An elongated microwave powered lamp (1) achieves the direct excitation of a double-length plasma column, without requiring further waveguides or the like with the best possible efficiency of the elongated lamp, and includes: a transparent elongated bulb (2) containing, in an inner space thereof, a material apt to be excited by microwave irradiation thereby emitting an electromagnetic radiation, the elongated bulb (2) extending along a continuous profile with two opposite bulb ends (21, 22); two microwave coaxial antennas (71, 72), placed outside said bulb (2), respectively connected to a microwave source (81, 82) via corresponding antenna leads (91, 92), said bulb (2) and said microwave coaxial antennas (71, 72) being displaced in a close relationship to each other to allow the microwave excitation of said material, wherein the bulb (2) is shaped so as to form an open column (4) in the form of a passing through hole extending said bulb (2) with two opposite column end openings (41, 42) at said bulb ends (21, 22) respectively, said coaxial antennas (71, 72) being inserted into the open channel (4) from respective opposite column end openings (41, 42) with their leads (91, 92) entering the bulb (2) at opposite ends (21, 22) thereof and being displaced head-to-head, forming a continuous line substantially corresponding to said continuous profile, with respective facing distal ends (73) of said coaxial antennas (71, 72) forming a gap therebetween.
ELONGATED MICROWAVE POWERED LAMP

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to an elongated microwave powered lamp, generally described as an electrodeless lamp wherein a plasma material is excited by radio frequencies, namely in the microwave frequency range, to emit light.

2. Description of the prior art

This kind of electrodeless lamp is generally known from US 5,013,976 A, US 4,189,661 A and US 4,266,167 A. Further, EP 1,780,303 disclose a MW discharge device using one or two electrodes inside a tubular vacuum chamber.

A lamp of this kind was described in US 4,586,115 A (Zimmerman et al.), wherein a lighting system includes tubular transparent enclosures filled with a radiation responsive fluorescent material on its interior wall surface, and containing a gas responsive to radio frequency electromagnetic radiation to activate said fluorescent material. Generating means for generating radio frequency electromagnetic energy were provided, transmitting said radio frequency electromagnetic energy through coaxial cables connected to a single coaxial antenna of said generating means for each of said enclosures.

US 7,095,163 B2 (Longo) is referred to a lamp without electrodes comprising one bulb having inside a material capable of being excited by means of microwaves irradiation, a recess formed in walls of the bulbs, accessible from the outside and a source of microwaves radiation inserted into said recess, namely one or two antennas energized by an antenna lead connected to means for exciting the microwave source.

US 6,731,074 B2 (Suzuki) discloses an electrodeless lamp equipment comprising a microwave-generating source and a microwave chamber receiving the microwaves from antennas energized through appropriate and respective waveguides connecting the generating source and an antenna end. Said antennas are located at the ends of an elongated bulb to better extend the lighting power along the whole bulb.

It should be noted that, in the last examples of prior art, the multiple antennas do not cooperate to with each other along the whole length of an elongated bulb, to obtain
the best possible interaction between antennas and the plasma material inside the bulb.

SUMMARY OF THE INVENTION

The technical problems underlying the present invention is to provide a microwave energized lamp allowing to obviate to the drawbacks mentioned with reference to the prior art.

Such problem is solved by an elongated, including a transparent elongated bulb containing, in an inner space thereof, a material apt to be excited by microwave irradiation thereby emitting an electromagnetic radiation, the elongated bulb extending along a continuous profile with two opposite bulb ends; and two microwave coaxial antennas, placed outside the bulb, connected to a respective microwave source via corresponding antenna leads, said bulb and said microwave antennas being displaced in a close relationship to each other to allow the microwave excitation of said material.

According to the present invention, the bulb is shaped so as to form an open channel in the form of a passing through hole extending said bulb with two opposite channel end openings at said bulb ends respectively, said coaxial antennas being inserted into the open channel from respective opposite channel end openings with their leads entering the bulb at opposite ends thereof and being displaced head-to-head, forming a continuous line substantially corresponding to said continuous profile, with respective facing distal ends of said coaxial antennas forming a gap therebetween.

