

- [54] **FLASHLAMP WITH IMPROVED COMBUSTIBLE FOIL**
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- [52] U.S. Cl. .... **431/95**
- [51] Int. Cl. .... **F21k 5/02**
- [58] Field of Search..... 431/93, 94, 95; 149/14, 15
- [56] **References Cited**  
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[57] **ABSTRACT**

A photo flashlamp containing an improved metallic combustible foil composite comprising a layer of a pyrophoric metal, for example, yttrium, interposed between two layers of nonpyrophoric metal, wherein nonpyrophoric metals such as aluminum, hafnium, magnesium or the like may be used. A method for making a metallic combustible foil composite comprising depositing, in a vacuum chamber, a layer of pyrophoric metal on a layer of combustible nonpyrophoric metal and then depositing a layer of combustible nonpyrophoric metal on the exposed surface of the pyrophoric metal layer.

**7 Claims, 5 Drawing Figures**

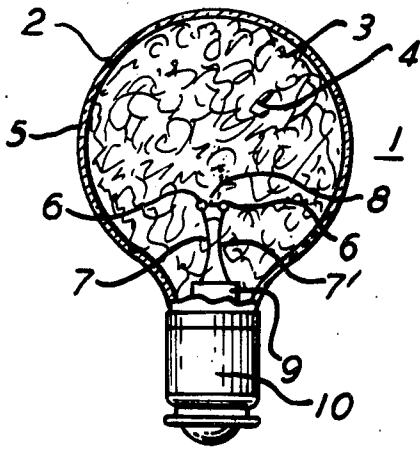


FIG. 1

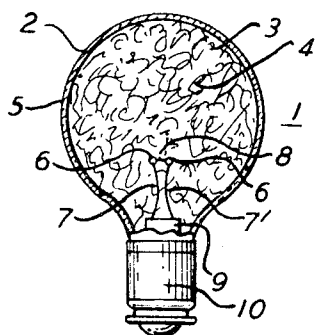


FIG. 2

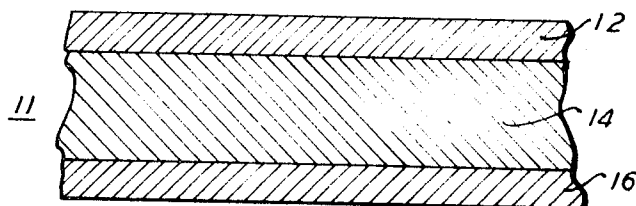


FIG. 3

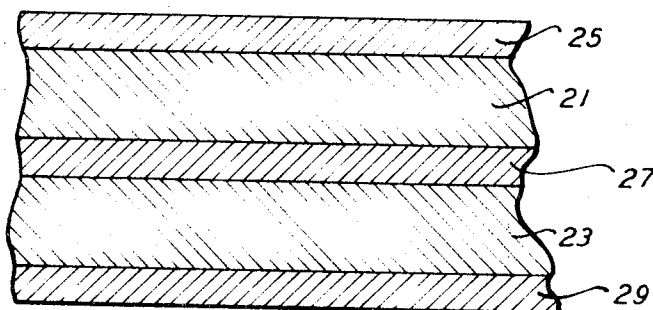
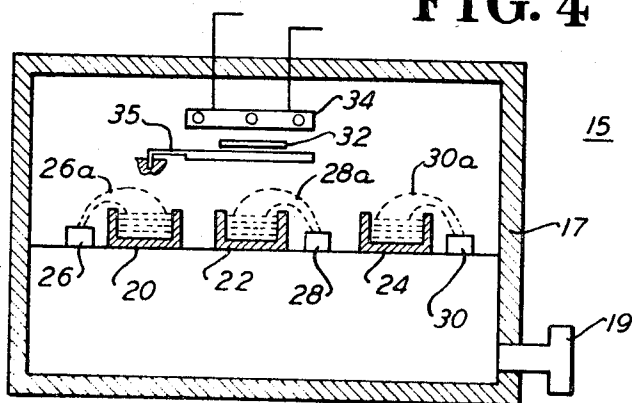
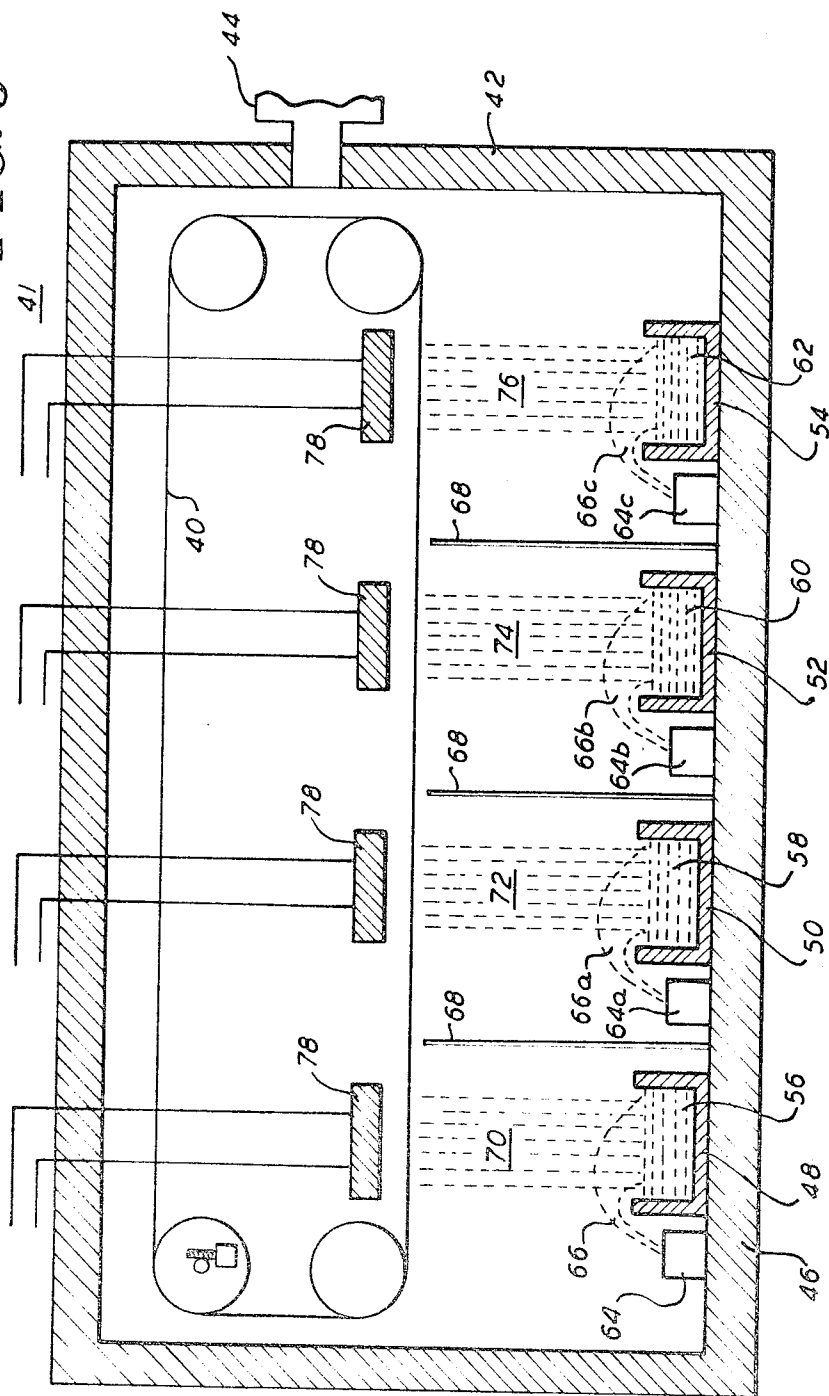


FIG. 4



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FIG. 5



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# FLASHLAMP WITH IMPROVED COMBUSTIBLE FOIL

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

This invention is directed toward a combustible material for photo flashlamps in composite foil form and to photo flashlamps containing the novel combustible material.

This invention further pertains to methods for making the novel metallic combustible foil composite for photo flashlamps.

