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Hough et al.

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[54] **PHOTOFLASH LAMP AND METHOD OF COATING SAME**

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Related U.S. Application Data

[62] Division of Ser. No. 268,576, July 3, 1972.

[52] **U.S. Cl.** **156/286;** 156/287; 156/294; 264/92; 264/102; 264/272; 431/93

[51] **Int. Cl.**^{2} **B65B 31/00**

[58] **Field of Search** .... 156/86, 160, 165, 198, 156/212, 213, 214, 229, 215, 267, 285, 286, 287, 293, 294, 303.1, 311, 289, 104; 264/271, 272, 319, 327, 90, 92, 102; 53/22 B; 215/12 A, 12 R, 11 E, 246; 431/94, 95; 206/316, 418

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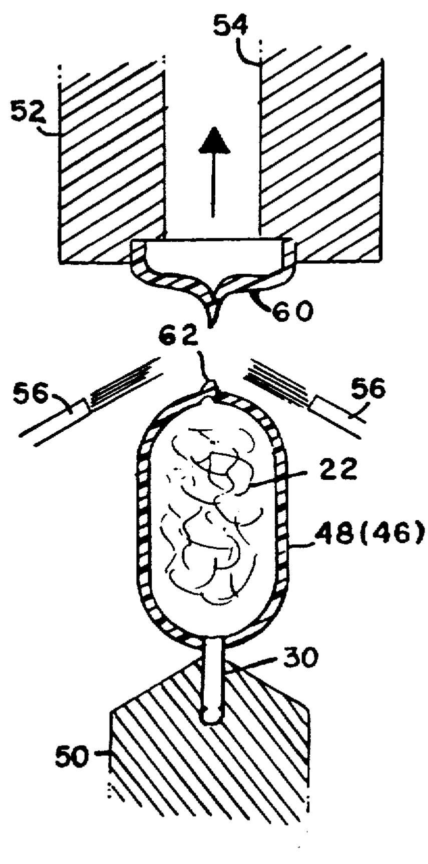
[57] **ABSTRACT**

A photoflash lamp having a vacuum-formed thermoplastic coating for reinforcing the glass envelope of the lamp and enhancing its containment capability upon flashing. Also, a method for applying the coating comprising: locating the glass envelope in a dried, preformed sleeve of thermoplastic material; drawing a vacuum in the space between the sleeve and the envelope; heating the assembly incrementally lengthwise to gradually form the sleeve onto the envelope; and then constricting and tipping off the sleeve at the conclusion of the heating process.