In this way, all the plasma material inside the bulb is excited by at least one antenna all along the bulb, achieving the best possible efficiency of the elongated lamp.

This kind of lamp may be arranged for the production of a visible, UV, or IR, pulsed or continuous radiation, within either a spectral or wide band wavelength range, especially with high lighting or heating powers in a safe and reliable way, without losing the compactness and the efficiency of the microwaves lamps directly excited by a microwave antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic sectional view of a first embodiment of a lamp according to the present invention; and

Figure 2 shows a schematic sectional view of a second embodiment of a lamp according to the present invention.
DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings and for all the embodiments herein described, a microwave energized lamp is generally indicated as 1. It comprises an elongated bulb 2 defined by a continuous external thick wall 3, of a material substantially transparent to the visible, UV, IR radiation, and to the MW radiation as well, e.g. glass, possibly a heat resistant glass suitable for lamp bulbs.

The elongated bulb 2 defines a closed chamber containing a microwaves irradiation excitable material, which may be a gas, a vapor, a dust, or a liquid, capable of emitting radiation by activation with other electromagnetic radiation and/or owing to hits between neutral or ionized particles (plasma atoms or molecules). The material can be put in with either a certain rate of vacuum or at a pressure higher than the atmospheric. A mixture of gases or vapors, or only a single atomic or molecular species can be used.

A possible bulb filling may be made with Argon at low pressure (2÷3 mmHg) and vapors of Mercury (Hg).

The elongated bulb 2 generally has a straight and tubular shape, comprising two opposite bulb ends 21, 22. Further, the bulb 2 is shaped so as to form a coaxial open channel 4 that, in the present embodiment, is a passing through hole extending end-to-end inside the bulb 2 from one bulb end 21 to the other 22.

The open channel 4 has a straight and tubular shape too, with two opposite channel end apertures 41, 42 at said opposite respective ends 21, 22 of the bulb 2.

The lamp 1 then comprises two distinct coaxial microwave antennas 71, 72, which are in turn respectively connected to corresponding microwave sources 81, 82 via respective antenna leads 91, 92.

This kind of antenna is substantially obtained from a coaxial cable having an inner wire conductor forming the core of the cable, an outer tubular conductor surrounding the inner wire conductor, a tubular insulator layer made of a dielectric material placed between the inner wire conductor and the outer tubular conductor to electrically separate them, and, in some cases, an external sheath covering the outer tubular conductor. To construct a coaxial antenna like the classical dipole radiator a short section of the external conductor is stripped off at on end of the coaxial cable. Conventionally, this kind of cable is flexible or semi-rigid and it can be bent or curved.
Both the active part of the coaxial cable, i.e. that part acting as antenna, and the antenna lead are made from said coaxial cable. The coaxial antenna is formed by the exposed inner wire conductor possibly covered by a protection layer transparent to the generated electromagnetic waves, namely microwaves; the tubular insulator layer can be seen as a good protection layer.

The antenna lead is instead embodied by a section of coaxial cable connected to said microwave source, comprising both the inner and the outer conductors. The coaxial antenna is placed outside the bulb.

The coaxial antenna, i.e. the active part of said coaxial cable, could have in principle any length to cope with different shapes and lengths of the bulb 2. It is noted that, in all the embodiments of the invention, each coaxial antenna is placed outside the bulb 2, i.e. in an outer space with respect to the bulb 2.

In general, the bulb 2 and said coaxial microwave antennas 71, 72 are displaced in a close relationship to each other, so as to allow the direct microwave excitation of the target material inside the bulb chamber. According to the present invention and in this first embodiment, the coaxial antennas 71, 72 are inserted inside the open channel 4, with spacers (not shown) arranged so as to leave a toroidal channel between the bulb walls and the coaxial antennas 71, 72. A further protection sheath, made of a material transparent to the microwaves, envelopes both the coaxial antennas 71, 72 and the section of antenna leads 91, 92 inside the open channel 4. The protection sheath is preferably made of PTFE.

