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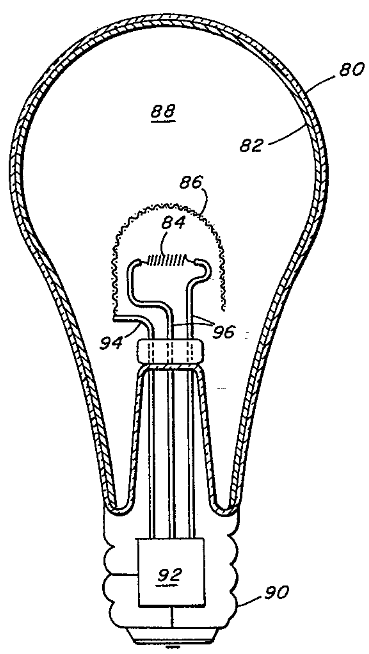
(54) **Beam mode fluorescent lamp.**

(57) A beam mode fluorescent lamp for general lighting applications. A light transmitting envelope (10), having a phosphor coating (12) on its inner surface, encloses a cathode (14) for emitting electrons, an anode (16) for accelerating the electrons and forming an electron beam, and a fill material, such as mercury, which emits ultraviolet radiation upon excitation. The anode (16) is spaced apart from the cathode (14) by a distance which is less than the electron range in the fill material and has a structure which permits the electron beam (22) to pass therethrough. The electron beam causes excitation of the fill material and emission of ultraviolet radiation in a relatively field-free drift region (20) havin a dimension which is greater than the electron range. The phosphor coating (12) absorbs the ultraviolet radiation and emits visible light.



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BEAM MODE FLUORESCENT LAMP

Background of the Invention

This invention relates to compact fluorescent lamps and, more particularly, to a fluorescent lamp wherein an electron beam causes discharge in a relatively field-free discharge region.

Although incandescent lamps are inexpensive and convenient to use, they are considerably less efficient than fluorescent lamps. Typically, incandescent lamps produce light with an efficacy of less than 20 lumens per watt of electrical input power, whereas fluorescent lamps typically produce 80 lumens per watt. However, fluorescent lamps have been optimized for overhead lighting in the form of elongated straight tubes and circular tubes. The straight tubes require application of power to both ends. In addition, fluorescent lamps require a ballast circuit to limit operating current. Thus, fluorescent lamps are not well adapted to many lighting needs presently met by the incandescent lamp. Numerous attempts have been made to provide a fluorescent lamp having the general configuration of an incandescent lamp. Such fluorescent lamps have been known as compact fluorescent lamps or incandescent replacements.

A variety of electroded compact fluorescent lamps have been disclosed in the prior art. Generally, these lamps involve a folding of the positive column discharge which occurs in an elongated straight fluorescent lamp. Both electrodes are located at one end of the lamp but the positive column discharge is forced, by the use of partitions within the discharge volume or by the use of a U-shaped discharge tube, to follow a generally U-shaped path between the electrodes. A different approach is taken in U. S. Patent No. 4,093,893, issued June 6, 1978 to Anderson. A relatively short fluorescent lamp utilizes special hollow cathode assemblies at opposite ends of the discharge volume and is operated from a radio frequency power source.

Others have utilized radio frequency excitation of compact fluorescent lamps. An electrodeless compact fluorescent lamp is disclosed by Hollister in U. S. Patent No. 4,010,400, issued March 1, 1977. A discharge lamp having the outer shape of an incandescent lamp utilizes inductive excitation of the fill material. In U. S. Patent No. 4,189,661, issued February 19, 1980 to Haugsjaa et al, an electrodeless fluorescent light source has an electrodeless lamp mounted in a termination fixture which is coupled to a high frequency power source. The termination fixture matches a low pressure discharge in the electrodeless lamp to the high frequency power source. Pending application Serial No. 092,916, filed November 9, 1979 and assigned to the same assignee as the present application, discloses a compact fluorescent lamp wherein high frequency power is capacitively coupled to a low pressure discharge. In all of these compact fluorescent lamps, a radio frequency power source is required for direct incandescent lamp replacement.

Summary of the Invention

It is a general object of the present invention to provide new and improved compact fluorescent light sources.

It is another object of the present invention to provide a compact fluorescent lamp wherein the requirement for partitioning of the lamp envelope is eliminated.

It is yet another object of the present invention to provide a compact fluorescent lamp wherein ionization by secondary electrons is inhibited and the problem of current runaway is alleviated.