### 2. Description of the Prior Art

The source of actinic light in photo flashlamps is the rapid combustion of filamentary combustible material. Actinic light is generally defined as light capable of including chemical changes, as for example in the emulsion of a photographic plate. These combustible materials are customarily made in the form of wire, foil, shredded foil or wool. The production and manufacture of these materials directly affects the ultimate performance of the flashlamps. For example combustion rate is affected by the characteristics of the filamentary material such as cross section area, chemical composition, amount of cold work and product uniformity.

It is well known that variations in wire diameter may detract from the uniformity and quality of photo flashlamps made with such material. Aside from variation in wire diameter, production of such wire is characterized by considerable breakage and low product yield during wire drawing. To obviate breakage those skilled in the art have developed various alloys of combustible metals such as aluminum-magnesium alloys. These alloys draw better but do not entirely solve the wire breakage problem attendant to such a manufacturing process.

Foil, another form of combustible filling for photo flashlamps is generally produced by hammering or cold rolling material of relatively thick cross section to foil thickness. The rate of combustion is considered to depend primarily on thickness; however, other factors affect combustion rates, such as variation in chemical analysis and trace elements. The known methods of making foil have been found troublesome in practice in that it is difficult to obtain a foil of constant thickness by hammering or cold rolling. Furthermore, cold rolling adversely affects electrical and thermal conductivity. It has been found that an additional annealing step is often necessary to negate the effects of cold rolling. Making foil in this manner has increased the overall cost of the material.

With the development of smaller photo flashlamps and mounting a plurality of small flashlamps in an individual photo flashlamp unit the shape of the filamentary material changed. The combustible material commonly used now is in the form of shredded foil. This material has a width comparable to its thickness and is produced by shredding foil. If the foil made in accordance with the prior art techniques exhibits poor thermal conductivity resulting from cold rolling or has an analysis containing undesirable trace elements the resultant shredded foil will also be so affected.

## SUMMARY OF THE INVENTION

The instant invention involves methods for making an improved combustible foil which methods avoid the serious drawbacks described above in connection with the prior art forms of making flashlamp material. The

invention entirely avoids the use of hammering or cold rolling to produce the foil. In summary the inventive method employs a unique series of vacuum techniques to form the desired layers of combustible material. The utilization of the vacuum furnace in the unique manner to be described hereinbelow assures both the purity of the layer being deposited, its thickness and also the interface adherence of the dissimilar layers.

The invention further involves the use of a heretofore unknown combination of elements in a unique arrangement to produce a composite foil containing at least one pyrophoric layer at least partially covered by a non-pyrophoric layer whereby the pyrophoric layer is protected from contacting the atmosphere surrounding it. In the preferred embodiment a pyrophoric layer of yttrium is encased in non-pyrophoric layers of aluminum or the like. In order for the non-pyrophoric material to be suitable for flash bulk material it must be combustible and have the desired color temperature, time to peak and short duration light characteristics. The particular pyrophoric and non-pyrophoric materials are selected on the basis of their individual aforementioned characteristics and the layer thicknesses are also selected to give the desired flash results.

The instant invention also contemplates utilizing multiple layers of pyrophoric and non-pyrophoric materials. The combustible foil made in accordance with this invention may or may not be shredded depending on the flash bulb requirements.

It is, therefore, an object of this invention to provide vacuum furnace techniques for the production of a combustible composite foil suitable for use in a flash bulb.

Another object of this invention is to provide a combustible composite foil composed of a pyrophoric film protected on at least one side by a combustible non-pyrophoric film.

A further object of this invention is to provide a metallic combustible composite composed of at least one layer of yttrium interposed between layers of a metal selected from aluminum, hafnium or magnesium.

Another object of this invention is to provide a metallic combustible composite made by vacuum vapor deposition.

## BRIEF DESCRIPTION OF THE DRAWINGS

With the above and related objects in view, this invention will be more fully understood from the following detailed description when read in conjunction with the accompanying drawings in which:

FIG. 1 is an elevational view, partly in section, of a photo flashlamp containing the unique material made in accordance with the present invention.

FIG. 2 is a representation of a cross section (partly broken away) of a combustible foil made in accordance with this invention.

FIG. 3 is a representation of a cross section of a combustible foil having a plurality of pyrophoric layers and made in accordance with this invention.

FIG. 4 is an elevational view, partly broken away, partly in section, of one form of vacuum vapor deposition apparatus for producing a composite foil in accordance with this invention.

