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[54] **INCANDESCENT LAMPS HAVING PROTECTION AGAINST VOLTAGE SURGES**

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[51] **Int. Cl.**[2] **H01K 1/62**

[58] **Field of Search** 315/46, 48, 71, 125, 205, 315/92, 58, 72, 75, 126, 311; 313/315; 338/219

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[57] **ABSTRACT**

A body of sintered polycrystalline varistor material connected across the filament of an incandescent lamp shunts a transient voltage surge thereby protecting the lamp filament. The body of varistor material is alternatively included in the lamp base member or comprises a pill of varistor material having contact members for insertion in a lamp socket.

11 Claims, 5 Drawing Figures

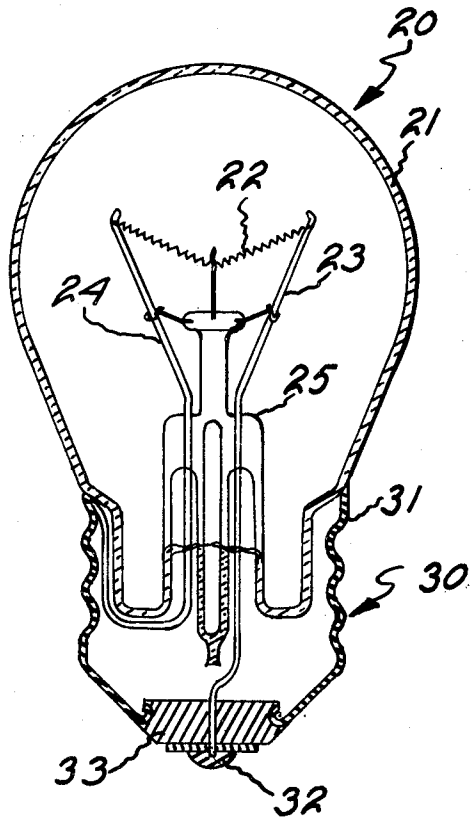


Fig.1

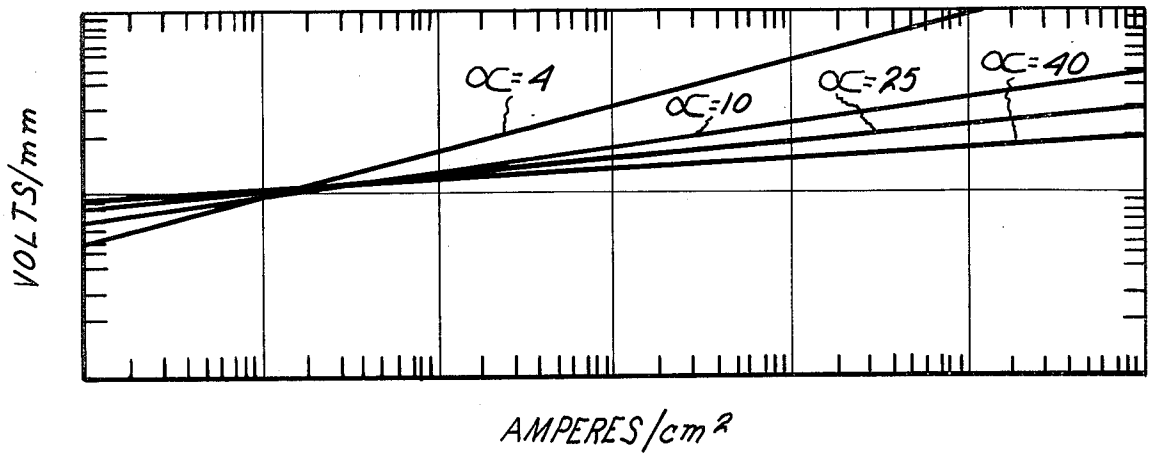


Fig.2

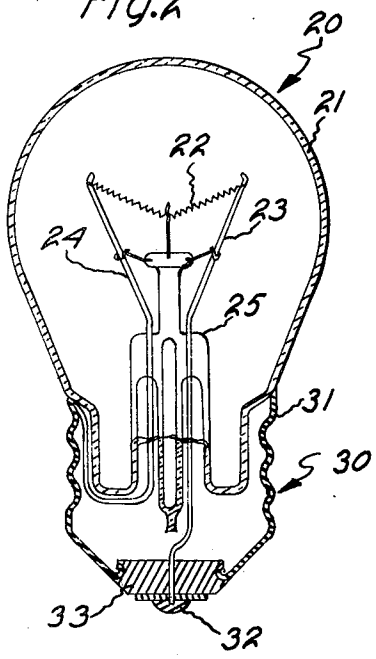


Fig.3

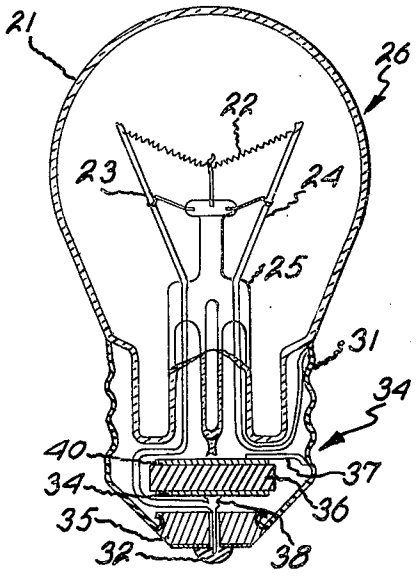


Fig.4

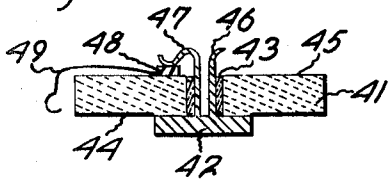
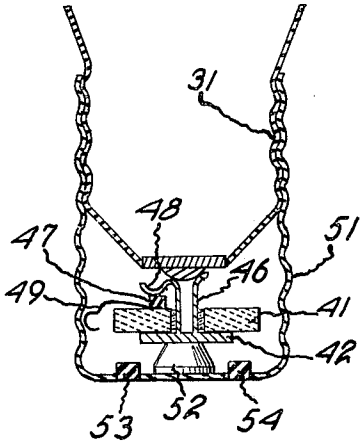


Fig.5



INCANDESCENT LAMPS HAVING PROTECTION AGAINST VOLTAGE SURGES

This invention relates to incandescent lamps. More particularly, this invention relates to protecting incandescent lamps from over-voltage damage by including a polycrystalline varistor electrically in parallel with the filament of the lamp.

This invention is related to my concurrently filed application Ser. No. 355,898. This related application is assigned to the assignee of this invention and is incorporated herein by reference thereto.

Incandescent lamps comprise a coiled tungsten filament contained in an envelope from which oxidizing agents are excluded. Tungsten metal is brittle and difficult to draw and, therefore, incandescent lamp filaments produced in an economically practical manner contain pinches, or thin regions therein. Because these thin regions have increased electrical resistance and decreased mechanical strength with respect to the rest of the filament, they represent weak spots at which filament failure is likely to occur when the lamp is subjected to an over-voltage condition on its