In particular, said coaxial antennas 71, 72 are inserted into the open channel 4 from respective opposite channel end openings 41, 42 with their leads 91, 92 entering the bulb at the opposite ends 21, 22 thereof.

Each antenna has a distal end 73 placed inside the open channel 4. According the present embodiment, the antenna distal ends 73 of the coaxial antennas 71, 72 are positioned in close proximity to each other, without any kind of contact, i.e. the coaxial antennas 71, 72 are displaced head-to-head inside the open channel 4, forming a continuous line substantially corresponding to said continuous profile but forming a gap between the respective and facing distal ends 73 thereof.

At said channel end apertures 41, 42 of the open channel 4, each antenna lead 91, 92 has a microwave choke 14 or trap applied onto the outer conductor, blocking the propagation of microwaves reflected back from the respective antenna, due to an incorrect impedance balancing. The microwave choke 14 substantially is a metallic
bushing, preferably made of copper or brass, with a length of λ/4 (λ = wavelength of microwaves) and a diameter multiple of the cable diameter.

The choke 14 is mounted outside the outer conductor near and comprises a coaxial conducting portion of diameter higher than the external conductor; a conducting collar for connecting the coaxial conductor to the external conductor, arranged along the coaxial conducting portion. The choke 14 may be filled with a high-temperature resistant dielectric material, e.g. a tubular piece of ceramic, with a complex permittivity ε = ε₀(ε' - jε'') with ε'' < 1 and ε' > 1 - allowing the construction of a compact, i.e. short, choke 14, the effective wavelength λ_eff in the choke being in this case

\[ \lambda_{eff} = \frac{\lambda_0}{\sqrt{\varepsilon'}} \]

with λ₀ = wavelength of microwaves in vacuum, and the length of the choke 14, being equal to λ₀/4, is lower than λ₀/4.

In this configuration the target material inside the bulb 2 may be excited by microwaves at a continuous power of about 1 kW, at a frequency of 2.45 GHz.

It should be noted that this kind of lamp 1 may be equipped with a heat removal system (not shown) wherein a refrigeration circuit is flown with a refrigerating fluid, and said open channel is arranged to define a bulb refrigeration path, which is part of said refrigeration circuit, wherein the refrigerating fluid is allowed to circulate. In the present embodiment, the open channel 4 can be arranged as a duct of said refrigeration circuit and the apertures 41, 42 thereof may act as inlet and outlet of said refrigeration path.

Otherwise, the whole bulb 2 may be immersed in a refrigerating bath inside a transparent container (not shown), which is part of the refrigeration circuit.

According to Figure 2, the lamp 1 may be provided with suitable coaxial connectors 61, 62 for the leads 91, 92. In this way, the lamp 1 may be connected to any microwave source provided at the installation site.

In the lamp operation, increasing the power of the microwave sources, the microwave power may be transferred to one antenna to the other, and superficial waves are excited and propagated along the coaxial configuration of the lamp 1.

For instance, applying a power of 250 W at only one antenna (see Figure 2), it is possible to transfer a power of 60 W to the other antenna if the corresponding microwave source is inactive.
Then it is possible to electronically vary the microwaves transmitted to each antenna in terms of frequency, intensity and modulation, so as to obtain different excitations in different portion of the bulb (Figure 2), achieving different lighting effects.

Then, it should be noted that the power transmission between the antennas may be prevented by simply putting uniline microwave fuses acting as unidirectional devices between the heads of the antennas.

It is apparent from the above disclosure that this bulb and antenna assembly can achieve the excitation of a double-length plasma column with respect to the one antenna assembly, without requiring further waveguides or the like.

Then it is also possible to operate a microwave lamp with antennas having different lengths, one of the antennas being passively used or acting as a sensor.