FIG. 5 is an elevation of a further apparatus for carrying out the methods of the instant invention to produce the unique combustible foil.

## DESCRIPTION OF PREFERRED EMBODIMENT

The invention can best be explained by reference to the drawing wherein FIG. 1 represents a conventional flashlamp containing the unique composite foil made in accordance with the present invention. The lamp comprises a hermetically sealed glass envelope 2 containing a combustion supporting atmosphere (usually pressurized), such as oxygen 3 and a shredded metallic combustible composite 4 capable of producing actinic light. In one form of the instant invention the combustible composite 4 is composed of a pyrophoric metallic layer interposed between non-pyrophoric metallic layers. The envelope 2 may be internally coated with a blue lacquer 5 in accordance with known practice. The thickness of the lacquer layer depends on the color temperature characteristics desired from the flashbulb. For outdoor daylight photography, high color temperature characteristics are desired. One well-known drawback to the application of the lacquer is that it absorbs light and thereby reduces the total level of illumination created by the bulb.

A typical lamp, such as shown in FIG. 1, further contains an ignition mechanism consisting of an explosive paste 6 applied to the terminals of the current supply wires 7 and 7' and filament 8. The current supply wires are supported within envelope 2 by support means 9. The current supply wires are connected to conventional base contacts (not shown) contained within base 10 in a manner well known in the art. The current supply wires transmit an electrical current through filament 8 causing the ignition of paste 6. The paste in turn ignites the composite combustible foil in the oxygen atmosphere.

The present invention may be employed in any number of photo flashlamp configurations such as a multiple lamp assembly, as shown in U.S. Pat. No. 3,315,070, issued to Pfefferle.

FIG. 2 is a graphical representation of a laminated composite 11 made in accordance with one form of the present invention and usable as the combustible composite in the bulb of FIG. 1. Composite 11 consists of a layer of a pyrophoric material 14, such as yttrium, interposed between layers 12 and 16 of a non-pyrophoric material such as aluminum, hafnium, magnesium, or thelike, or combinations thereof.

The use of pyrophoric materials in flashlamp is well known; however, in the applications heretofore known the pyrophoric material was placed in an evacuated atmosphere in the bulb to prevent premature ignition. When it was desired to ignite the material, the bulb was punctured or the atmosphere was in some other way allowed to contact the pyrophoric material. When this occurred, the material flashed producing the desired light. Producing such bulbs was a costly undertaking and the pyrophoric materials heretofore used have not produced the desired results.

The instant invention contemplates the use of yttrium foil as the basic pyrophoric material. This material produces highly acceptable actinic light and has suitable color temperature and other characteristics. The invention involves manufacturing such foil by the use of vacuum vapor deposition techniques. These techniques are used in order to achieve accurate film thickness and avoid film contamination with impurities. It was also recognized that such methods would avoid

the problems encountered when films are formed by hammering or cold rolling.

No difficulty was encountered in forming yttrium layers by vapor deposition techniques; however, it was found that when the layers, which were of approximately 1.0 mil. in thickness, were suddenly exposed to the atmosphere, they immediately flashed due to the rapid exposure to the air. Thus when the yttrium foil was stripped from the substrate or when the vacuum was rapidly broken, the foil ignited and was consumed. In order to prevent the ignition of the yttrium foil, the pyrophoric material was encompassed in a layer of non-pyrophoric material whereby the surface of the pyrophoric material was protected from the atmosphere. Such a composite could, therefore, be removed from a vacuum furnace or other place of manufacture and modified so as to be in a form suitable for insertion into a flashbulb. In accordance with known techniques the composite foil could be shredded and then used in the bulb. It would seem that shredding of the composite foil would expose the pyrophoric material to the atmosphere; however, the non-pyrophoric material is deformed in the shredding process and is pinched over the pyrophoric material to maintain a layer thereover and prevent appreciable exposure to the atmosphere. Furthermore, any small exposed portion of the pyrophoric material, such as the edges, would be protected by an oxide and would not ignite spontaneously.

