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Stuart et al.

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[54] **ION SLEEVE FOR ARC LAMP ELECTRODE**

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[73] Assignee: **Varian Associates,** Palo Alto, Calif.

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[52] **U.S. Cl.** **313/217,** 313/184;198;208;356

[51] **Int. Cl.** **H05b 37/00**

[58] **Field of Search** 313/184, 198, 208, 217, 313/326, 351, 356, 357

[56] **References Cited**

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[57] **ABSTRACT**

The voltage required to initiate an arc across the electrode gap in a gas-filled arc lamp can be significantly reduced by providing a refractory metal sleeve overhanging the tapered end of one of the electrodes. The direction and extent of the overhang must be such that the electric field strength at the distal end of the overhanging portion of the sleeve is greater than at the apex of the electrode to which the sleeve is affixed.

4 Claims, 4 Drawing Figures

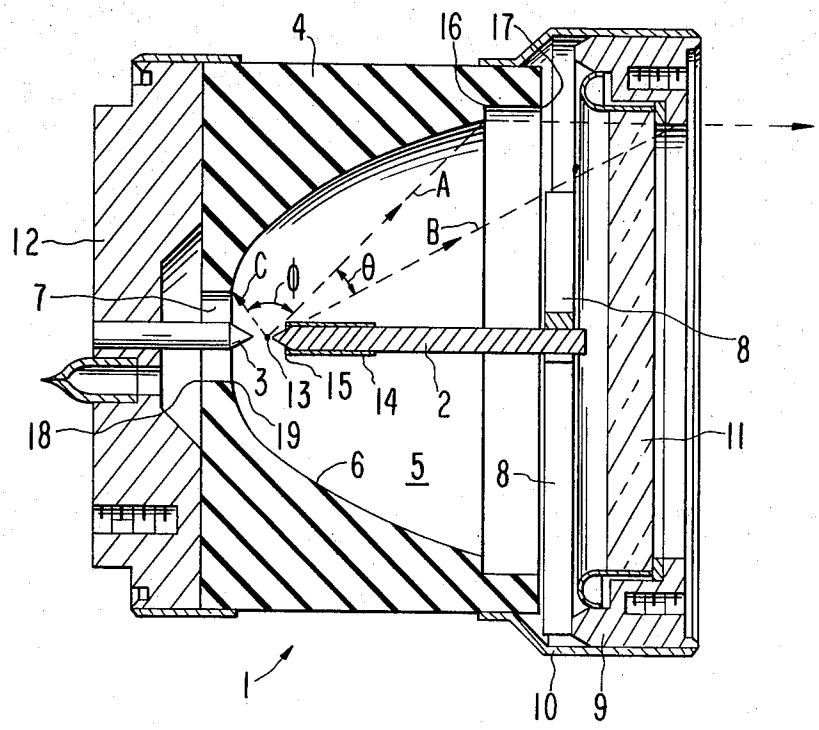


FIG. 1

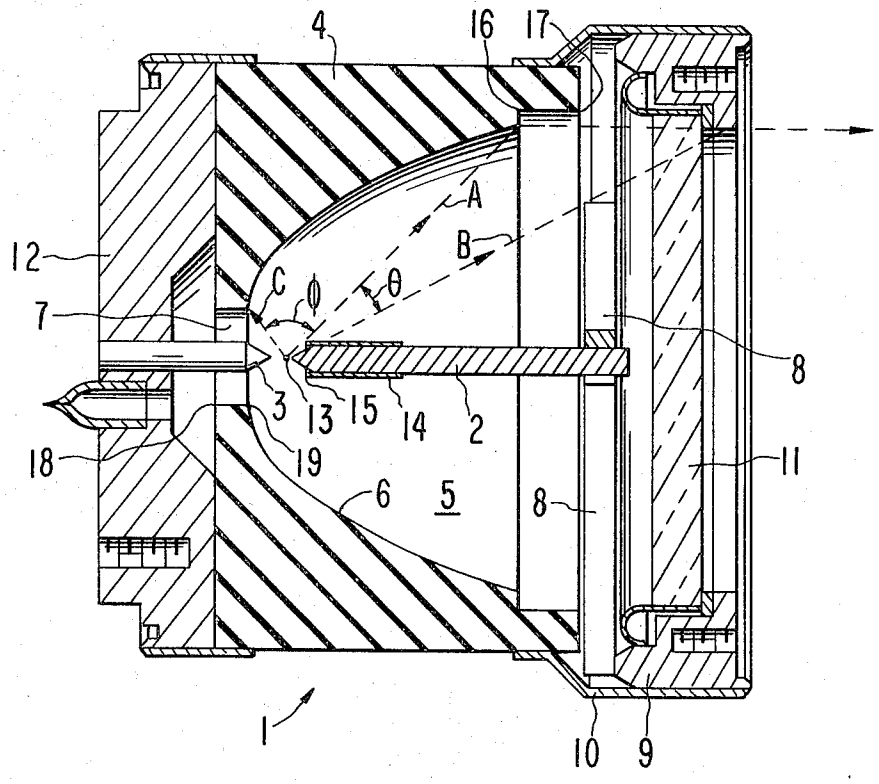


FIG. 4

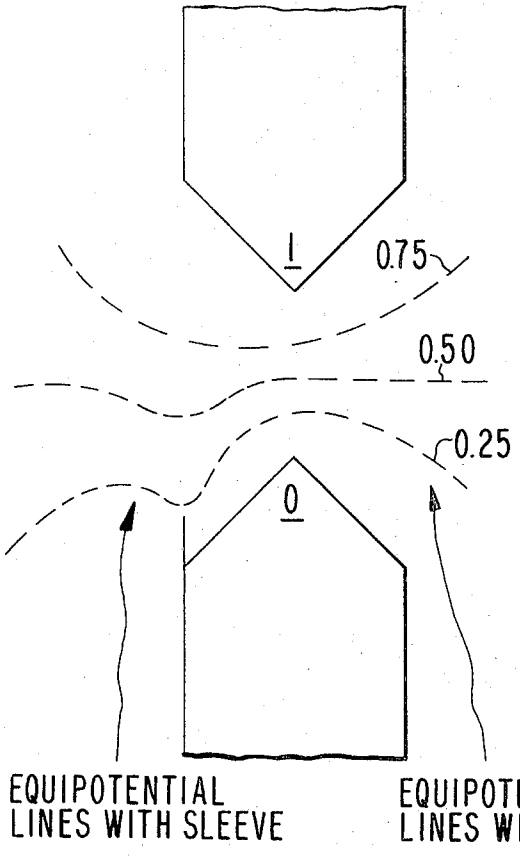


FIG. 2

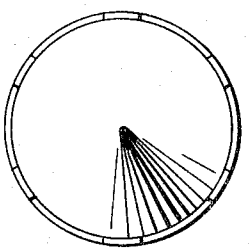
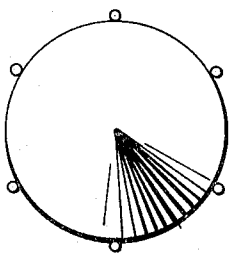


FIG. 3



ION SLEEVE FOR ARC LAMP ELECTRODE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention is a further development in the art of lowering the voltage required to initiate an arc between the electrodes of a gas-filled arc lamp.

2. Description of the Prior Art