According to the present invention, these and other objects and advantages are achieved in a beam mode fluorescent lamp. The beam mode fluorescent lamp includes a light transmitting envelope enclosing a fill material which emits ultraviolet radiation upon excitation. A phosphor coating on an inner surface of the envelope emits visible light upon absorption of ultraviolet radiation. A cathode for emitting electrons is located within the envelope. An anode for accelerating the electrons and forming an electron beam in response to a voltage applied between the anode and the cathode is located within the envelope.

The anode is spaced apart from cathode by a distance which is less than the electron range in the fill material and has a structure which permits the electron beam to pass therethrough. The fluorescent lamp further includes a drift region within the envelope through which the electron beam drifts after passing through the anode. The drift region has a dimension in the direction of travel of the electron beam which is greater than the electron range in the fill material. Electrons in the electron beam collide with atoms of the fill material in the drift region, thereby causing excitation of a portion of the fill material atoms and emission of ultraviolet radiation and causing ionization of another portion of the fill material atoms and emission of secondary electrons. The secondary electrons cause further emission of ultraviolet radiation. The fill material typically includes mercury and can include a noble gas at low pressure. The anode is typically in the form of a conductive wire mesh.

Brief Description of the Drawings

In the drawings:

FIG. 1 is a schematic diagram of a beam mode fluorescent lamp according to the present invention;

FIG. 2 illustrates various cathode-anode configurations which can be utilized in the fluorescent lamp of FIG. 1; and

FIG. 3 illustrates a beam mode fluorescent light source according to the present invention.

For a better understanding of the present invention together with other and further objects, advantages and capabilities thereof, reference is made to the following disclosure and appended claims in connection with the above-described drawings.

Detailed Description of the Invention

Referring now to FIG. 1, there is shown a beam mode fluorescent lamp according to the present invention. A vacuum-tight lamp envelope 10 made of a light transmitting substance, such as glass, encloses a discharge volume. The discharge volume contains a fill material which emits ultraviolet radiation upon excitation. A typical fill material includes mercury and can include a noble gas or mixtures of noble gases at low pressure. The inner surface of the lamp envelope 10 has a phosphor coating 12 which emits visible light upon absorption of ultraviolet radiation. Also enclosed within the discharge volume by the lamp envelope 10 are a cathode 14 and an anode 16. The cathode 14 and the anode 16 can have various configurations as described hereinafter. In general, however, the function of the cathode 14 is to emit electrons while the function of the anode 16 is to accelerate the electrons emitted by the cathode 14. The anode 16 has one or more holes which permit electrons to pass through it and is typically a wire mesh. The cathode 14 and the anode 16 are closely spaced in relation to the overall dimensions of the lamp for reasons described hereinafter. In the example shown in FIG. 1, the cathode 14 is indirectly heated by a heater element 18. Vacuum-tight feedthroughs provide for external electrical connections of the cathode 14, the anode 16 and the heater element 18 through the lamp envelope 10. A drift region 20 is the region on the side of the anode 16 opposite the cathode 14 through which the electrons drift after passing through the anode 16. The drift region 20 extends between the cathode 16 and the end 24 of the lamp.

In operation, a voltage is applied to the heater element 18 causing heating of the cathode 14 and thermionic emission of electrons. A dc voltage applied to the anode 16 causes acceleration of the electrons in the direction of the anode 16 and formation of an electron beam 22. Due to the open configuration of the anode 16, most of the electrons in the electron beam 22 pass through the anode 16 into the drift region 20. The drift region 20 is relatively field-free in comparison with the region between the cathode 14 and the anode 16 and little further acceleration of the electron beam 22 occurs. The anode 16, as shown in FIG. 1, is generally dome shaped around the cathode 14, causing dispersal of the electron beam over a wide angle.

The anode 16 and the cathode 14 are closely spaced to prevent electron multiplication in the region between the anode 16 and the cathode 14 and possible current runaway conditions, such as can occur in positive column fluorescent lamps. For a given fill material type and pressure and a given electron energy, electrons on the average travel a distance known as the electron range before collision with atoms of the fill material. When a collision occurs, secondary electrons can be liberated. In an applied electric field, the secondary electrons are accelerated and can cause further liberation of electrons, thereby providing an avalanche effect. In this situation, current runaway conditions occur and a stabilizing device or ballast circuit is required to limit the discharge current. However, when the spacing D between the anode 16 and the cathode 14 is less than the electron range in the fill material, there is a low probability that the electrons emitted by the cathode 14 will suffer collisions with the fill material atoms before reaching the anode 16. Therefore, current runaway conditions are avoided.