supply line. Another filament failure mechanism results from the fact that the filament is coiled. Current flowing through the coiled filament sets up a magnetic field which tends to pull the turns of the coil together. A voltage surge causes an increased current to flow through the filament which in turn increases the intensity of the magnetic field which further draws the turns together and may cause turn-to-turn shorting. Such shorting decreases the electrical resistance of the filament causing more current to flow further increasing the intensity of the magnetic field and shorting more turns in a chain reaction fashion until the filament burns out. As a result of these factors, it is empirically known that the operating lifetime of an incandescent lamp filament is inversely proportional to the voltage applied across the filament raised to the thirteenth power.

It is also known that incandescent lamp filaments exhibit a positive temperature coefficient of resistance such that the resistance of the filament of a lamp at operating temperature is approximately 10–20 times the resistance of the same filament when cold. Naturally, the currents through the lamp exhibit the same 10:1 –20:1 ratio inversely to the resistance. Therefore, a lamp is most likely to fail at the moment of turn-on and is most susceptible to voltage transients on its supply line at that time. It has been shown that a typical residential electrical system is statistically subjected to a voltage transient exceeding 500 volts once per day, a voltage transient exceeding 1000 volts once per week, and a voltage transient exceeding 10,000 volts once per year.

It is, accordingly, one object of this invention to prevent supply line voltage surges from being impressed across the filaments of incandescent lamps to thereby prolong the operating life of the lamps.

Another object of this invention is to be so protect lamp filaments by means of a polycrystalline varistor member connected electrically in parallel with the lamp filaments and mechanically configured to be reliably and inexpensively includable in lamp circuits of current manufacture.