The representation in FIG. 2 shows a typical foil in cross section. In one embodiment of the invention a composite foil of aluminum layers surrounding a layer of yttrium was successfully produced. The aluminum layers were each approximately 0.1-0.2 mil. in thickness and the yttrium layer approximately 0.5-0.6 mil. in thickness. The thicknesses of the layers may be correlated to provide the desired flashbulb characteristics. Aluminum has long been used as a flashbulb material and its characteristics are well-known. By combining this material with yttrium which has great capacity for producing actinic light and high temperature color characteristics, a new flexibility is afforded flashbulb manufacturers and photographers. In addition to using aluminum, this invention also contemplates using other combustible non-pyrophoric foils to encompass the pyrophoric material. For example, hafnium and magnesium may be used. In addition, mixtures and alloys of the aforementioned materials may be used. It is also contemplated that different non-pyrophorics on opposite sides of the pyrophoric layer will be used. Such non-pyrophorics must be combustible and, in addition, are capable of being vapor deposited on the pyrophoric material.

It is also within the scope of the invention to use other than planar layers of material. Thus the pyrophoric material may be in the form of wire, rods, arcuate shapes, etc. The non-pyrophoric material may be deposited to cover either all or only a part of the external surface of the pyrophoric material. In addition, as discussed above, it is contemplated that more than one type of non-pyrophoric material to cover a pyrophoric layer will be used. Thus aluminum could be applied to one side and magnesium to another.

Although we have referred to yttrium as our preferred pyrophoric material we also contemplate using other pyrophoric materials of similar character. Such material would have good capability for producing actinic light and be vapor depositable.

FIG. 3 is a cross section of a composite consisting of five layers of material. Yttrium layers are designated by 21, 23 and magnesium layers by 25, 27, 29. In composing such composite layers care must be taken to select materials which have desired and compatible burning characteristics. The thickness of the individual layers and the total thickness of the composite foil regulates the burning rate of the composite. The outer layer of the composite foil may be of a material different from that contained in the inner layers. The outer layer material should generally be selected on the basis of ease of ignition. Thus magnesium has been selected as a most suitable material for the outer layer. The inner layers of material must also be selected to create the desired burning rate. Volatile materials such as magnesium and aluminum may, therefore, be interspersed as the interior layers in concert with the pyrophoric layer or layers. By layering the materials as desired, the combustion rate of the composite can be regulated.

The embodiment shown in FIG. 3 is only representative of one possible composite of pyrophoric and non-pyrophoric layers. Other combinations of multiple layering of the desired pyrophoric and non-pyrophoric layers are within the scope of this invention.

Having described the characteristics of the novel composite foil, we will now describe in greater detail the apparatus and methods used to make the composite.

In FIG. 4 there is illustrated in pictorial form an apparatus suitable for making the subject composite. The apparatus comprises an electron beam furnace 15 which includes an outer enclosure 17 which is constructed to permit evacuation to very low pressure via a conduit 19. This conduit leads to a suitable vacuum pump (not shown).

Supported in the vacuum chamber are a plurality of hearths 20, 22, 24 with associated electron guns 26, 28, 30 which are capable of producing sufficient electron bombardment 26a, 28a, 30a respectively to heat the substance in each hearth or crucible to the desired temperature for evaporation. Electron guns of any suitable construction may be employed. Suitable control systems may be used to regulate the evaporation rate utilizing feedback from monitors (not shown), to proportionately increase or decrease the power being supplied to the associated electron gun in order to obtain evaporation of the substance in the associated crucible at precisely the desired rate.

Electron beam bombardment has proven to be the most satisfactory technique for heating the material contained within the crucibles. However, other techniques such as resistance heating, induction heating, or the like may be employed without departing from the spirit and scope of this invention.

Spaced above the crucibles and supported in the chamber is metallic substrate 32. The substrate is pre-heated by heating means 34 to at least approximately one-third to one-half of the absolute melting point of the material to be deposited in order to improve the metallic properties of the resultant vapor deposited coating. The selection of the pre-heat temperature depends upon the material to be deposited. Interposed between substrate 32 and the crucibles is a shutter 35. The shutter is movable about a vertical axis so that it can be moved over the substrate to shield the same from the crucibles.

Deposition is controlled by activating the electron beam gun adjacent to the crucible containing the material to be evaporated. The shutter 35 remains over the substrate until the desired evaporation rate is achieved.