The drift region 20 has a dimension L in the direction of electron beam travel which is greater than the electron range. Therefore, the electrons in the electron beam 22 have a high probability of suffering collisions with the fill material atoms in the drift region 20. A portion of the collisions results in ionization of the fill material atoms and production of secondary electrons. Another portion of the collisions results in the excitation of mercury atomic energy levels which result in the production of ultraviolet radiation near 254 nanometers, as is known in the fluorescent lamp art. The ultraviolet radiation provides effective excitation of the phosphor coating 12 to yield visible light. The secondary electrons produced by the electron beam 22 also collide with mercury atoms and result in the production of ultraviolet radiation. Since the drift region 20 is relatively field-free, the secondary electrons produced therein are not substantially accelerated and further ionization is inhibited. Thus, the problem of current runaway is alleviated. The secondary electrons produced in the drift region 20 are collected by the anode 16. Since the drift region 20 is relatively field-free, the secondary electrons have low energies and do not cause significant heating of the anode 16. Furthermore, the diffusion of secondary electrons within the drift region 20 provides a uniform discharge.

As noted hereinabove, the lamp fill material typically includes mercury and can include a noble gas or mixtures of noble gases at low pressure. A small droplet of mercury, for example 3 milligrams, or a mercury-containing amalgam is used. The noble gas pressure is typically 0.1 torr or less to provide a substantial electron range in the drift region 20. The beam mode fluorescent lamp can be operated with no noble gas included in the fill material. Also, helium and neon are preferred because these lighter noble gases provide a greater electron range and more extensive diffusion of mercury atoms in the drift region 20.

Phosphors commonly used in commercially available fluorescent lamps are suitable for use as the phosphor coating 12. One suitable phosphor is calcium halophosphate. However, known rare earth phosphors and blends thereof are preferred because of their ability to withstand the relatively high wall loading characteristic of the lamp according to the present invention. Wall loading is the lamp power dissipation per unit area of light emitting surface.

When the fill material is mercury vapor and neon at a pressure of 0.1 torr and the temperature is below about 60°C, the electron range for 10-100 electron volt electrons is on the order of several centimeters. Therefore, when the dimension D between the anode 16 and the cathode 14 is about one (1) centimeter, the majority of electrons emitted by the cathode 14 pass through the anode 16 without collision with the fill material atoms. When the dimension L of the drift region 20 is larger than the electron range, that is, at least about five (5) centimeters, the electron beam 22 is largely absorbed by collisions with the fill material atoms which result in the production of ultraviolet radiation and the consequent excitation of the phosphor coating 12.

For this configuration, the preferred voltage between the cathode and the anode is about 20 volts. Higher voltages produce more energetic electrons which extend the discharge region but disadvantageously produce energetic ions which cause the sputtering of the cathode. Since the operating voltage is fairly low, the input current must be high to achieve a given power level. Thus, an efficient thermionic cathode is required. For example, 40 watt operation requires two (2) amperes of electron current to be supplied by the cathode. Thermionic cathodes from standard fluorescent lamps, having emissive coatings of barium oxide, are suitable. Low ac voltages, for example, six (6) volts, are typically utilized for heating of the cathode.

Referring now to FIGS. 2A-2E, there are shown various anode and cathode configurations which are suitable for use in the beam mode fluorescent lamp of the present invention. In all of the configurations, the anode has an open structure which permits the electrons emitted by the cathode to pass through the anode and has a large area in comparison with the area of the cathode so that the resultant electron beam is spread over a wide angle. The wide angle electron beam ensures maximum excitation of ultraviolet radiation in the drift region and a uniform discharge. FIG. 2A illustrates a directly heated hot cathode 30 supported by leads 32. A wire mesh anode 34 has a generally cylindrical shape and is supported by a lead 36. The cathode 30 is positioned in the interior of the cylindrical anode 34. FIG. 2B illustrates a hot cathode 40 supported by leads 42 and a generally planar wire mesh anode 44 supported by a lead 46. The planar anode 44 is positioned just above the cathode 40 and can have any convenient shape. FIG. 2C illustrates a hot cathode 50 supported by leads 52 and a semi-cylindrical wire mesh anode 54 supported by lead 56. The axis of the semi-cylindrical anode 54 is collinear with the axis of the cathode 50. FIG. 2D illustrates an indirectly heated cathode 60 which is heated by a heater element 61 and supported by the leads 62. The indirectly heated cathode 60 can be utilized to provide an extended flat cathode surface. A planar anode 64 is similar to the anode 44 in FIG. 2B. FIG. 2E illustrates a hot cathode 70 supported by leads 72 and an anode 74 in the form of a conductive loop supported by a lead 76.

