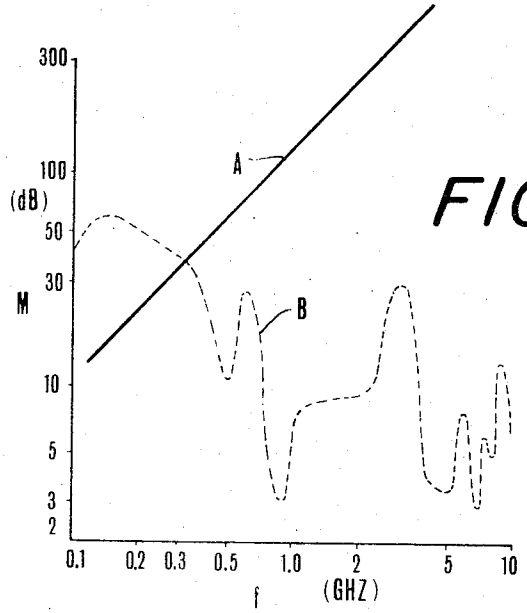




FIG. 6

INVENTORS

TOMOKATSU OGURO,
MITSURU WATANABE, HIDEO TAKATSUKI,
KUNIHIKO OKAMOTO & TERUO SUDA

BY

Craig, Antonelli & Hill

ATTORNEYS

# MAGNETRONS

## BACKGROUND OF THE INVENTION

This invention relates to a magnetron suitable for use in a microwave oven.

As is weld known in the art, in the operation of a magnetron not only the fundamental wave of the oscillation, but also higher harmonics and electromagnetic waves the VHF and UHF bands are radiated from the filament lead wires of the magnetron, and such radiated electromagnetic waves act as a source of external noise for wireless communication apparatus, such as radio receivers, television receivers and the like. To prevent such objectional radiation of electromagnetic waves from the filament lead wires of the magnetron, it has been the common practice to connect a noise eliminating filter hereinafter, merely called a filter) comprising a plurality of capacitors and inductors between the cathode filament terminals of the magnetron and the external terminals.

Since such a filter is constituted by lumped constant circuit elements, it can provide a satisfactory filtering for noises of relatively low frequencies below VHF, but its filtering ability is greatly reduced for noises in the UHF or microwave band. More particularly, when operating at high frequencies, the inductor comprising the filter becomes capacitive due to its distributed electrostatic capacitance. Whereas, the capacitor becomes inductive because the material having a high dielectric constant, such as barium titanate ceramic, rapidly decreases it static capacitance in high frequency bands of the range of the VHF band. Moreover, as the leakage from the filament lead wires of a magnetron oscillator utilized in a microwave oven includes the fundamental oscillation frequency (2,450 $MH_z$), which has a relatively high intensity, standard filters comprising lumped constant circuit elements cannot provide sufficient filtering.

Across the external terminals of the two filament leads, wires of the magnetron are applied to a voltage of power line frequency for heating the cathode filament, this voltage having a high negative potential with respect to the anode electrode for bringing the electron trajectories into an oscillating condition; but, as above-described, since he filter is included in the circuit the number of electrical connections between circuit elements increases. This not only reduces the reliability of the magnetron itself, but also increases the number of manufacturing steps associated with the reduction thereof.

Since the conventional filter comprises a number of lumped constant circuit elements, the physical size of the filter itself, and hence of the shield casing thereof, become large, thus increasing the size of the magnetron apparatus.

## SUMMARY OF THE INVENTION

It is an object of this invention to provide an improved magnetron here in a coaxial cable is used as the lead wire extending from the cathode filament terminal and the distributed constant of the cable is selected to cause it to act as a filter.

A further object of this invention is to provide a novel magnetron wherein said coaxial cable acts to efficiently prevent radiation of the electromagnetic wave in a broad frequency band ranging from the UHF band through the fundamental oscillating frequency to its higher harmonics.



Another object of this invention is to provide an improved magnetron in which there is no electrical component element connected between the filament terminal and the external terminal leading to the cathode source.

Still another object of this invention is to provide a compact magnetron apparatus with a small shield casing.

In accordance with this invention, there is provided a magnetron of the class comprising a cathode, an anode electrode coaxial with the cathode, magnet means for supplying a magnetic field to an interaction space between the cathode and anode electrodes and filament lead wires connecting the terminals of the filament of the cathode with eternal source terminals characterized in that each of the lead wires comprises a coaxial cable including a core conductor for passing heating current to the filament, at least one insulator layer surrounding the core conductor and having a large microwave loss, ad an electroconductive outer conductor surrounding the insulator layer.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 shows an elevation, partly broken away, of one embodiment of the magnetron in accordance with the present invention;

FIG. 2 shows a cross section of the magnetron shown in FIG. 1 taken along line II—II;

FIG. 3 shows a cross-sectional view o a coaxial cable utilized as the filament lead wire of the magnetron of this invention;

FIG. 4 is a perspective view of a portion of a shield casing;

