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(54) Gas discharge lamp system

(57) The invention relates to a gas discharge lamp (1) system and to a method for manufacturing an electrode (3) of a gas discharge lamp. According to the invention, at least one electrode (3) of the gas discharge lamp (1) is designed as a heat pipe. This provides for a very efficient and easy to use possibility of cooling the electrode (3).

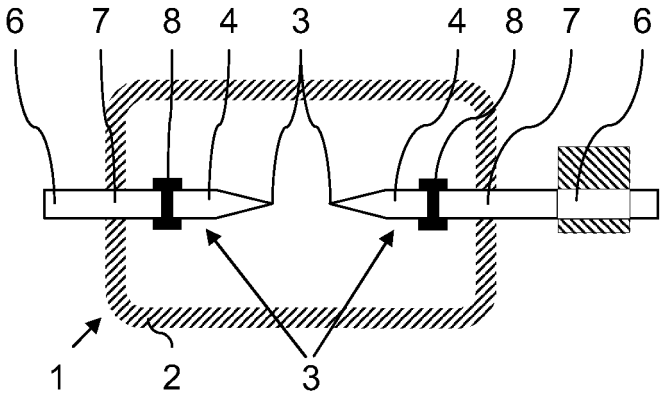

FIG. 1

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Description

[0001] The invention relates to a gas discharge lamp system, and especially to an improved cooling system for a gas discharge lamp as well as to a method of operating such as gas discharge lamp system, e.g. especially to an improved cooling for a gas discharge lamp.

Technical Background

[0002] Electrodes for gas discharge lamps, especially for small high power lamps, must be cooled in order to avoid that they act as welding rods, transferring material from one electrode to the other. In order to prevent this, typically tungsten is used as a material for the electrodes because of its high melting temperature. Typically, for the electrodes, tungsten rods are connected to molybdenum metal strips which have a similar coefficient of expansion as glas. Around this molybdenum structure, glass is molten and pressed to seal the glass bulb of the lamp and its contents. The bulb and the tungsten and molybdenum part of the electrodes, respectively, have to be kept beneath maximum temperatures. Usually, this is done by external blowing of air with a fan or even with a compressor.

[0003] However, such cooling must be done from a distance, since fans or air guides should not obstruct the active area of the reflector for the lamp. Further, this indirect way of cooling results in electrode distances which have to be larger than a certain minimum length which is not ideal since in this way, no point source for the light is achieved.

Summary of the invention

[0004] It is the object of the invention to provide an efficient and easy way to use cooling for a gas discharge lamp.

[0005] According to the invention, this object is solved by a gas discharge lamp system which comprises two electrodes for generating an electric arc in between, wherein at least one of these electrodes is implemented as a heat pipe.

[0006] A heat pipe is a device with a heat transfer mechanism which is able to transport large quantities of heat with a rather small difference in temperature between the hotter interface and the colder interface. According to a preferred embodiment of the invention, the electrode which is designed as a heat pipe comprises a sealed non-porous tube with a porous interior. This means that the total interior volume can be porous, but it is also possible that only a part of the volume is filled with a porous material, e.g. the outer part near to the walls of the tube.

[0007] Further, it is preferred that the porous interior is provided with a cooling medium. Preferably, this cooling medium evaporates near the region of the electrode where the electric arc is generated and condenses at the colder end of the electrode. Preferably, evaporation occurs in a temperature range from 800 to 980 °C, more preferably in a temperature range from 850 to 950 °C. Further, it is preferred that the cooling medium condenses in a temperature range from 100 to 280 °C, more preferably in a temperature range from 150 °C to 250 °C. Toluene, Mercury, Sodium, Lithium can be used as suitable materials depending on the operations temperature of the electrodes.

[0008] According to a preferred embodiment of the invention, the pressure in the porous interior of the electrode is less than ambient pressure. Further, it is preferred that the electrode is connected to a heat sink. With respect to this, it is especially preferred that the lamp comprises a glass bulb and the heat sink is provided outside the glass bulb.

[0009] Accordingly, with a gas discharge lamp system as described above, the cooling of an electrode can be achieved as follows: In a case in which the pressure in the porous interior of the electrode is less than ambient pressure, this means that a partial vacuum is applied. If the partial vacuum is near or below the vapor pressure of the cooling medium, some of the cooling medium is in the liquid phase and some is in the gas phase. Due to the porous structure of the interior of the electrode, a capillary pressure is exerted on the liquid phase of the cooling medium. The porous interior of the electrode can be achieved with a sintered metal powder and/or a series of grooves which run parallel to the axis of the tube. However, capillary pressure is not necessary if gravity or any other force is sufficient to overcome surface tension and cause the condensed cooling medium to flow back to the hot end of the electrode.