Gas-filled arc lamps that are started by the initiation of an arc between two fixed electrodes are well-known to the prior art. With such lamps, high voltages are necessary to cause ionization in the gap between the electrodes. For example, high-intensity arc lamps of the type described in U.S. Pat. No. 3,731,133, issued May 1, 1973 and assigned to Varian Associates, typically require a difference of potential on the order of 24 kilovolts to initate an arc between the anode and the cathode. Such high starting voltages render likely the possibility of arcing between the electrodes or their supporting structures and other metallic components of the lamp. The possibility of arcing between an electrode and the reflector of the lamp is a particularly detrimental consequence of such high voltages. A reflector surface typically comprises a thin metallic coating upon a supporting member, and arcing from an electrode or electrode support to such a coating could cause spotting or discoloration of the reflector which would seriously diminish the optical efficiency of the lamp. Furthermore, the higher the starting voltage of such a lamp, the longer must be the axial dimension of the insulating member separating the anode assembly from the cathode assembly. However, as the axial length of the insulating member separating the electrode assemblies increases, the amount of light falling on the insulating member also increases. Any light falling on an internal component of the lamp and not reflected out through the lamp window is absorbed and therefore lost. Hence, any decrease in the axial length of the insulating member separating the electrode assemblies will provide a corresponding increase in the optical efficiency of such a lamp.