FIG. 5 is a perspective view, partly removed, of another example of a coaxial cable utilized as the filament lead wire of a magnetron in accordance with the present invention; and

FIG. 6 is a plot comparing the attenuation characteristics of the electromagnetic waves radiated from a conventional magnetron and a magnetron embodying this invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. 1 and 2, the magnetron shown therein comprises an anode electrode 1 of conventional construction, cooling fins 2 made of aluminum, copper and the like and secured around the anode electrode 1 for heat dissipation, and a permanent magnet 3 having yokes 11 and 42 for conveying the magnetic flux to an interaction space, not shown, within anode electrode 1. A probe 5 for radiating the high frequency oscillation energy from the magnetron is secured to the bottom of the magnetron by means of an insulating cylinder 6 of ceramic, glass or the like. A cathode electrode formed by a filament, not shown, is disposed at the center of the anode electrode to define the interaction space therebetween. The cathode electrode emits electrons required for creating a high frequency oscillation and one end of the cathode is lead out to the side opposite the probe 5 and is fixed by a bottomed insulating cylinder 7 of ceramic or the like

insulating material. The cathode electrode is connected on this side t filament lead wires **22** embodying the invention.

Although the detail of lead wires **22** will be described later, it should be mentioned that the lead wires extend outwardly through a shield casing **15**. The shield casing **15** is made of metal, aluminum, for example, and is clamped about the periphery of cooling fins by means of a metal band **16** and secured in position by spot-welding or caulking. A cap **17** is secured to the shield casing **15** by means of self-tapping screws **19**. A plurality of air flow openings **20** a7 formed through the upper end **171** of the cap **17** to supply the cooling are flowing along cooling fins. Thus, the shield casing **15** also acts as a duct for the cooling air.

Two terminals connected to the filament project through the insulating bottomed cylinder **7** and the filament lead wires **22** are connected to respective terminals as above described Each filament lead wire **22** comprises a type of a coaxial cable having a construction shown in FIG. **3**.

Referring now to FIG. **3**, the coaxial cable comprises a core or inner conductor **221** of copper or aluminum, for example, having a cross-sectional area sufficient to pass the filament heating current and disposed at the longitudinal center of the cable, an insulative noise-absorbing layer **222** made of rubber in which ferrite powder is dispersed, an insulating strength improving insulating layer of polyethylene **223** surrounding the noise-absorbing layer **222**, and an outer conductor **224** surrounding the insulator layer so as to be concentric with the core conductor **221**. The outer conductor **224** may be formed by braiding metal wires of copper or aluminum or may comprise a layer of electroconductive resin in which is dispersed a powder of metal or carbon. Also, it should be noted that the outer conductor **224** may be formed of a thin metallic layer such as formed by plating, since the filament heating current never flows through the outer conductor.

To use the coaxial cable as a filament lead wire, the cable is cut to a desired length. The outer conductor **224** of the cable near its outer terminal is removed for a sufficient length, for example, 5 mm., to expose insulator layers **222** and **223** and a mounting terminal **12** is connected to the exposed core conductor **221**. On the opposite end, that is, the end of the cable to be connected with the filament terminal, external conductor **224** is stripped off over a relatively large length to expose insulating layers **223** and **222**. Thereafter, portions of these exposed insulating layers **223** and **222** are removed to expose core conductor **221** which is inserted in one of two metal sleeves **26** soldered to the insulating bottomed cylinder **7** and are electrically connected to the filament. Pressure is then applied to the outside of the sleeve to secure the inner end of the core conductor. Portions of the outer conductor **224** not removed are electrically connected to the wall of a lead-out opening **27** through the side wall of the shield casing **15**.

One example of the lead-out opening **27** is illustrated in FIG. **4**. As shown, a cable support **151** is formed by clitting and bending a portion of the upper end of shield casing **15** and the upper surface of the cable support **151** is formed with two depressions **152** each having a radius of curvature corresponding to the outer diameter of the outer conductor **224** so as to ensure good electrical contact with the outer conductor **224** of the filament lead wire **22**. A complementary cable support **172** is provided for the cap **17** of the shield casing **15**, thereby to clamp the outer conductors of the filament lead wires between cable supports **151** and **172** and to assure good electrical connection between them. As described above, the present magnetron device is operated with the anode at ground potential since the anode, radiator and shield casing are clamped together by means of metal band **16**. Accordingly, the outer conductor **224** is grounded through a low impedance path.

FIG. **5** shows a modified coaxial cable utilized as the filament lead wire of this invention. Portions corresponding to those shown in FIG. **3** are designated by the same reference numerals. The cable shown in FIG. **5** is different from that shown in FIG. **3** in that the core conductor **221** is helical to increase the effective length of the cable.