Then the shutter is swung away and the desired thickness of material is deposited on the substrate. At that time the shutter is swung back over the product and the gun is turned off. In this manner the crucibles are sequentially activated to place the desired layers of material on the substrate. In one form of the invention a layer of aluminum is first applied to a substrate which was previously treated with a parting agent, a layer of yttrium is then applied and finally a layer of aluminum is again applied. The composite foil is then stripped from the substrate by known techniques.

In accordance with the above principles, a composite foil in an apparatus such as schematically described in FIG. 4 was successfully produced. This operation will now be described in detail; however, it should be understood that this example is merely illustrative of one embodiment of the invention and is not to be considered as in any way limiting the scope of the invention as defined in the following claims.

A stainless steel substrate was positioned within the chamber 15 as illustrated by the reference numeral 32. The chamber was evacuated to a pressure of approximately  $10^{-5}$  to  $10^{-6}$  torr.

Crucible 20, containing the parting agent calcium fluoride, was energized by applying a power level of 0.5 kw to electron beam gun 26. When the  $\text{CaF}_2$  was heated to the desired temperature for evaporation, the shutter 35 was swung away from the substrate 32, exposing the substrate to vapor deposition. A layer of  $\text{CaF}_2$ , approximately 1,000–3,000 Å in thickness was then applied. The thickness of the applied layer was determined by the power level applied to the gun correlated with the time of disposition. The shutter was then moved to mask the substrate and the gun 26 de-energized. The temperature of the substrate and parting layer was then adjusted to 800° F by heater 34.

Approximately 2 kw of power was then supplied to gun 28 so as to evaporate the aluminum metal contained within the crucible 22. The distance from the crucible to the substrate was about 13 inches and it was determined that at this power level a deposit of aluminum would build up to from 0.1 to 0.2 mil. in about 1 minute. When the aluminum reached its vaporization temperature the shutter 35 was swung away and aluminum was deposited for one minute resulting in a layer thickness of 0.1 to 0.2 mil. The shutter then masked the composite and the gun 28 was shut down.

Approximately 6 kw of power was then supplied to the electron beam gun 30 so as to heat and then evaporate yttrium metal contained within the crucible 24. The source to substrate distance was maintained at approximately 13 inches. Deposition time to deposit about 1 mil of yttrium at these conditions was approximately at 10 to 15 minutes. When the yttrium reached its vaporization temperature the shutter 35 was swung away from the substrate and a coating thickness of approximately 0.5 to 0.6 mil of yttrium was deposited. Shutter 35 was then rotated to close off the path of the vapor and the electron beam gun 30 power level was turned off.

Another 0.1 to 0.2 mil layer of aluminum was then deposited on the yttrium layer from crucible 22 in the manner as hereinbefore described.

The substrate was then allowed to cool and the vacuum broken in the furnace. The resultant composite, approximately 0.7 to 1.0 mil. thick was then stripped from the substrate in a manner well known in the art. The material did not flash when exposed to the atmosphere and was of a quality suitable for shredding and usage as a combustible foil in a flashbulb.

The apparatus of FIG. 4 could also be used for the deposition of additional layers of material such as described above in connection with the embodiment shown in FIG. 3. Magnesium and/or hafnium layers could, therefore, be deposited in the same manner in combination with a pyrophoric material to produce the desired foil.

In FIG. 5 there is shown a still further embodiment of an apparatus for forming the novel composite foil. This apparatus is designed for depositing a series of layers of materials on a continuously moving substrate. The apparatus includes an electron beam furnace 41 having an outer enclosure 42 adapted to maintain the desired vacuum. The connection 44 is associated with proper equipment, vacuum pump, etc. for pulling and maintaining a desired vacuum.

The substrate 40, which may be a belt of stainless steel or other desired material, is trained around a series of pulleys, at least one of which has a power driven connection.

Separate heaters 78 are positioned over the substrate at each evaporation region so as to heat the substrate to the desired temperature for deposition of each layer.

Supported in the chamber on hearth 46 are a series of crucibles 48, 50, 52 and 54 containing the desired materials 56, 58, 60 and 62.