SUMMARY OF THE INVENTION

This invention provides a sleeve structure that can be affixed to an arc lamp electrode to reduce the voltage required to start the lamp.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 shows a cross-sectional view of an arc lamp embodying the ion sleeve of this invention, and also shows rays of light from the brightest spot of the arc of such a lamp.

FIG. 2 shows an end view of one embodiment of the ion sleeve of this invention affixed to either the anode or the cathode of an arc lamp.

FIG. 3 shows an end view of another embodiment of the ion sleeve of this invention affixed to either the anode or the cathode of an arc lamp.

FIG. 4 shows a schematic view of the electric field between the electrodes of the arc lamp of FIG. 1, with the left-hand portion of FIG. 4 showing equipotential lines for the electric field of a lamp embodying the ion sleeve of this invention and the right-hand portion showing equipotential lines for the electric field of a lamp without the ion sleeve of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The lamp shown in FIG. 1 is substantially similar in most respects to that described in the U.S. Pat. No. 3,731,133 referred to above, and for purposes of this disclosure is illustrative of any gas-filled arc lamp that is started by the application of a difference of electrical potential between two fixed electrodes. The present invention is not restricted in its applicability to an arc lamp of the design shown in FIG. 1, but will find general applicability in any gas-filled arc lamp that provides for a difference of potential to be applied between a fixedly positioned cathode and a fixedly positioned anode to ionize a gas in the gap between these two electrodes.

The lamp **1** shown in FIG. **1** has a cathode **2** and an anode **3**, which are electrically insulated from each other by a ceramic insulator **4**. Insulator **4** is cylindrically configured, with a reflector-shaped concavity **5** in one end symmetrically disposed about the cylindrical axis thereof. The surface **6** of the concavity **5** is typically coated with a reflective metallic coating, as by a vapor deposition process, to provide maximum reflectance of light impinging thereon. The end of insulator **4** opposite the concavity **5** has a hole **7** symmetrically disposed with respect to the axis of the insulator **4** and extending into concavity **5** to provide communication from one end of insulator **4** through to the other end. Cathode **2** is fixedly mounted on supporting struts **8** which are brazed to a ring **9**, which is itself brazed to a surrounding annular structure **10**. Annular structure **10** supports not only the cathode mounting members **8** and **9** but also a window with its mounting members (not numbered). The surface **6** of concavity **5**, as well as annular structure **10**, window **11** and certain window mounting members (not numbered), partially define an envelope for confining an ionizable gas, which is typically xenon. Anode **3** is mounted on base plate **12** and extends through hole **7** into concavity **5**. Base plate **12** completes the envelope for confining the ionizable gas. Both cathode **2** and anode **3** are elongate along the axis of insulator **4**, and the tip **13** of cathode **2** is fixedly positioned with respect to the focus of reflective surface **6**. The lamp **1** is most conveniently operated with cathode **2** being maintained at ground potential, inasmuch as cathode **2** is in electrical contact with annular structure **10** which serves to cover and protect the front end of the lamp. Therefore, a difference of potential is applied between cathode **2** and anode **3** by applying a voltage to anode **3** through base plate **12**. It is important that a positive voltage be applied to base plate **12**, so that electrode **3** will function as the anode rather than as the cathode. In an arc between a cathode and an anode, the brightest portion of the arc is a small region immediately adjacent the tip of the cathode. Most of the light from the arc originates from this so-called "hot spot." In order to maximize the amount of light reflected out through the lamp window, it is necessary to fixedly position the tip of the cathode with respect to the focus of the reflector so that the hot spot remains constantly at the focus of the reflector during lamp operation. In the lamp design shown in FIG. **1**, the forward electrode **2** is supported by struts **8** in such a way that relative movement of the electrode tip **13** with respect to the focus of reflective surface **6** is substantially prevented as the various components of the lamp ther-