Briefly, and in accordance with one embodiment of this invention, a body of polycrystalline metal oxide varistor material is mechanically included in the base member of an incandescent lamp and is connected electrically in parallel with the filament of the lamp to protect the filament against voltage surges. In accordance with another embodiment of this invention, a body of polycrystalline metal oxide varistor material having a spring contact member is provided for insertion into an incandescent lamp socket so that the body of varistor material is electrically in parallel with the filament of the lamp when the lamp is inserted into its operating position in the socket.

The novel features of this invention sought to be patented are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may be understood from a reading of the following specification and appended claims in view of the accompanying drawings in which:

FIG. **1** is a log-log graphical representation of the current density vs. voltage gradient characteristic of the polycrystalline varistor used in practicing this invention.

FIG. **2** is a cross-sectional elevation view of a protected incandescent lamp in accordance with this invention.

FIG. **3** is a cross-sectional elevation view of an alternative embodiment of a protected incandescent lamp in accordance with this invention.

FIG. **4** is a cross-sectional elevation view of a varistor lamp protector adapted for insertion in a lamp socket in accordance with this invention.

FIG. **5** is a cross-sectional elevation view of a lamp socket having a lamp base inserted therein and including a protective device of FIG. **4** illustrating the operational interaction between the device of FIG. **4** and the protected lamp and its socket.

There are a few known materials which exhibit nonlinear resistance characteristics and which require resort to the following equation to relate quantitatively current and voltage:

$$I = \left(\frac{V}{C}\right)^{\alpha}$$

where V is the voltage between two points separated by a body of the material under consideration, I is the current flowing between the two points, C is a constant, and α is an exponent greater than 1. Both C and α are functions of the geometry of the body formed from the material and the composition thereof, and C is primarily a function of the material grain size whereas α is primarily a function of the grain boundary. Materials such as silicon carbide exhibit nonlinear or exponential resistance characteristics and have been utilied in commercial silicon carbide varistors, however, such nonmetallic varistors typically exhibit an alpha (α) exponent of no more than 6. This relatively low value of alpha represents a nonlinear resistance relationship wherein the resistance varies over only a moderate range. Due to this moderate range of resistance variation, the silicon carbide varistor is often connected in series with a gap when used in a circuit for transient voltage suppression since continuous connection of the varistor could exceed the power dissipation capabilities thereof unless a relatively bulky body of such material is used in which case the steady state power dissipation

is a rather severe limitation. An additional drawback is the ineffectiveness of the voltage clamping action as a result of the limited value of silicon carbide alpha exponent. The moderate range of resistance variation results in voltage limitation which may be satisfactory for some applications, but is generally not satisfactory when the transient voltage has a high peak value.

A new family of varistor materials having alphas in excess of 10 within the current density range of 10^{-3} to 10^{2} amperes per square centimeter has recently been produced from metal oxides. The metal oxide varistor material is a polycrystalline ceramic material formed of a particular metal oxide with small quantities of one or more other metal oxides or halides being added. As one example, the predominant metal oxide is zinc oxide with small quantities of bismuth oxide being added. Other additives may be aluminum oxide, iron oxide, magnesium oxide, and calcium oxide for example. The predominant metal oxide is sintered with the additive oxide(s) to form a sintered ceramic metal oxide body. Since the varistor is fabricated as a ceramic powder, the material can be pressed into a variety of shapes of various sizes. Being polycrystalline, the characteristics of the metal oxide varistor are determined by the grain (crystal) size, grain composition, grain boundary composition, and grain boundary thickness, all of which can be controlled in the ceramic fabrication process.

The nonlinear resistance relationship of polycrystalline metal oxide varistors is such that the resistance is very high (10,000 megohms has been measured) at very low current levels in the microampere range and progresses in a nonlinear manner to an extremely low value (tenths of an ohm) at high current levels. The resistance is also more nonlinear with increasing values of alpha. These nonlinear resistance characteristics result in voltage versus current characteristics wherein the voltage is effectively limited, the voltage limiting or clamping action being more enhanced at the higher values of the alpha exponent as shown in FIG. **1.** Thus, the voltage versus current characteristics of the polycrystalline metal oxide varistor is similar to that of the Zener diode with the added characteristics of being bidirectional and of operating over more decades of current.

The voltage versus current characteristics plotted in FIG. **1** of the drawings illustrate the nonlinear or exponential resistance characteristics exhibited by varistor material, and in particular, the increasing nonlinearity and enhanced voltage limiting obtained with increased values of the exponent alpha (α) wherein the top line $\alpha = 4$ is typical for silicon carbide varistors and the three lines $\alpha = 10$, 25, and 40 apply to varistors fabricated of polycrystalline metal oxide material. It should be understood that metal oxide materials are available having alpha exponents even greater than 40 which thereby obtains even greater enhanced voltage clamping action than that exhibited for the $\alpha = 40$ line.