Electron beam generators 64, 64a, 64b and 64c produce electron beams 66, 66a, 66b, and 66c which are directed on to the top of these molten baths for bombardment heating thereof in order to maintain said baths in a molten state. Shields or baffles 68 are located between crucibles 48, 50, 52 and 54 respectively to maintain vapors 70, 72, 74 and 76 in a pure, uncontaminated state.

As substrate 40 passes over crucible 48 a vaporized parting agent such as calcium fluoride or the like is emitted from molten bath 56 and deposited upon the substrate, forming a thin coating of approximately 1,000 to 3,000 Å in thickness thereupon. As the substrate passes over crucible 50, a non-pyrophoric metallic vapor 72 emitted from molten bath 58, for example, aluminum, hafnium, magnesium or the like is deposited upon the substrate forming a coating thereupon. As the coated substrate then passes over crucible 52 a vapor 74 emitted from molten bath 60, for example, yttrium is deposited upon the exposed surface of the previously deposited non-pyrophoric metal, and forms a coating of yttrium thereon. The coated substrate then passes over crucible 54 and a non-pyrophoric metallic vapor 76 emitted from molten bath 62 is deposited upon the yttrium layer. Thus a substrate may be coated sequentially with pyrophoric and non-pyrophoric layers of material to produce a laminated combustible foil uniquely suited for use in flashbulbs.

The formed composite is thereafter stripped from the substrate in a manner well known to those skilled in the art. Such a process could be continuous and therefore avoid the problems associated with batch operations.

The thickness of the various deposited layers can be

varied thereby permitting the composite to exhibit different combustion rates. Varying coating thickness can be accomplished by adjusting the power level of the guns, by altering the speed at which the substrate travels or by moving the baffles, thereby altering the exposure time in the respective vapor zones.

The apparatus and methods which are pictorially represented in FIG. 5 can also be used to apply additional layers of materials to the composite.

In addition to the embodiments of the invention discussed above, it has also been found that the unique combination of pyrophoric and non-pyrophoric layers may occur in still another form. It was found that when a pure yttrium layer, whose external surface had oxidized to the point where flashing did not occur, was stripped from a substrate, the quick exposure to the atmosphere of the non-oxidized surface resulted in flashing of the material. Therefore, it was necessary to develop a process whereby yttrium could be deposited on a layer of combustible non-pyrophoric material in a manner that permits stripping the resultant composite without flashing. In this embodiment the exposed surface of the yttrium must be allowed to oxidize slowly such as by very gradual exposure to oxygen or air, so that it prevents pyrophoric flashing. This can be accomplished by allowing the air to enter the vacuum chamber slowly. Thus one side of the pyrophoric material will be protected by an oxide and the other by a vapor deposited layer of non-pyrophoric material.

We claim:

1. A photoflash lamp comprising a sealed light-transmitting envelope, a combustion-supporting gas atmosphere in said envelope, a quantity of combustible composite material positioned in said envelope, said composite including a first constituent formed from vacuum deposited non-pyrophoric material, a second constituent formed from a vacuum deposited pyrophoric material, wherein said non-pyrophoric material at least partially encloses said pyrophoric material and all portions of said pyrophoric material not enclosed by said non-pyrophoric material are covered with a protective oxide whereby undesired spontaneous ignition in said envelope is prevented and ignition means in said envelope in operative relationship with said composite.

2. A photoflash lamp as defined in claim 1 wherein said non-pyrophoric material is selected from the group consisting of aluminum, hafnium, magnesium and mixtures and alloys thereof.

3. A photoflash lamp as defined in claim 1 wherein said pyrophoric material is yttrium.

4. A photoflash lamp as defined in claim 1 wherein said composite material comprises a multi-layered foil having at least one layer of pyrophoric material and at least one layer of non-pyrophoric material.

5. A photoflash lamp as defined in claim 4 wherein said pyrophoric material is yttrium and said non-pyrophoric material is selected from the group consisting of aluminum, hafnium, magnesium and mixtures and alloys thereof.

6. A photoflash lamp as defined in claim 4 wherein said multi-layered foil includes at least four discrete layers made up of said pyrophoric and non-pyrophoric materials.

7. A photoflash lamp as defined in claim 4 wherein said foils are shredded.

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