25 Claims, 7 Drawing Figures



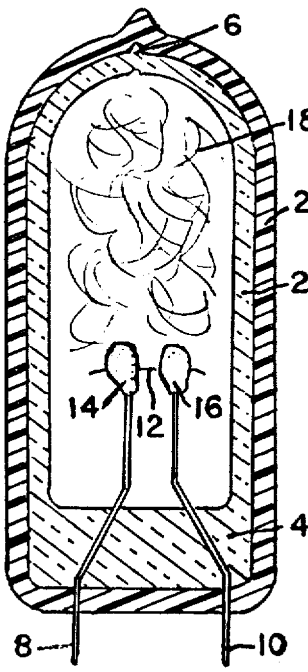


FIG. 1

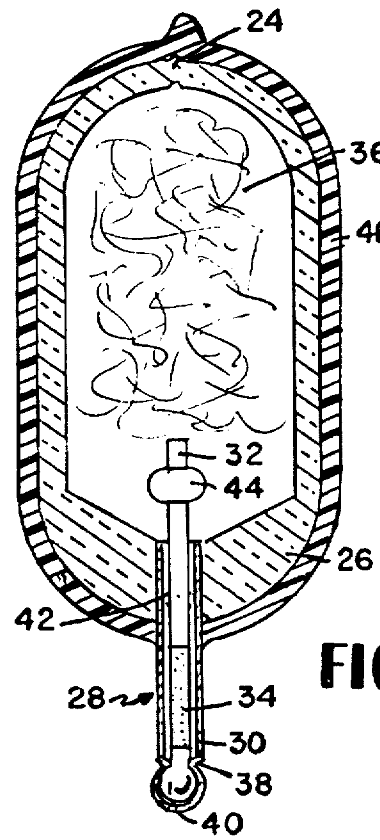


FIG. 2

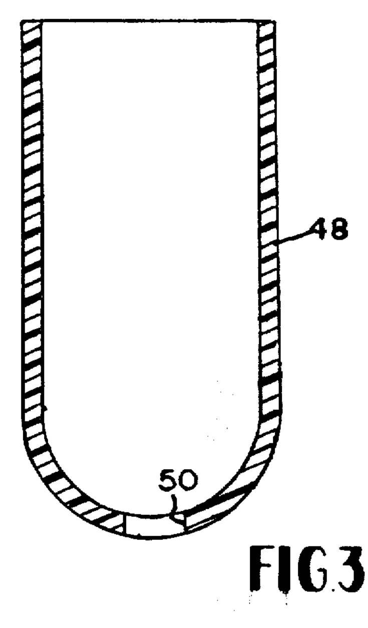


FIG. 3

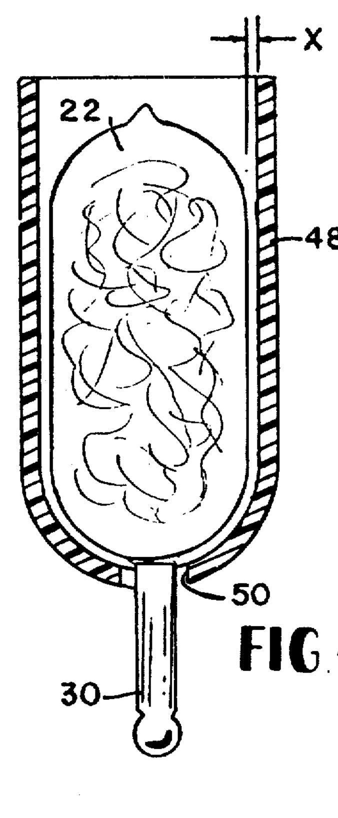


FIG. 4

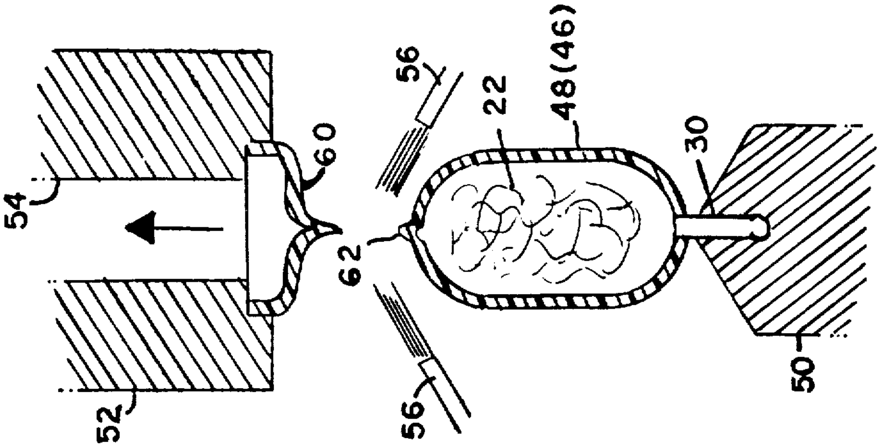


FIG 7

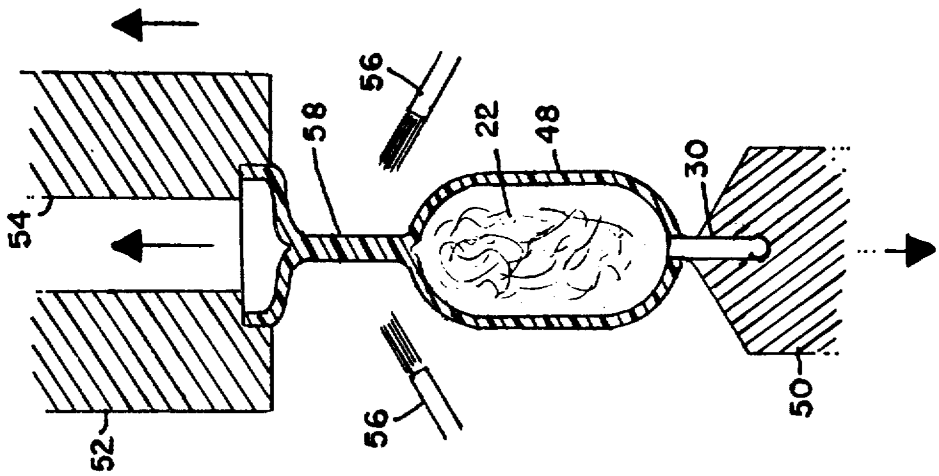


FIG 6

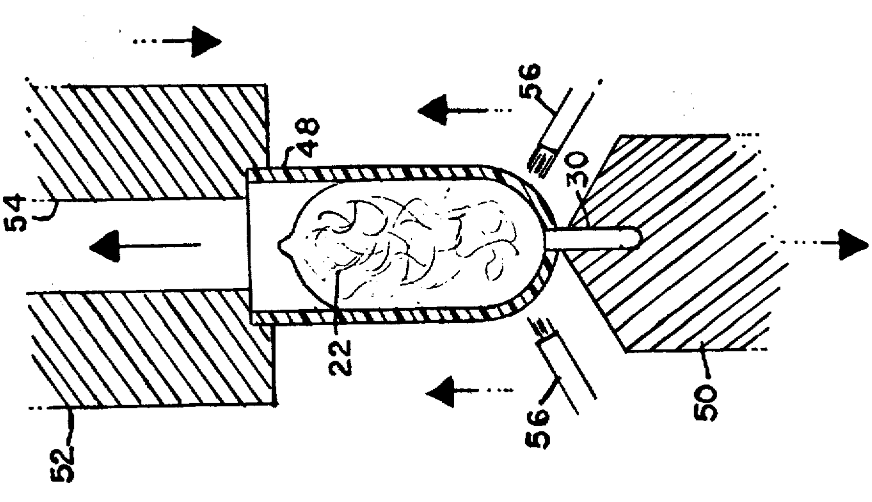


FIG 5

PHOTOFLASH LAMP AND METHOD OF COATING SAME

This is a division of application Ser. No. **268,576** filed July **3, 1972.**

BACKGROUND OF THE INVENTION

This invention relates to photoflash lamps and, more particularly, to a protective coating for flashlamps and a method for applying such a coating.

A typical photoflash lamp comprises an hermetically sealed glass envelope, a quantity of combustible material located in the envelope, such as shredded zirconium or hafnium foil, and a combustion supporting gas, such as oxygen, at a pressure well above one atmosphere. The lamp also includes an electrically or percussively activated primer for igniting the combustible to flash the lamp. During lamp flashing, the glass envelope is subject to severe thermal shock due to hot globules of metal oxide impinging on the walls of the lamp. As a result, cracks and crazes occur in the glass and, at higher internal pressures, containment becomes impossible. In order to reinforce the glass envelope and improve its containment capability, it has been common practice to apply a protective lacquer coating on the lamp envelope by means of a dip process. To build up the desired coating thickness, the glass envelope is generally dipped a number of times into a lacquer solution containing a solvent and a selected resin, typically cellulose acetate. After each dip, the lamp is dried to evaporate the solvent and leave the desired coating of cellulose acetate, or whatever other plastic resin is employed.

In the continuing effort to improve light output, higher performance flashlamps have been developed which contain higher combustible fill weights per unit of internal envelope volume, along with higher fill gas pressure. In addition, the combustible material may be one of the more volatile types, such as hafnium. Such lamps, upon flashing, appear to subject the glass envelopes to more intense thermal shock effects, and thus require stronger containment vessels. One approach to this problem has been to employ a hard glass envelope, such as the borosilicate glass envelope described in U.S. Pat. No. **3,506,385,** along with a protective dip coating. Although providing some degree of improvement in the containment capability of lamp envelopes, the use of dip coatings and hard glass present significant disadvantages in the areas of manufacturing cost and safety. More specifically, the hard glass incurs considerable added expense over the more commonly used soft glass due to both increased material cost and the need for special lead-in wires to provide sealing compatibility with the hard glass envelope. In addition, even through more resistant to thermal shock, hard glass envelopes can also exhibit cracks and crazes upon lamp flashing, and, thus, do not obviate the need for a protective coating.