FIG. **2** is a cross-sectional elevation view of a protected incandescent lamp in accordance with one embodiment of this invention. A lamp indicated generally at **20** comprises an envelope **21** of a light transmissive fluid impervious material such as glass containing a filament **22,** leads **23** and **24,** and support member **25** in an atmosphere excluding reagents capable of reaction with tungsten. Lamp **20** also includes a base member indicated generally at **30** comprising a metallic shell **31** which is configured with a plurality of ridges to adapt lamp **20** to be screwed into a socket and which serves as an electrical contact between the socket and lead **24** which fluid-sealingly penetrates support member **25,** a second electrical contact **32** which provides for connection between a corresponding second contact in the socket and filament **22** through lead **23** which also fluid-sealingly penetrates support member **25,** and a body of polycrystalline metal oxide varistor material **33** disposed electrically and mechanically between contacts **31** and **32.** In steady state operation of lamp **20,** varistor **33** functions as an insulator between contacts **31** and **32.** When on the other hand, a voltage surge occurs on the power lines supplying power to lamp **20,** varistor member **33** becomes conductive and the surge current flows between contacts **31** and **32** almost entirely through varistor member **33** and only insubstantially flows in filament **22,** thereby protecting the filament.

FIG. **3** illustrates another version of a protected incandescent lamp in accordance with this invention. Lamp **26** has envelope **21,** filament **22,** leads **23** and **24,** and support member **25** which are similar to the corresponding elements of lamp **20** of FIG. **2.** Lamp **26** also includes base member **34** comprising shell member **31** and contact member **32** corresponding to the similarly numbered elements of FIG. **2.** In lamp **26,** shell member **31** and contact member **32** are spaced and electrically isolted from each other by conventional insulator member **35.** Base member **34** further includes a body of polycrystalline metal oxide varistor material **36** having electrodes **39** and **40** on opposite faces thereof. Conductive tab **37** connects shell member **31** to electrode **40** of varistor **36,** electrically in parallel with the connection of filament **22** to shell member **31** by lead **24.** Similarly, contact **32** is connected by lead **38** to electrode **39** of varistor member **36,** electrically in parallel with the connection of filament **22** to contact **32** by lead **23.** Thus, under normal steady state operating conditions, varistor member **36** exhibits a very high resistance and substantially all current flowing between contact members **31** and **32** flows through filament **22.** Upon the occurrence of a voltage spike exeeding the varistor voltage of varistor member **36,** member **36** becomes substantially conductive and substantially all of the surge current flowing between contact members **31** and **32** flows through varistor member **36** and almost no surge current flows through filament **22.**

In accordance with another embodiment of this invention, surge protection of conventional incandescent lamps is provided by inserting the protective device of FIG. **4** in a conventional lamp socket as illustrated in FIG. **5.** The protective device of FIG. **4** comprises a disk **41** of polycrystalline metal oxide varistor material having a cylindrical hole through the approximate center thereof. Because of the mechanical properties of the polycrystalline varistor material, the central hole may be formed either in the initial molding of the disk or by subsequent drilling of a solid molded disk. The cylindrical hole through varistor disk **41** contains a cylindrical sleeve **43** of electrically insulating material. An electrically conductive member **42** provides electrical contact to a first face **44** of varistor disk **41.** Member **42** includes conductive spring member projections **46** and **47** which traverse the hole in varistor member **41** interiorily to insulating sleeve **43** to provide for electrical contact between member **42** and a contact member of an incandescent lamp base. At least one of members **46** and **47** is adapted to apply downward pressure upon conductive spring finger member **49**

through insulator block **48** when member, for example, **47** as shown, is compressed by a lamp base. Conductive spring member **49** forms an electrical contact to a second face **45** of varistor member **41** and upon compression through insulator block **48** is urged outwardly to contact the shell member of a lamp base.