A preferred embodiment of the beam mode fluorescent lamp, which provides direct replacement for an incandescent lamp, is illustrated in FIG. 3. A light transmitting envelope 80 is generally pear shaped, as is characteristic of incandescent lamps. The envelope 80 includes a phosphor coating 82 on the inner surface thereof and encloses a fill material such as mercury which emits ultraviolet radiation upon excitation. The fill material can also include a noble gas at low pressure. A cathode 84 and an anode 86, having the characteristics described hereinabove in connection with FIGS. 1 and 2, are mounted within the lamp envelope 80 at a spacing which is less than the electron range in the fill material. An electron beam, generated by the cathode 84 and accelerated by the anode 86, produces discharge in a drift region 88 as described hereinabove in connection with FIG. 1. The phosphor coating 82 absorbs ultraviolet radiation produced by the discharge in the drift region 88 and emits visible light. The light source of FIG. 3 further includes a lamp base 90 which receives ac electrical power from a source such as the ac line voltage in a home. The base 90 provides a housing for a power supply 92. The power supply 92 receives ac electrical power through the lamp base 90 and provides operating voltages and currents for the light source. One output of the power supply 92 is coupled to the anode 86 by a support wire 94 which also provides mechanical support for the anode 86. Power supply 92 has another output coupled to the cathode 84 by support wires 96 which also provide mechanical support for the cathode 84. One suitable power supply includes a stepdown transformer to provide 60Hz, 6 volt ac power to heat the cathode 84 and includes a dc power supply which provides an anode voltage of about 20 volts dc. Since the power supply 92 is self-contained within the light source of FIG. 3, the disclosed light source can directly replace incandescent lamps.

Thus, there is provided by the present invention a compact fluorescent lamp which has a single ended input and which can replace incandescent lamps in many applications. There is also provided a fluorescent lamp wherein ionization by secondary electrons is inhibited and the problem of current runaway is alleviated.

While there has been shown and described what is at present considered the preferred embodiments of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A beam-mode fluorescent lamp comprising:

a light transmitting envelope enclosing a fill material which emits ultraviolet radiation upon excitation;

a phosphor coating, which emits visible light upon absorption of ultraviolet radiation, on an inner surface of said envelope;

a cathode located within said envelope for emitting electrons;

an anode located within said envelope for accelerating said electrons and forming an electron beam in response to a voltage applied between said anode and said cathode, said anode being spaced apart from said cathode by a distance which is less than the electron range in said fill material and having a structure which permits said electron beam to pass therethrough;

a drift region within said envelope through which said electron beam drifts after passing through said anode, said drift region having a dimension in the direction of travel of said electron beam which is greater than the electron range in said fill material so that the electrons in said electron beam collide with the atoms of said fill material in said drift region, thereby causing excitation of a portion of said fill material atoms and emission of ultraviolet radiation and causing ionization of another portion of said fill material atoms and emission of secondary electrons, said secondary electrons causing emission of additional ultraviolet radiation; and

means for connecting said cathode and said anode to a power source external to said envelope.

2. The beam-mode fluorescent lamp as defined in claim 1 wherein said fill material includes mercury, wherein said fill material includes a noble gas at low pressure, wherein said anode is in the form of a conductive wire mesh, wherein said cathode is a thermionic cathode, wherein said noble gas includes neon at a

pressure below about 0.1 torr, wherein the spacing between said anode and said cathode is less than about one centimeter, and wherein said dimension of said drift region in the direction of travel of said electron beam is at least about five centimeters.

3. The beam mode fluorescent lamp as defined in claim 2 wherein said anode is dome-shaped.

4. The beam mode fluorescent lamp as defined in claim 2 wherein said anode is in the shape of a cylinder with a closed end and said cathode is located within said cylinder.