mally expand and contract. Details of this electrode mounting technique are provided in U.S. Pat. No. 3,725,714, issued Apr. 3, 1973 and assigned to Varian Associates. On the other hand, for the way rear electrode **3** is mounted, as shown in FIG. **1**, relative movement of the arc end of rear electrode **3** with respect to the focus of the reflective surface **6** during lamp operation cannot be prevented. Thus, it is important that forward electrode **2** function as the cathode and that rear electrode **3** function as the anode.

Once a lamp of the type shown in FIG. **1** is in operation, a very low voltage on the order of 20 volts is all that is needed to maintain operation. However, to initiate the arc across the electrodes in order to start the lamp, a voltage on the order of 24 kilovolts is typically needed. The actual required starting voltage will depend upon the particular configuration of the components of the lamp and on the type and pressure of the gas used. The required starting voltage is usually applied in the form of a pulse of short duration.

In general, it is always desirable to reduce the starting voltage requirements for arc lamps that are to be used, for example, in aviation, industrial or medical applications. The higher the voltage requirements, the more costly the necessary power supplies become. Also, the higher the difference of potential between the electrodes, the more likely is there to occur arcing from the electrodes or electrode supports to other metallic components of the lamp. The greater the likelihood of such arcing, the greater is the uncertainty that the lamp will start when the starting circuit is energized. Furthermore, arcing between an electrode or an electrode support and the reflector is likely to cause pitting and discoloration of the reflector with consequent diminution in the reflectance of the reflector surface. For a lamp as shown in FIG. **1**, the higher the difference of potential between the cathode **2** and the anode **3**, the greater must be the total length of the nonmetallized internal portions of insulator **4** in its axial dimension, (e.g., the portion between points **16** and **17** and the portion between points **18** and **19** of the lamp shown in FIG. **1**). However, the greater the axial length of the insulator **4**, the further the window **7** must be located from the hot spot of the arc and the greater will be the amount of light from the arc falling upon nonreflective internal components of the lamp. Thus, the optical efficiency of such a lamp could be improved by lowering the voltage required to start the lamp.

It has been found that by providing an electrode of the lamp shown in FIG. **1** with a sleeve structure, which is designated herein as an "ion sleeve," as will be described more fully below, it is possible to reduce the starting voltage from approximately 24 kilovolts to approximately 13 kilovolts. The actual amount of reduction in the required starting voltage for any given lamp will depend upon the configuration of the components of the lamp. However, for any given arc lamp design, the starting voltage can be dramatically reduced by affixing an ion sleeve according to this invention to one of the electrodes of the lamp.

As illustrated in FIG. **1**, ion sleeve **14** is a cylindrical structure having a continuous sharp-edged surface overhanging the tapered end of cathode **2**. The ion sleeve **14** is made of a refractory metal such as tungsten, and could be affixed to the electrode by spot-welding. The extent of the overhang is limited by the fact that light rays emanating from the arc, and in particular from the hot spot of the arc, are intercepted by the overhanging portion of the ion sleeve. To appreciate the fact that the ion sleeve **14** shown in FIG. **1** obstructs a certain portion of the light emanating from the hot spot of the arc between cathode **2** and anode **3**, it is instructive to consider light rays A, B and C emanating from the hot spot located immediately adjacent the tip **13** of the cathode **2**. Light in the solid angle ϕ between rays A and C is reflected from reflective surface **6** out through window **11**. Light in the solid angle θ between rays A and B, on the other hand, is obstructed by the overhanging portion of the ion sleeve **14**. However, the obstruction by ion sleeve **14** of light in the solid angle θ is of no consequence with respect to the optical efficiency of the lamp. If the ion sleeve **14** were not present, the light in solid angle θ would be absorbed by nonreflective internal components of the lamp and would never pass out through the window **11**. Thus, for the design illustrated in FIG. **1**, the optimum overhang of the ion sleeve **14** is the amount necessary to intercept all light in the solid angle θ without blocking any light in the solid angle. ϕ . If the overhang of ion sleeve **14** were to extend into solid angle ϕ , light would be blocked which would otherwise be reflected out through window **11**, and the optical efficiency of the lamp would thereby be reduced. If the overhang of ion sleeve **14** were less extensive than as illustrated in FIG. **1**, there would be no diminution in optical efficiency because of the blockage of light that could otherwise be reflected, but there would be a diminution in optical efficiency caused by the consequences discussed above of failing to lower the starting voltage as much as possible (for reasons that will be discussed hereinafter).