[0010] In general, the shape of the electrode can be conventional; especially, the electrode may comprise a constant diameter throughout its whole length. However, according to a preferred embodiment of the invention, the diameter of the electrode in a region near to the forefront is less than in a region more distant to the forefront. This has the advantage that further away from the forefront where the electric art is generated, a higher cross-section for conducting the heat away from the forefront is provided.

[0011] In general, the electrode which is designed as a heat pipe can be made from different materials. However, according to a preferred embodiment of the invention, the electrode which is designed as a heat pipe comprises a first refractory metal such as tungsten. Further, with respect to this, it is especially preferred that the first refractory metal such as tungsten is provided in the region near to the forefront of the electrode where the electric arc is to be generated.

[0012] Further, it is also preferred that the electrode which is designed as a heat pipe comprises a second refractory metal such as molybdenum. Especially, it is preferred that the second refractory metal such as molybdenum is provided in the region far from the forefront of the electrode. According to a preferred embodiment

of the invention, the electrode comprises a first and a second refractory metal such as tungsten and molybdenum, wherein the first refractory metal region such as the tungsten region is coupled to the second refractory metal region such as the molybdenum region via a solid connection, preferably via a hydraulic coupling.

[0013] The invention also concerns a method for manufacturing an electrode of a gas discharge lamp system. According to the invention, this method comprises a step wherein the electrode is designed as a heat pipe by rapid prototyping. The rapid prototyping step can including making an electrode that is porous at the inside and at the same time has a heat sink-shape at the outside.

[0014] Rapid prototyping is understood to be the automatic construction of physical objects using solid freeform fabrication. Rapid prototyping takes virtual designs from a CAD software, transforms them into thin, horizontal cross-sections and then creates each cross-section in physical space, one after the other until the model is finished. With additive fabrication, the machine reads in data from a CAD drawing and lays down successive layers of liquid, powder, or sheet material, and in this way builds up the model from a series of cross sections. These layers, which correspond to the virtual cross section from the CAD model, are joined together or fused automatically to create the final shape. The primary advantage to additive fabrication is its ability to create almost any shape or geometric feature. Especially, in this way, a porous interior of a heat pipe electrode can be achieved in an easy and efficient way.

[0015] According to a preferred embodiment of the invention, this method of rapid prototyping comprises at least one of the following techniques: selective laser sintering, fused deposition modelling, selective laser melting and electron beam melting.

[0016] Further embodiments are described by the dependent claims attached.

[0017] These and other aspects of the invention will be more apparent from and elucidated with reference to the embodiment described hereinafter.

Brief Description of the drawings

[0018] In the drawings:

Fig. 1 schematically depicts a gas discharge lamp system according to an em- bodiment of the invention in a cross-sectional view,

Fig. 2 shows a cross-section through an electrode which is designed as a heat pipe according to an embodiment of the invention, and

Fig. 3 shows a schematic side view of an electrode according to another em- bodiment of the invention.

Description of the illustrative embodiments

[0019] The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes.

[0020] Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

[0021] Moreover, the terms top, bottom, over, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other orientations than described or illustrated herein.

[0022] It is to be noticed that the term "comprising", used in the claims, should not be interpreted as being restricted to the means listed thereafter; it does not exclude other elements or steps. Thus, the scope of the expression "a device comprising means A and B" should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

[0023] Similarly, it is to be noticed that the term "coupled", also used in the claims, should not be interpreted as being restricted to direct connections only. Thus, the scope of the expression "a device A coupled to a device B" should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means.

[0024] Fig. 1 shows a gas discharge lamp system according to an embodiment of the invention. This gas discharge lamp system comprises a gas discharge lamp 1 with a glass bulb 2 and two electrodes 3. The electrodes 3 are glass sealed into the glass bulb 2. The electrodes 3 are provided in a two-part form, e. g. comprising a first refractory metal region, e.g. a tungsten region 4 near the forefront 5 and a second metal region which can also be a refractory metal region, e.g. a molybdenum region 6 more distant to the forefront 5. In the following reference to tungsten or molybdenum includes within its scope any suitable refractory metal. Refractory metals are Tungsten, Molybdenum, Niobium, Tantalum, Rhenium. The tungsten region 4 is connected to the molybdenum region

6 via a tight connection, i. e. a hydraulic coupling 8. Further, both electrodes 3 are connected with their molybdenum region with a heat sink 9 which is further cooled with a cooling system 10 comprising a fan 11.