5. The beam mode fluorescent lamp as defined in claim 2 wherein said anode is generally planar.

6. The beam mode fluorescent lamp as defined in claim 2 wherein said anode is in the form of a conductive ring.

7. A beam-mode fluorescent lamp comprising:

a light transmitting envelope enclosing a fill material which emits ultraviolet radiation upon excitation;

a phosphor coating on an inner surface of said envelope which emits visible light upon absorption of ultraviolet radiation;

a cathode located within said envelope for emitting electrons;

an anode located within said envelope and spaced apart from said cathode by a distance which is less than the electron range in said fill material, said anode being operative, in response to a voltage applied between said anode and said cathode, to accelerate said electrons and form an electron beam which passes through said anode into a drift region wherein the electrons of said electron beam collide with the atoms of said fill material causing emission of ultraviolet radiation; and

means for coupling said cathode and said anode to a power source external to said envelope.

8. The beam-mode fluorescent lamp as defined in claim 7 wherein said fill material includes mercury, wherein said fill material includes a noble gas at low pressure, wherein said anode is in the form of a conductive wire mesh, wherein said cathode is a thermionic cathode, and wherein said noble gas includes neon at a pressure below 0.1 torr.

9. A beam-mode fluorescent light source comprising:

a light transmitting envelope enclosing a fill material including mercury which emits ultraviolet radiation upon excitation;

a phosphor coating on an inner surface of said envelope which emits visible light upon absorption of ultraviolet radiation;

a cathode located within said envelope for emitting electrons;

an anode located within said envelope and spaced apart from said cathode by a distance which is less than the electron range in said fill material, said anode being operative, in response to a voltage applied between said anode and said cathode, to accelerate said electrons and form an electron beam which passes through said anode into a drift region wherein the electrons of said electron beam collide with the atoms of said fill material causing emission of ultraviolet radiation; and

a power source coupled through said envelope to said cathode and said anode for receiving ac power and for providing operating power to said cathode and said anode.

10. The beam-mode fluorescent light source as defined in claim 9 further including a lamp base which encloses said power source, whereby said light source can be operated directly from ac power, and wherein said power source provides a dc voltage of about 20 volts between said anode and said cathode.

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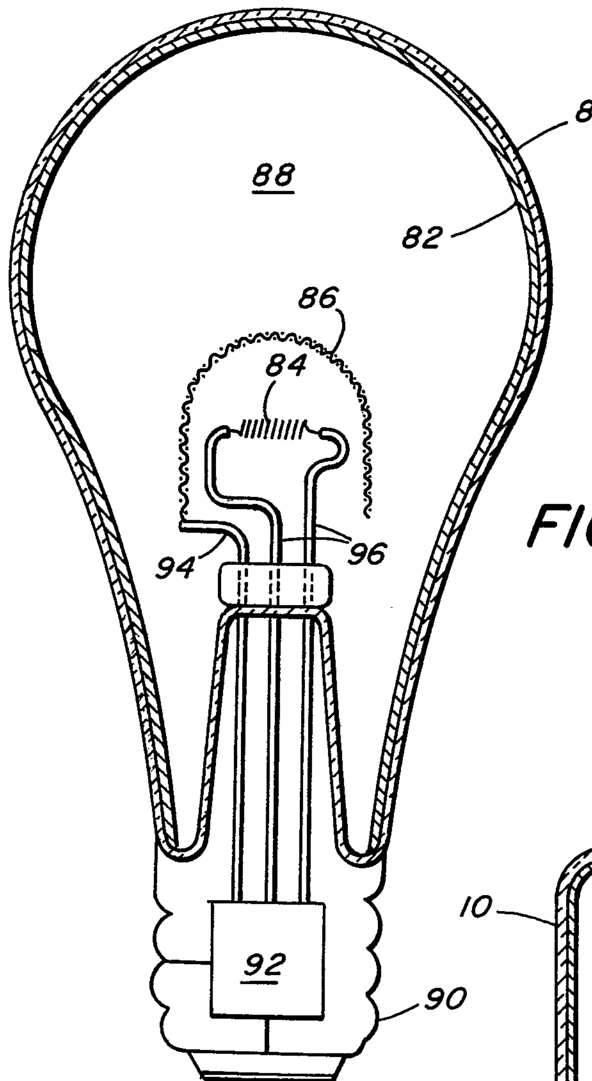