In the typical dipping process for applying protective coatings, a large number of flashlamps are loaded on a rack and then successively dipped in a solvent solution and oven dried three or four times to build up the desired coating thickness. Such a process is time consuming, uses a relatively large area of production floor space, and involves considerable hand labor, all of which add significantly to manufacturing cost. Further, as the lacquer solution includes a highly flammable solvent, such as acetone, an inadvertant flashing of one of the lamps in either the dip bath or drying oven can ignite the solvent fumes. To substantially reduce or eliminate this hazard, costly automatic extinguishing equipment must be employed. In the event of a solvent ignition, the resulting downtime and consumption of fire extinguishing chemical also adds to the manufacturing cost.

Application of the protective coating by means of a dipping process can also preclude the use of more desirable reinforcing materials. For example, a much stronger containment vessel could be provided by the use of a polycarbonate coating, due to its higher impact strength and higher softening temperature, as compared to cellulose acetate. By using the conventional dipping and drying process to apply polycarbonate, however, a relatively cloudy coating results. In order to obtain a clear, transparent coating, an extremely low humidity must be maintained in the drying ovens, which in turn requires the drying of **5,000** to **10,000** cubic feet of air per minute. The incorporation of such a drying operation would be prohibitively expensive.

SUMMARY OF THE INVENTION

In view of the foregoing, a principal object of the invention is to provide a photoflash lamp having a stronger envelope structure for providing improved containment during flashing.

Another object of the invention is to economically provide an improved containment vessel for a flashlamp.

A further object of the invention is to provide an improved method for coating the glass envelope of a photoflash lamp with a thermoplastic material.

These and other objects, advantages and features are attained, in accordance with the invention by vacuum forming a thermoplastic coating on the exterior surface of the glass envelope. The improved method comprises: placing the glass envelope within a performed sleeve of the thermoplastic material; drawing a vacuum in the space between the thermoplastic sleeve and the glass envelope; and, simultaneously heating the assembly incrementally along its length, whereby the temperature and vacuum cause the thermoplastic to be incrementally formed onto the glass envelope with the interface substantially free of voids, inclusions and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will be more fully described hereinafter in conjunction with the accompanying drawings, in which:

FIG. **1** is an enlarged sectional elevation of an electrically ignitable photoflash lamp having a protective coating in accordance with the invention;

FIG. **2** is an enlarged sectional elevational of a percussive-type photoflash lamp having a protective coating in accordance with the invention;

FIG. **3** is an enlarged sectional elevational of a preformed sleeve of thermoplastic adapted for assembly and vacuum forming onto the glass envelope of a percussive-type photoflash lamp;

FIG. **4** is an enlarged elevation, partly in section, showing a percussive flashlamp assembled in the thermoplastic sleeve of FIG. **3,** prior to vacuum forming;

FIG. **5** is a simplified fragmentary elevation, partly in section, of apparatus adapted for carrying out the method of the present invention, this veiw illustrating the simultaneous vacuum drawing and heating steps;

FIG. 6 illustrates the constricting step carried out by the apparatus of FIG. 5; and

FIG. 7 illustrates the tipping off step carried out by the apparatus of FIG. 5.

DESCRIPTION OF PREFERRED EMBODIMENT

The teachings of the present invention are applicable to either percussive or electrically ignited photoflash lamps of a wide variety of sizes and shapes. Accordingly, FIGS. 1 and 2 respectively illustrate electrically ignited and percussive-type photoflash lamps embodying the principles of the invention.

Referring to FIG. 1, the electrically ignitable lamp comprises an hermetically sealed lamp envelope 2 of glass tubing having a press 4 defining one end thereof and an exhaust tip 6 defining the other end thereof. Supported by the press 4 is an ignition means comprising a pair of lead-in wires 8 and 10 extending through and sealed into the press. A filament 12 spans the inner ends of the lead-in wires, and beads of primer 14 and 16 are located on the inner ends of the lead-in wires 8 and 10 respectively at their junction with the filament. Typically, the lamp envelope 2 has an internal diameter of less than one-half inch, and an internal volume of less than 1 cc., although the present invention is equally suitable for application to larger lamp sizes. A combustion-supporting gas, such as oxygen, and a filamentary combustible material 18, such as shredded zirconium or hafnium foil, are disposed within the lamp envelope. Typically, the combustion-supporting gas fill is at a pressure exceeding one atmosphere, with the more recent subminiature lamp types having oxygen fill pressures of up to several atmospheres. As will be described in more detail hereinafter, the glass envelope 2 is reinforced, in accordance with the invention, by a vacuum-formed thermoplastic coating 20 on its exterior surface.