[0025] As can be seen from Fig. 2 which shows a cross-sectional view of the tungsten region 4 of one electrode 3, the electrode 3 of the embodiment according to the invention is designed as a heat pipe. For that, the electrode 3 comprises a non-porous sealed tube 12 with a porous interior 13. The porous interior 13 is formed by porous tungsten which acts as a "metallic sponge". This porous tungsten is only provided near the inner walls of the tube 12, leaving a hollow space 14 in the tube 12.

[0026] The electrode 3 can be made by rapid prototyping. The rapid prototyping step can including making an electrode that is porous at the inside and at the same time has a heat sink-shape at the outside. In a further embodiment the heat pipe electrode is provide having 3 parts formed from two refractory metals and a third metal, e.g. a Tungsten part, a Molybdenum part and a third part which at its outside is shaped and acts as heat-sink (e.g. aluminium or other good conductive material). Such electrodes may be made bay rapid prototyping, rapid manufacturing or additive manufacturing or combinations of such techniques with other methods.

[0027] Rapid prototyping is understood to be the automatic construction of physical objects using solid free-form fabrication. Typically, rapid prototyping takes virtual designs from a CAD software, transforms them into thin, horizontal cross-sections and then creates each cross-section in physical space, one after the other until the model is finished. With additive fabrication, the machine reads in data from a CAD drawing and lays down successive layers of liquid, powder, or sheet material, and in this way builds up the model from a series of cross sections. These layers, which correspond to the virtual cross section from the CAD model, are joined together or fused automatically to create the final shape. Especially, in this way, a porous interior of the electrode which is designed as a heat pipe can be achieved in an easy and efficient way.

[0028] According to a preferred embodiment of the invention, this method of rapid prototyping comprises at least one of the following techniques: selective laser sintering, fused deposition modelling, selective laser melting and electron beam melting.

[0029] The tube 12 is partly filled with a cooling medium at a pressure which is less than ambient pressure. In this way, the functionality of a heat pipe as described further above is achieved by the electrodes 3 themselves which provides for a very efficient possibility of moving heat away from the forefront 5 of the electrode 3. Accordingly, the heat can be transported further away from the electric arc where there is more room for getting rid of the heat. When using the gas discharge lamp 1, the temperature of the electrodes 3 is less and, thus, the length of the electric arc can be made shorter, giving increased possibilities for capturing light with the electric arc approaching the ideal "point source".

[0030] Further, from Fig. 3 an electrode 3 according to another embodiment of the invention can be seen. This electrode 3 is also designed as a heat pipe, i.e. the interior of this electrode 3 is essentially the same as described before with respect to Fig. 2. However, this electrode 3 has a diameter and cross-section which is smaller near the forefront and greater further away from the forefront. This provides for better cooling possibilities due to the higher cross-section while still providing an almost ideal point source due to the small diameter end of the electrode 3. Also this electrode can be made by rapid prototyping such as by at least one of the following techniques: selective laser sintering, fused deposition modelling, selective laser melting and electron beam melting.

[0031] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. For example, there are other ways of sealing between glass and a refractory metal such as tungsten that can be applied, such as the provision of graded or different glass layers, e.g. graded from a Coefficient of Thermal Expansion similar to Tungsten (at the contact surface with the electrodes) to another glass with CTE, similar to the glass used for the bulb. When applying this type of sealing, only one material is necessary for the heatpipe-electrodes as used in embodiments of the present invention. In such a case, there is no need for a further connection with molybdenum for example.

[0032] Also any of the manufacturing methods of Additive Fabrication, Rapid Prototyping (RP) or Rapid Manufacturing (RM) are considered to be included in, and interchangeable for all references above to rapid prototyping.

[0033] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. Gas discharge lamp system, with a gas discharge lamp (1) comprising two electrodes (3) for generating an electric arc in between, wherein at least one electrode (3) is provided as a heat pipe.

2. Gas discharge lamp system according to claim 1, wherein the electrode (3) which is provided as a heat pipe comprises a sealed non-porous tube (12) with at least a partially porous interior (13).

3. Gas discharge lamp system according to claim 2, wherein the at least partially porous interior (13) is provided with a cooling medium (14).

4. Gas discharge lamp system according to claim 2 or 3, wherein the pressure inside the sealed non-porous tube (12) of the electrode (3) is less than ambient pressure.