For any given arc lamp design, the optimum configuration and overhang of the ion sleeve represents a compromise between an attempt to lower the voltage needed to initiate an arc between the electrodes and an attempt to reflect as much light as possible out through the window. Thus, for the design illustrated in FIG. **1**, the cylindrical ion sleeve **14** overhangs the beginning of the tapered portion of the arc end of cathode **2** by approximately one-quarter of the distance from the beginning of the tapered portion to the tip **13** of cathode **2**. Because of the configuration of the reflective surface **6** and the other components of the lamp, there is no advantage in flaring the overhanging portion of the ion sleeve **14**. However, for some particular arc lamp design, a flared overhanging portion might represent the best compromise between a desired reduction in starting voltage and a tolerable obstruction of light rays to the reflector.

For an arc lamp design similar to that illustrated in FIG. **1**, with the additional constraint that the axial length of insulator **4** may not be as long as that illustrated in FIG. **1**, it may be necessary to extend the overhang of ion sleeve **14** into solid angle ϕ in order to achieve significant reduction in the starting voltage of the lamp. In such a situation, a certain diminution in the amount of light reflected out through the window **11** must be tolerated. However, in order to allow more light to reach the reflective surface **6** than would be possible if the ion sleeve **14** were a continuous surface, it is expedient to cut slots in the overhanging portion of the ion sleeve **14** as illustrated in the end view provided in FIG. **2**. With a slotted overhanging portion, light in solid angle ϕ would pass through the slots to the reflective surface **6**, and would be blocked only by the re-

maining areas of the overhanging portion. Depending upon the particular configurations of the various internal components of the arc lamp and on the relative importance of reduced starting voltage versus maximum optical efficiency, it may be desirable to make the slots more or less wide. The limiting case of an ion sleeve having a slotted overhanging portion would be a crown-like sleeve having sharply pointed spikes projecting from the electrode to which it is affixed, as illustrated by the end view shown in FIG. **3.**

The ion sleeve of this invention could be advantageously affixed to the anode rather than to the cathode, as will be shown hereinafter. If for a particular arc lamp design the amount of light emitted through the lamp window would not be too severely diminished, it would be desirable from the standpoint of lowering the starting voltage to affix an ion sleeve to each of the electrodes. It will also be appreciated that each of the ion sleeve embodiments described above could be formed integrally with an electrode rather than being a separate structure affixed thereto as by spot-welding.

To understand the effect of the ion sleeve of this invention, it is instructive to consider the equipotential lines for the electric field between the anode and the cathode of an arc lamp. The right-hand side of FIG. **4** shows equipotential lines for an arc lamp without an ion sleeve, and the left-hand side shows equipotential lines for the same arc lamp with an ion sleeve. The sharp edge of the overhanging surface (or the sharp point of a projecting spike in the case of that embodiment) of the ion sleeve has a radius of curvature that is much smaller than the radius of curvature of the tip of the electrode to which the sleeve is attached. Consequently, there is a steeper gradient for the equipotential lines, and therefore a higher electric field strength, at the edge of the ion sleeve than at the tip of the electrode to which the sleeve is attached. In FIG. **1,** there is a greater electric field strength at the edge **15** of ion sleeve **14** than at the tip **13** of cathode **2,** even though edge **15** is further away than tip **13** is from anode **3.**