The percussive-photoflash lamp illustrated in FIG. 2 comprises a length of glass tubing defining an hermetically sealed lamp envelope 22 constricted at one end to define an exhaust tip 24 and shaped to define a seal 26 about a primer 28 at the other end thereof. The primer 28 comprises a metal tube 30, a wire anvil 32, and a charge of fulminating material 34. A combustible 36, such as filamentary zirconium or hafnium, and a combustion supporting gas, such as oxygen, are disposed within the lamp envelope, with the fill gas being at a pressure of greater than one atmosphere. As will be detailed hereinafter, the exterior surface of glass envelope 22 is covered by a vacuum-formed thermoplastic coating 46 in accordance with the invention.

The wire anvil 32 is centered within the tube 30 and is held in place by a circumferential indenture 38 of the tube 30 which loops over the head 40, or other suitable protuberance, at the lower extremity of the wire anvil. Additional means, such as lobes 42 on wire anvil 32 for example, may also be used in stabilizing the wire anvil, supporting it substantially coaxial within the primer tube 30 and insuring clearance between the fulminating material 34 and the inside wall of tube 30. A refractory bead 44 is fused to the wire anvil 32 just above the inner mouth of the primer tube 30 to eliminate burn-through and function as a deflector to deflect and control the ejection of hot particles of fulminating material from the primer. The lamp of FIG. 2 is also typically a subminature type having envelope dimensions similar to those described with respect to FIG. 1.

Although the lamp of FIG. 1 is electrically ignited, usually from a battery source, and the lamp of FIG. 2 is percussion-ignitable, the lamps are similar in that in each the ignition means is attached to one end of the lamp envelope and disposed in operative relationship with respect to the filamentary combustible material. More specifically the igniter filament 12 of the flash lamp in FIG. 1 is incandesced electrically by current passing through the metal filament support leads 8 and 10, whereupon the incandesced filament 12 ignites the beads of primer 14 and 16 which in turn ignite the combustible 18 disposed within the lamp envelope. Operation of the percussive-type lamp of FIG. 2 is initiated by an impact onto tube 30 to cause deflagration of the fulminating material 34 up through the tube 30 to ignite the combustible 36 disposed within the lamp envelope. The invention is also applicable to other types of electrically ignited lamps, such as those having spark gap or primer bridge ignition structures.

In accordance with the present invention, we have discovered a solventless, vacuum forming method for applying an optically clear protective coating on the exterior surface of the glass envelope. The method provides a significantly faster, safer and more economical manufacturing process, and it may be easily integrated on automated production machinery. The process permits use of the stronger, more temperature resistant thermoplastics, and the resulting coating maintains the glass substrate under a compressive load, thereby making the glass envelope itself more resistant to thermal shock. As a result, this coating reduces the cost of materials by permitting the use of soft glass to meet high containment requirements.

The improved coating method of the invention will now be described with reference to FIGS. 3–7. Referring first to FIG. 3, the thermoplastic material to be coated on the exterior surface of the lamp envelope is initially provided as a preformed sleeve 48 having the shape of a test tube. To facilitate the one or more metallic members depending from the lamp envelope (i.e. leads 8 and 10, or primer tube 30) one or more holes are provided at the bottom of test tube-shaped sleeve. For purposes of example, the method of FIGS. 3–7 will be described with reference to vacuum forming the thermoplastic coating 46 on the percussive lamp of FIG. 2, although it will be understood that a similar method may be employed with the electrically ignited lamp of FIG. 1. Accordingly, sleeve 48 is provided with a single coaxially disposed hole 50 to facilitate passage of coaxially projecting primer tube 30. Sleeve 48 may be formed by a molding or extrusion process, and to minimize possible checks and crazes in the plastic upon being vacuum formed to the glass envelope, the preformed sleeve 48 should be prebaked at about 125°C for at least 15 minutes to drive away residual moisture prior to assembly with the glass envelope.