5. Gas discharge lamp system according to any of claims 1 to 4, wherein the electrode (3) is connected to a heat sink (9) or is shaped as at least part of a heat sink.

6. Gas discharge lamp system according to claim 5, wherein the gas discharge lamp (1) comprises a glass bulb (2) and the heat sink (9) is provided outside the glass bulb (2).

7. Gas discharge lamp system according to any of claims 1 to 6, wherein the diameter of the electrode (3) in a region near to the forefront (5) of the electrode is less than in a region more distant to the forefront (5).

8. Gas discharge lamp system according to any of claims 1 to 7, wherein the electrode (3) which is provided as a heat pipe comprises a first refractory metal.

9. Gas discharge lamp system according to claim 8, wherein the first refractory metal is provided in the region to the forefront (5) of the electrode (3) where the electric arc is to be generated.

10. Gas discharge lamp system according to any of claims 1 to 9, wherein the electrode (3) which is provided as a heat pipe comprises at least a second refractory metal.

11. Gas discharge lamp system according to claim 10, wherein the at least one second refractory metal is provided in the region far from the forefront (5) of the electrode (3).

12. Gas discharge lamp system according to any of claims 1 to 11, wherein a tungsten region (4) is coupled to a molybdenum region (6) via a connection, preferably via a hydraulic coupling (8).

13. Method for manufacturing an electrode (3) of a gas discharge lamp (1), wherein the electrode is formed as a heat pipe by rapid prototyping.

14. Method according to claim 13, comprising at least one of the following techniques: selective laser sintering, fused deposition modelling, selective laser melting and electron beam beam melting.

15. Method of cooling a gas discharge lamp comprising two electrodes (3) for generating an electric arc in between, the cooling of at least one electrode (3) is done via a heat pipe.

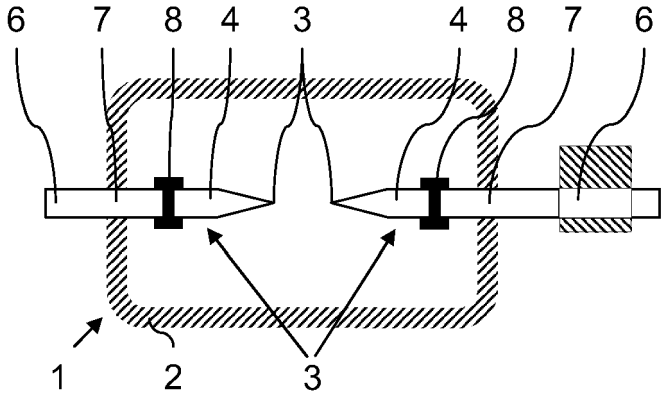

FIG. 1

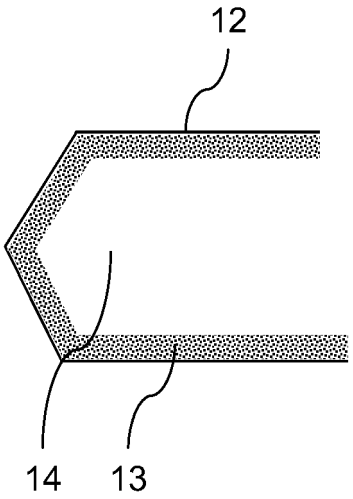

FIG. 2

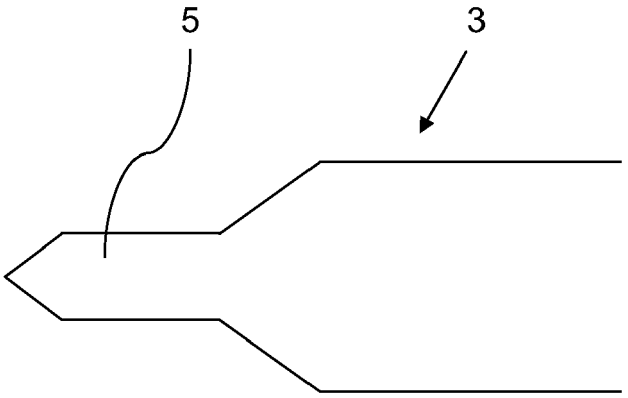

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 08 16 0467

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 1 498 799 A (BRITISH AIRCARFT CORPERATION LTD) 25 January 1978 (1978-01-25) * page 1, line 69 - line 78 * * page 2, line 65 - line 71; figure 1 *	1-6,10, 11,13-15	INV. H01J61/52 H01J61/073 H01J9/02
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 December 2008	Smith, Christopher

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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