When the ion sleeve is affixed to the cathode, as illustrated in FIG. **1,** the effect of the ion sleeve is as follows. When a voltage is applied to the anode, electrons will be emitted very copiously from the sleeve edge (which is at cathode potential with respect to the anode) by the well-known field emission process. These emitted electrons will ionize the gas in the vicinity by the well-known Townsend avalanche process, with field intensification as described, for example, in *Gaseous Conductors: Theory and Engineering Applications* by J. D. Cobine; Dover Publications, Inc., New York, 1958, Chapter 7. Subsequent events leading to the final steady-state arc discharge between the cathode and the anode may follow two alternative courses, or a combination of both courses. According to one alternative, the initial stream of electrons from the sleeve edge to the anode results in the creation of a number of positive ions, which travel to the cathode where the kinetic energy of the impinging positive ions heats the cathode and thereby releases fresh electrons for migration to the anode. These fresh electrons create additional positive ions, which in turn impinge upon the cathode to cause more electrons to be emitted. The process is repeated until the cathode itself becomes hot enough to emit electrons copiously by thermiomic emission. According to the other alternative, a number of positive ions created by the initial electron stream from the sleeve edge to the anode return to the sleeve, where they very rapidly set up a self-sustained arc discharge between the sleeve and the anode. The arc discharge between the sleeve and the anode rapidly transfers to the gap between the anode and the cathode due to a combination of electric and magnetic forces. It is clear that a low work-function surface on the sleeve would promote field emission, and therefore would reduce even further the voltage that would be required to initiate the arc discharge. Thus, when the ion sleeve is affixed to the cathode electrode, a low work-function surface at the edge of the sleeve would be highly desirable.

The schematic illustration shown in FIG. **4** represents an ion-sleeve (of whatever configuration) affixed either to the cathode (as shown in FIG. **1**) or to the anode. The distortion of the electric field caused by the ion sleeve is the same, whether the sleeve is affixed to the anode or to the cathode. Where the sleeve is affixed to the anode, the effect of the sleeve on the initiation of the arc discharge involves the positive corona phenomenon as described, for example, in Chapter **8** of *Gaseous Conductors: Theory and Engineering Applications*, referred to above. Ionization occurs close to the sharp edge of the sleeve, because the electric field strength at the sleeve edge is great enough that the Townsend avalanche process can produce a high positive ion density even though the initial electron density is low. Electron emission from the cathode is not necessary because the natural abundance of free electrons in the gas (caused, for example, by background radiation) is sufficient. As in the case where the sleeve is affixed to the cathode, the positive ions migrate to the cathode, thereby setting up a self-sustained arc discharge between the sleeve and the cathode. This arc may very rapidly transfer to the gap between the anode and the cathode. Alternatively, the positive ions produced close to the sleeve edge may migrate to cathode, and the electrons thereby emitted from the cathode may travel directly to the anode rather than to the sleeve, thereby directly setting up the arc between the anode and the cathode. It is likely that a combination of both mechanisms actually occurs. However, it has been found experimentally that the arc soon stabilizes between the anode and the cathode and does not persist between the sleeve and the opposite electrode.

What is claimed is:

1. An arc lamp comprising an envelope for confining an ionizable gas, a reflector in said envelope, first and second electrodes mounted within said envelope on a common axis and being separated from each other along said axis in non-overlapping arrangement to form an arc gap between the facing ends of said electrodes, said first electrode having a generally conical surface at its end which faces the opposite electrode, said common axis being substantially parallel to the direction taken by light reflected from said reflector, said first electrode also having a projecting portion which extends from the base of said conical surface toward said gap, whereby an electrical potential between said electrodes will establish an electrical field which is greater at the distal end of said projecting portion than at the apex of said first electrode.

2. The arc lamp of claim **1** wherein said projecting portion comprises a sleeve forming a continuous annular surface at its end which projects toward said gap.

3. The arc lamp of claim 1 wherein said projecting portion extends parallel to said axis.

4. The arc lamp of claim 1 wherein said arc gap, said reflector, and the projecting end of said projecting portion are positioned relative to each other such that said projecting end of said projecting portion intercepts no light from said arc which would otherwise fall on said reflector.

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