FIG. **5** illustrates the installation of the protective device of FIG. **4** in a lamp socket. A lamp socket as shown in FIG. **5** comprises a shell contact member **51** and a center contact member **52** electrically isolated from each other by insulator members **53** and **54.** Shell member **51** is adapted to receive a shell contact member **31** of a lamp base and contact **52** is positioned to provide electrical connection to a contact member **32** of a lamp base when the lamp is screwed into the socket. In accordance with this invention, the protective device of FIG. **4** is positioned in the lamp socket of FIG. **5** with conductive member **42** resting upon and in electrical contact with contact member **52** of the socket. Electrical conduction is provided by spring members **46** and **47** between contact member **52** through contact **42** and the spring members to contact **32** of the lamp base. When the lamp is securely screwed into the socket, lamp contact member **32** compresses spring member **47** which through insulating member **48** exerts a compressive force on spring contact member **49** thereby urging it outwardly and into electrical contact with socket shell member **51.** Accordingly, as hereinbefore discussed, the lamp filament is protected against surges in that steady state current flows from contact **52** through conductive member **42** and spring contact members **46** and **47** to lamp contact **32,** through the filament of the lamp, lamp base shell contact **31** and socket shell **51.** Surge currents, on the other hand, flow from socket contact **52** through conductive member **42,** varistor **41,** and spring contact **49** directly to socket shell member **51** without going through the lamp. In the drawing and in the foregoing discussion, this invention has been illustrated in connection with screw-type lamp bases. Other lamp base configurations, however, such as bayonet, may be substituted in practicing this invention without departing from the scope thereof.

While this invention has been described with reference to particular embodiments and examples, other modifications and variations will appear to those skilled in the art in view of the above teachings. Accordingly, it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than is specifically described.

The invention claimed is:

1. A voltage surge protected incandescent lamp comprising:

a filament;

an envelope for containing said filament in an oxidizing agent excluding atmosphere; and

polycrystalline varistor means connected electrically in parallel with said filament for shunting voltage surges to protect said filament therefrom.

2. The surge protected lamp of claim **1** wherein:

said lamp further comprises a base member including two conductive members for connecting said filament to a source of electrical energy; and

said polycrystalline varistor means is disposed between said conductive members in electrical and mechanical contact therewith.

3. The surge protected lamp of claim **1** wherein:

said lamp further comprises a base member including two conductive members for connecting said filament to a source of electrical energy and an insulating member disposed between said conductive members; and

said polycrystalline varistor means comprises a body of polycrystalline varistor material having a pair of opposed faces, each of said opposed faces being electrically connected to a corresponding one of said pair of conductive members.

4. The surge protected lamp of claim **1** wherein said polycrystalline varistor means is a body of polycrystalline varistor material comprising zinc oxide as a major constituent and a minor constituent selected from the group consisting of other metal oxides and halides.

5. The surge protected lamp of claim **4** wherein said body has a varistor α exponent in excess of 10 in the current density range of 10^{-3} to 10^{2} amperes per square centimeter.

6. The surge protected lamp of claim **1** wherein said polycrystalline varistor means is adapted to be inserted in a lamp socket and comprises:

a body of polycrystalline varistor material having a pair of substantially parallel opposed faces and a void in said body extending from a first of said faces to a second of said faces;

first conductor means connected to said first face for providing electrical connection between said first face and a center contact of a lamp socket;

second conductor means connected to said first conductor means and traversing said void for providing electrical connection between said first conductor means and a center contact of a lamp base; and

third conductor means connected to said second face for providing electrical connection between said second face and a shell contact of a lamp socket.

7. The surge protected lamp of claim **6** wherein said third conductor means is a conductive spring member and further including:

means responsive to compressive forces provided by a lamp base secured in said lamp socket for urging said conductive spring member into contact with said shell contact.

8. The surge protected lamp of claim **7** wherein said means responsive to compressive forces comprises:

an extension of said second conductor means depending toward said third conductive means; and

insulator means disposed between said extension and said third conductor means for transmitting mechanical forces and preventing electrical contact therebetween.

9. The surge protected lamp of claim **6** wherein said body of polycrystalline varistor material comprises zinc oxide as a major constituent and a minor constituent selected from the group consisting of other metal oxides and halides.

10. The surge protected lamp of claim **9** wherein said body has a varistor α exponent in excess of 10 in the current density range of 10^{-3} to 10^{2} amperes per square centimeter.

11. A surge protective device adapted to be inserted in a lamp socket comprising:

a body of polycrystalline varistor materiai having a pair of substantially parallel opposed faces and a void in said body extending from a first of said faces to a second of said faces;

first conductor means connected to said first face for providing electrical connection between said first face and a center contact of a lamp socket;

a second conductor means connected to said first conductor means and traversing said void for providing electrical connection between said first conductor means and a protected device; and

third conductor means connected to said second face for providing electrical connection between said second face and a shell contact of said lamp socket.

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