In the next step, shown in FIG. 4, the glass envelope 22 of the percussive lamp is placed within the preformed thermoplastic sleeve 46, with the primer tube 30 projecting through hole 50. It will be noted that both the sleeve 48 and the lamp envelope 22 have generally tubular sidewalls. To facilitate the vacuum forming process, the fit should be as close as possible. Accordingly, the outside diameter of the tubular envelope 22 and the inside diameter of the tubular sleeve 48 are dimensioned so that, when the envelope is placed within the sleeve, there exists a clearance x of from about 0.001 to 0.010 inch between the tubular sidewalls thereof prior to heating and vacuum forming.

The next step, heating and vacuum forming, is illustrated in FIG. 5. The envelope and sleeve assembly 22, 48 is held during the evacuating and heating processes by means of a chuck 50 gripping the primer tube 30. Another chuck 52, having an evacuating tube 54, grips the open end of the thermoplastic sleeve 48. One or more localized sources of heat, represented by heaters 53, encircle the envelope and sleeve assembly for uniformly applying heat about the tubular sleeve in a substantially localized elevational plane. In operation, the process comprises drawing a vacuum in the space between the sleeve 48, and envelope 22, while simultaneously heating the envelope and sleeve assembly incrementally along its length. More specifically, the vacuum is drawn through tube 54, in the direction of the arrow, at the open end of sleeve 48. At the same time, the heaters 56 are controlled to heat the sleeve to approximately the softening temperature of the thermoplastic material. A relative incremental axial movement is effected between the envelope-sleeve assembly and the heaters, so that incremental heating in a localized elevational plane starts at the end of the sleeve 48 through which the primer tube 30 projects, and then proceeds toward the open end of the sleeve from which the vacuum is being drawn. In this manner, the temperature and vacuum cause the thermoplastic sleeve 48 to be formed onto the glass envelope 22 with the interface therebetween substantially free of voids, inclusions and the like.

Referring to FIG. 5, this incremental heating process may be accomplished at one station by either moving chucks 50 and 52 downward with respect to a set of stationary heaters 56, or by moving heaters 56 upward with respect to a set of stationary chucks 50 and 52. A preferred method of effecting the incremental heating, however, is to index the envelope-sleeve assembly through a plurality of heating stations, with the heaters at each station positioned at successively higher elevations.

At the conclusion of the incremental heating process, the sleeve 48 is constricted at portion 58 (FIG. 6) by slowly pulling chucks 50 and 52 away from each other, while continuing to apply heat and draw a vacuum. Finally, as shown in FIG. 7, the vacuum formed sleeve 48 on the lamp is separated from the portion 60 of the sleeve held in chuck 52 and tipped off at point 62, thereby completing the encapsulation of glass envelope 22 in the thermoplastic coating 46.

The composition of sleeve 48, and thus coating 46, may be of any vacuum formable light-transmitting thermoplastic material having a reasonably high impact strength and softening temperature. Suitable materials include acrylic, acrylonitrile-butadiene-styrene, cellulose acetate, ionomers, methylpentene polymer, nylon, polycarbonate, polystyrene, polysulfone, or alloys thereof. In the case of some of the harder materials, it may also be desirable to add a small amount (10–20%) of a compatible plasticizer to the composition. Further, commerical blue dyes can be used in the sleeve, or coating, for color corrections desirable with various photographic color film.

Preferably, the thermoplastic material is selected to have a coefficient of thermal expansion several times greater than the coefficient of thermal expansion of the glass envelope. In this manner, the coating 46, provided by the above described vacuum forming process, will exert a compressive load on the glass envelope 22 to thereby in effect strengthen the glass and make it more resistant to thermal shock. For example, with a coefficient of thermal expansion at least six times greater than that for the glass, the thermoplastic coating may exert a compressive load of from about 1000 to about 4000 pounds per square inch on the glass envelope.