Considering the length of the filament lead wire by denoting the complex permeability of the insulator of a coaxial cable by $\dot{\mu} = \mu - j\,\mu'$ and the complex dielectric constant by $\dot{\epsilon} = \epsilon - j\,\epsilon'$ then the attenuation M of the electric wave at a frequency $f$ is given by the following equation

$$M \bar{N} \cdot ( \sqrt{\epsilon/\mu} \cdot \mu' + \sqrt{\mu/\epsilon} \cdot \epsilon' ) \cdot f \cdot l \,(\mathrm{dB})$$

where $l$ represents the length of the coaxial cable. As can be clearly noted from this equation, at the fundamental frequency, or at a sufficiently high frequency such as a higher harmonic thereof, the attenuation M of the electric wave is sufficiently large, but the attenuation decreases at a relatively low frequency, such as VHF, so that in order to increase the attenuation, it is necessary to sufficiently increase the cable length $l$.

FIG. **6** is a plot to compare the attenuations. Solid line A shows the relationship between the attenuation of the wave per meter of a coaxial cable and the frequency, wherein both insulating layers **222** and **223** of the coaxial cable are made of ferrite rubber. As can be noted from solid line A the attenuation increases with the frequency of the coaxial cable. Considering the fact that the noise wave leakage to the cathode side of the magnetron mainly occurs at the fundamental frequency of 2,450 $MH_z$ and its higher harmonics, solid line A shows that the attenuation of the wave of the cable is sufficiently large to efficiently prevent radiation of the objectional high frequency noise. Dotted line curve B shown in FIG. **6** shows the attenuation versus frequency characteristic of a conventional filter comprising lumped constant circuit elements of inductors and capacitors having values of $L = 5\mu H$ and $c =$ 500 pF, respectively, at a frequency of 1 $KH_z$. This curve clearly shows that at frequencies above the HF range, the ability of the filter is very small and that no appreciable filtering effect can be expected at particular frequencies.

As above described, since the novel magnetron utilizes coaxial cables capable of absorbing noise signals in its filament lead wires, it is possible to perfectly absorb objectional electromagnetic waves over a wide frequency band without the necessity of utilizing such expensive filter component elements as conventional choke coils, barium titanate ceramic condensers or the

like. In addition, the lead wires themselves do not radiate waves. Moreover, since in this invention the filament terminals and the external terminals of the leads are interconnected by the coaxial cables, there are no connections between component parts of the filter as in the conventional design, thus improving the reliability of the magnetron. Further, elimination of the filter using large size component parts, for example, inductors and condensers, decreases the cost. Since it is not necessary to house the filter elements in the shield casing as in the conventional design, it is possible to decrease the distance between the yoke **4** and the top surface **171** of the cap **17**, thus decreasing the size of the magnetron.

While the invention has been shown and described in terms of some preferred embodiments, it should be understood that the invention is by no means limited to these embodiments. For example, the ferrite rubber used as the noise absorber of the coaxial cable may be replaced by a carbon-containing resin. It should be noted that this resin could be a so-called high molecular compound, which is, for example, silicon rubber or such plastics as vinyl chloride.

Instead of using the two layers, such as noise-absorbing layer **222** and insulation improving polyethylene layer **223**, use of only the noise-absorbing layer is sufficient. Further, an insulative resin layer may be applied on the outer conductor; and, in order to prevent the conduction of heat from the filament to the filament lead wires, heat-dissipating means may be suitably mounted on metallic pipes of the cathode terminal or on the exposed core conductors of the coaxial cables connected to the pipes.

It is also possible to eliminate cable support **171** from the shield casing by forming a perforation through the shield casing so as to hold the lead wires in the perforation by means of a suitable fitting.

Further, in order to prevent corona discharge at the cut edge of the outer conductor, an additional insulator may be interposed between the cut edge of the outer conductor and the insulator of the cable or the cut edge of the outer conductor may be suitably deformed.

We claim:

**1**. A magnetron comprising a cathode, an anode electrode coaxial with said cathode, magnet means for supplying a magnetic field to an interaction space between said cathode and said anode electrode, a shield casing secured to a conductive magnetron cover enclosing at least portions of said cathode and anode electrode, and filament lead wires extending through said shield casing and connecting the terminals of the filament of said cathode with external source terminals, each of said lead wires comprising a coaxial cable including a core conductor for passing filament-heating current to said filament terminal, at least one noise-absorbing insulator layer having a large microwave loss characteristic surrounding said core conductor, and an outer conductor of good conductivity surrounding said insulator layer, opposing portions of said shield cover and said casing being clamped around said outer conductor so that said outer conductor is grounded through said shield casing and cover to provide electrostatic shielding.

**2**. The magnetron according to claim **1**, wherein said one noise-absorbing insulator layer comprises a layer of high molecular compound containing a powder of ferromagnetic material.

**3**. The magnetron according to claim **1**, wherein said one noise-absorbing insulator layer comprises a layer of high molecular compound containing fine particles of electroconductive material.

**4**. The magnetron according to claim **1**, wherein the noise-absorbing insulator layer of said coaxial cable comprises a layer of high molecular compound having a large microwave loss surrounding said core conductor, and further including an insulation strength-improving layer surrounding said noise-absorbing insulator layer.

* * * * *