The lamp is capable of emitting radiation with a line spectrum, a band spectrum or mixed spectrum, in a wide range of wavelengths. It works without any electrodes in contact with the particles that emit the radiation, in a continuous or pulsed way. The spectral composition of the radiation as emitted depends from the substances used for filling the bulb, their quantity ratio, as well as the power and the frequency of the microwaves used for excitation.

To the above described microwave powered lamps a man skilled in the art, in order to meet specific requirements and contingencies, may bring further modifications, all falling within the scope of protection of the present invention, as defined by the annexed claims.
CLAIMS

1. Elongated microwave powered lamp (1) including:
   • a transparent elongated bulb (2) containing, in an inner space thereof, a
     material apt to be excited by microwave irradiation thereby emitting an
     electromagnetic radiation, the elongated bulb (2) extending along a
     continuous profile with two opposite bulb ends (21, 22);
   • two coaxial microwave antennas (71, 72), placed outside said bulb (2),
     connected to a respective microwave source (81, 82) via corresponding
     antenna leads (91, 92),

said bulb (2) and said microwave coaxial antennas (71, 72) being displaced in a
close relationship to each other to allow the microwave excitation of said material,
wherein the bulb (2) is shaped so as to form an open channel (4) in the form of a
passing through hole extending said bulb (2) with two opposite channel end
openings (41, 42) at said bulb ends (21, 22) respectively, said coaxial antennas (71,
72) being inserted into the open channel (4) from respective opposite channel end
openings (41, 42) with their leads (91, 92) entering the bulb (2) at opposite ends (21,
22) thereof and being displaced head-to-head, forming a continuous line
substantially corresponding to said continuous profile, with respective facing distal
ends (73) of said coaxial antennas (71, 72) forming a gap therebetween.

2. Elongated microwave powered lamp (1) according to claim 1, wherein both
   the microwave coaxial antennas (71, 72) and are substantially coaxial to the open
channel (4) leaving a toroidal elongated space surrounding the microwave
antennas.

3. Elongated microwave powered lamp (1) according to any of the preceding
   claims, wherein said microwave antennas (71, 72) forms a continuous straight line.

4. Elongated microwave powered lamp (1) according to claim 1, wherein the
   elongated bulb (2) has a straight and tubular shape, the open channel (4) being
   coaxial to the bulb (2).

5. Elongated microwave powered lamp (1) according to claim 1, wherein, at
   said channel end apertures (41, 42) of the open channel (4), each coaxial antenna
   lead (91, 92) has a microwave choke (14) applied onto a outer conductor thereof,
   blocking the propagation of microwaves reflected back from the respective coaxial
   antenna.
6. Elongated microwave powered lamp (1) according to claim 1, wherein each antenna lead (91, 92) is provided with suitable coaxial connectors (61, 62).

7. Elongated microwave powered lamp (1) according to claim 1, wherein a unidirectional device is put between the coaxial antenna heads (73) inside the open channel (4).

9. Elongated microwave powered lamp (1) according to claim 1, wherein the coaxial antennas (71, 72) have different lengths.

10. Elongated microwave powered lamp (1) according to claim 9, wherein one of the coaxial antennas (71, 72) is passively used and/or is acted as a sensor.
**INTERNATIONAL SEARCH REPORT**

**PCT/IB2014/059813**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. H01J65/04

**ADD.**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>DE 195 03 205 CI (MUEGGE ELECTRONIC GMBH [DE]) 11 July 1996 (1996-07-11) col umn 1, line 33 - col umn 2, line 55 col umn 2, line 65 - col umn 4, line 60; figures claims 1-4, 10, 11, 12, 15, 16 ------</td>
<td>1-6,8,9</td>
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<td>Y</td>
<td>EP 1 780 303 A2 (APPLI ED MATERI ALS GMBH &amp; CO KG [DE]; APPLI ED M) 2 May 2007 (2007-05-02) cited in the application paragraphs [0010], [0011]; figures 2, 3 ------</td>
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Schmidt-Kast, S

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