The added containment strength provided by this compressive loading may be better understood by briefly considering the effects of the combustion process. Upon flashing the lamp and igniting the shreds of combustible, the inner surface of the glass envelope is subjected to severe thermal shock in the form of impact from hot globules of metal oxide; for example, zirconium oxide has a melting point of 2715°C. Each thermal impact against the internal glass surface produces a thermal stress gradient through the wall of the glass envelope, which serves as an insulator to the conducted heat, and causes expansion of the glass. any thermoplastic coating on the glass will be under tension (T_D) and there will be localized tensile stress (T_x) at the interface of the coating and glass, opposite the point of globule impact. The build up of the localized tensile stress T_x by the thermal stress gradient is what can eventually cause a crack through the glass wall. On the other hand, the compression loading (C) which is exerted on the glass envelope by the coating functions to counteract the tensile loading of T_D and T_x by delaying the thermal stress gradient through the glass wall; this may be illustrated as $T_D + T_x - C$. Accordingly, the higher the compressive loading, the stronger the glass. Also, however, an increase in the compressive loading on the glass results in a corresponding increase in the tensile loading on the coating. Hence, a compressive load that is too high can be detrimental. Where necessary, the compressive loading can be relieved by the inclusion of a small amount of plasticizer in the coating composition and/or fillers that alter the thermal expansion coefficient.

Another aspect of this encapsulated lamp structure to be noted is that the vacuum forming process leaves a well defined interface between the envelope and the coating—the coating is not sealed to the envelope. As a result, a crack in the glass envelope will stop at the interface and be contained by the thermoplastic coating.

In one typical embodiment of the invention, a percussive flashlamp of the type shown in FIG. 2 was provided with a clear vacuum-formed coating 46 of polycarbonate resin having a wall thickness of about 0.020 inch. The lamp contained a combustible fill 36 comprising 18.5 mgs. of shredded zirconium foil and oxygen at a fill pressure of 20 atmospheres. The tubular envelope 22 was formed of G-1 type soft glass and had a nominal outside diameter of 0.250 inch. In the process of coating the lamp, an injection molded sleeve 48 of clear polycarbonate resin having a nominal inside diameter of 0.260 inch and a wall thickness of 0.020 was employed. During vacuum forming, the molded sleeve was incrementally heated to a temperature of about 400°F by a nitrogen flow serpentine heater. The coefficient of thermal expansion of soft glass of this type ranges from 85 to 95 × 10^{-7} in./in./°C between 20° and 300°C, whereas the coefficient of thermal expansion of unfilled polycarbonate between 25° and 140°C is about 660×10^{-7} in./in./°C. Upon measuring several sections of lamps made as described above, the average compressive stress exerted by the coating 46 upon the glass envelope 22 was found to be about 1392 pounds per square inch. Flashing of a number of these lamps in both the vertical and horizontal position exhibited no containment failures.

Although the invention has been described with respect to specific embodiments, it will be appreciated that modifications and changes may be made by those skilled in the art without departing from the true spirit and scope of the invention.

What we claim is:

1. A method of coating the glass envelope of a photoflash lamp with a light-transmitting thermoplastic material, said method comprising:

placing said glass envelope within a preformed sleeve of said thermoplastic material, and

drawing a vacuum in the space between said thermoplastic sleeve and said glass envelope, while simultaneously

heating said sleeve and envelope assembly incrementally along the length-thereof so that the temperature and vacuum cause said thermoplastic sleeve to be incrementally formed with a substantially uniform thickness onto the entire exterior surface of said glass envelope with the interface therebetween substantially free of voids, inclusions and the like, whereby after cooling, said thermoplastic coating exerts a compressive load on said glass envelope and a stronger envelope structure is obtained for providing improved containment during flashing.

2. The method of claim 1 wherein heat is applied uniformly about said sleeve and envelope assembly by one or more localized sources of heat encircling said assembly, and a relative incremental axial movement is effected between said assembly and said one or more sources of heat.

3. The method of claim 1 wherein heat is applied uniformly about said sleeve and envelope assembly by one or more localized sources of heat encircling said assembly, and said assembly is indexed through a plurality of heating stations, each of which has said one or more localized sources of heat positioned at successively higher elevations.

4. The method of claim 1 wherein the heating of said sleeve and envelope assembly is controlled to bring said thermoplastic sleeve to approximately the softening temperature thereof.

5. The method of claim 1 including the further step of prebaking said thermoplastic sleeve to remove the moisture therefrom prior to assembling said sleeve with said glass envelope.

6. The method of claim 5 wherein said prebaking of the sleeve is conducted at a temperature of about 125°C for at least 15 minutes.

7. The method of claim 1 including the further steps of constricting and tipping off said vacuum-formed sleeve at the conclusion of said incremental heating process.