FIG. 3

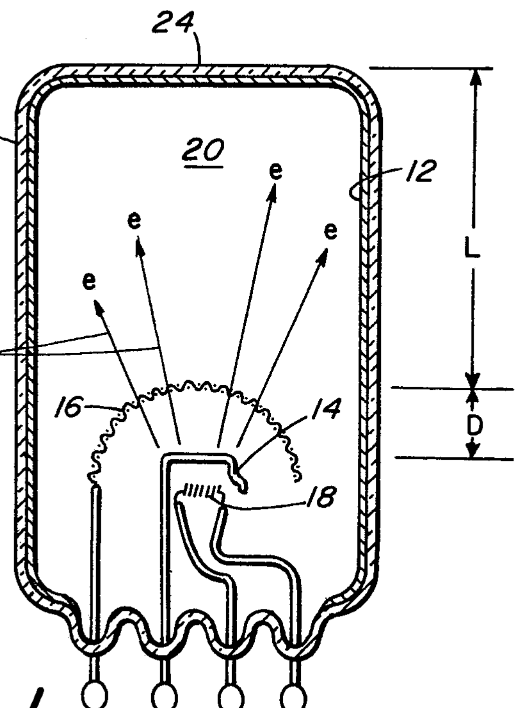

FIG. 1

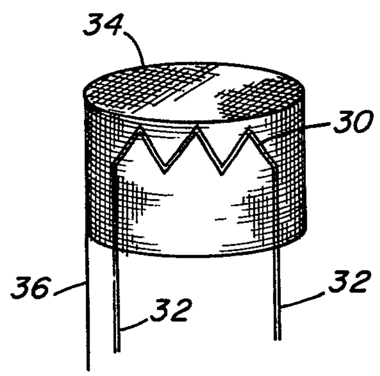

FIG. 2A

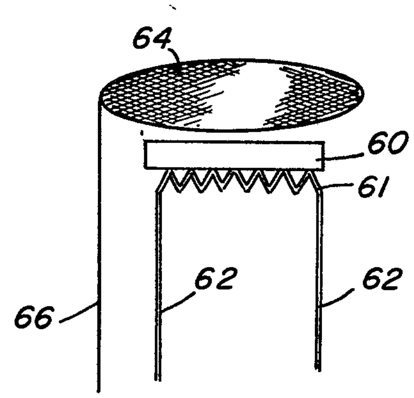

FIG. 2D

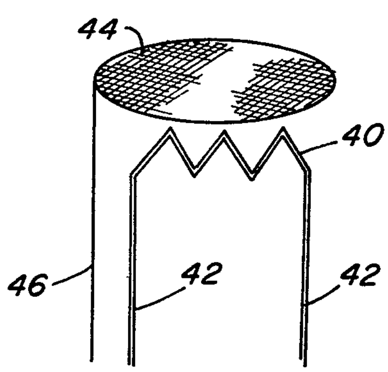

FIG. 2B

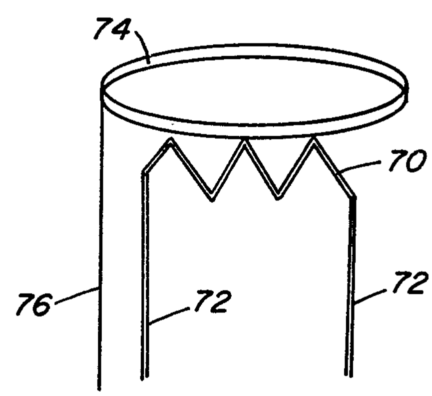

FIG. 2E

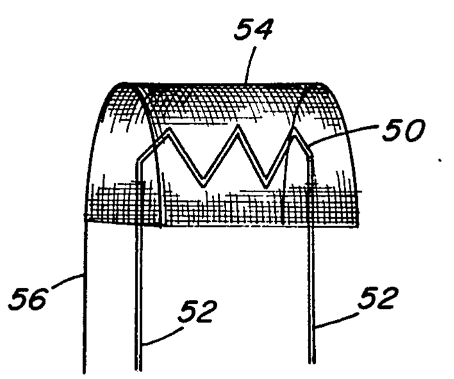

FIG. 2C

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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 81110674.9

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
A	US - A - 4 171 503 (KWON) * Fig. 1; claims 1-3 * --	1,7,9
A	US - A - 4 119 889 (HOLLISTER) * Abstract; fig. 2 * --	1,7,9
A	US - A - 4 117 378 (GLASCOCK) * Fig. 1 * --	1,7,9, 10
D,A	US - A - 4 189 661 (HAUGSJAA) * Abstract * --	1,7,9
D,A	US - A - 4 093 893 (ANDERSON) * Abstract * --	1,7,9, 10
D,A	US - A - 4 010 400 (HOLLISTER) * Abstract * ----	1,7,9

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

H 01 J 61/16

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

H 01 J 61/00
H 01 J 1/00
H 01 J 17/00
H 01 J 65/00
H 05 B 41/00

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	19-03-1982	VAKIL

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