8. The method of claim 1 wherein both said thermoplastic sleeve and said glass envelope have generally tubular sidewalls, and the outside diameter of said tubular envelope and inside diameter of said tubular sleeve are dimensioned so that, when said envelope is placed within said sleeve, there exists a clearance of from about 0.001 to 0.010 inch between the tubular sidewalls thereof prior to heating.

9. The method of claim 1 wherein said lamp has at least one metallic member depending from said glass envelope, said preformed thermoplastic sleeve is shaped like a test tube having at least one hole in the bottom thereof, and in said step of placing said glass envelope within said sleeve, said metallic member is inserted through said hole to thereby project outside said test tube-shaped sleeve.

10. The method of claim 9 wherein said vacuum is drawn at the open end of said test tube-shaped sleeve opposite the end through which said metallic member projects, and said incremental heating of said assembly proceeds from the end of said sleeve through which said metallic member projects toward the open end of said sleeve from which said vacuum is being drawn.

11. The method of claim 10 wherein said envelope and sleeve assembly is held during said evacuating and heating processes by means of a chuck gripping said projecting metallic member.

12. The method of claim 11 wherein said photoflash lamp is a percussive-type, and said metallic member comprises a primer tube coaxially projecting from one end of said envelope.

13. The method of claim 1 wherein the coefficient of thermal expansion of said thermoplastic sleeve is at least about six times greater than the coefficient of thermal expansion of said glass envelope.

14. The method of claim 1 wherein the composition of said sleeve comprises a light-transmitting thermoplastic selected from the group consisting of acrylic, acrylonitrilebutadiene-styrene, cellulose acetate, ionomers, methylpentene polymer, nylon, polycarbonate, polystyrene, polysulfone, and alloys thereof.

15. The method of claim 14 wherein the composition of said sleeve further includes a small amount of plasticizer.

16. The method of claim 1 wherein said thermoplastic sleeve comprises a polycarbonate resin.

17. The method of claim 16 wherein the thickness of said polycarbonate sleeve is about 0.020 inch.

18. The method of claim 10 wherein: both said sleeve and said envelope have generally tubular sidewalls; the outside diameter of said tubular envelope and the inside diameter of said tubular sleeve are dimensioned so that, when said envelope is placed within said sleeve, there exists a clearance of from about 0.001 to 0.010 inch between the tubular sidewalls thereof prior to heating; and the heating of said sleeve and envelope assembly is controlled to bring said thermoplastic sleeve to approximately the softening temperature thereof; and including the further steps of prebaking said thermoplastic sleeve at a temperature of about 125°C for at least 15 minutes to remove the moisture therefrom prior to assembling said sleeve with said glass envelope, and constricting and tipping off said vacuum formed sleeve at the conclusion of said incremental heating process.

19. A method of coating the glass envelope of a photoflash lamp with a light-transmitting thermoplastic material, said method comprising:

placing said glass envelope within a preformed sleeve of said thermoplastic material, and

forming said sleeve with a substantially uniform thickness onto the entire exterior surface of said glass envelope by heating said sleeve and drawing a vacuum in the space between said sleeve and said glass envelope, whereby after cooling, said thermoplastic coating exerts a compressive load on said glass envelope and a stronger envelope structure is obtained for providing improved containment during flashing.

20. The method of claim **19** including the further step of prebaking said thermoplastic sleeve to remove the moisture therefrom prior to assembling said sleeve with said glass envelope.

21. The method of claim **20** wherein said prebaking of the sleeve is conducted at a temperature of about **125**°C for at least **15** minutes.

22. The method of claim **19** including the further steps of constricting and tipping off said formed sleeve at the conclusion of said forming process.

23. The method of claim **19** wherein both said thermoplastic sleeve and glass envelope have generally tubular sidewalls.

24. The method of claim **19** wherein said lamp has at least one metallic member depending from said glass envelope, said preformed thermoplastic sleeve is shaped like a test tube having at least one hole in the bottom thereof, and in said step of placing said glass envelope within said sleeve, said metallic member is inserted through said hole to thereby project outside said test tube shaped sleeve.

25. The method of claim **24** wherein the heating of said test-tube shaped sleeve starts at the end thereof through which said metallic member projects and proceeds toward the open end of the sleeve, and said vacuum is drawn at said open end of the sleeve.

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