This invention relates to an electroluminescent device of the type in which light is produced by the application of a varying voltage across two conductors separated by an electroluminescent phosphor, and particularly to such a device in which the conductors are wires and the device is designed to produce a thin line of electroluminescence.

In various display and panel electroluminescent devices it frequently is convenient and desirable to produce electroluminescent symbols, letters, numerals, indicator hands, etc., for the purpose of presenting information to be read out of the electroluminescent devices. This situation frequently occurs in connection with instrument panels, such as those employed in cockpits of aircraft, control rooms of petroleum and chemical processes installations, and various instrumentation operations, such as computers, etc.

In the prior art, electroluminescent wires have been made in various ways. For example, two wires are wrapped in parallel spaced relationship with respect to each other around an insulating support and an electroluminescent phosphor is positioned between the spaced wires. The prior art flexible wires and methods of manufacture thereof suffer from such disadvantages as bulky and costly construction, lack of flexibility in the resulting electroluminescent wire, uneven and erratic light effects, and manufacturing difficulties related to wrapping the spaced conductors around the insulating support.

Accordingly, it is an important object of my invention to provide an improved flexible electroluminescent strand characterized by a high degree of flexibility, uniform production of light along the cord, and low construction costs.

Another object of this invention is to produce an electroluminescent strand having a long service life, a high degree of reliability and the capability of being conveniently and utilized in a wide variety of electroluminescent devices.

A further object is to provide an efficient method for producing highly flexible electroluminescent wire which produces light uniformly and efficiently.

Additional objects will become apparent from the following description, which is given primarily for purposes of illustration and not limitation.

Briefly stated in general terms, the objects of my invention are attained by spacing two elongate electrical conductors or wires with respect to each other and disposing an electroluminescent phosphor adjacent the two conductors, preferably in the space therebetween. A preferred embodiment of the invention is produced by wrapping an elongate conductor, such as an insulated wire, around another elongate conductor, such as an uninsulated or insulated wire, and applying an electroluminescent phosphor coating between the adjacent wrappings of the wrapped wire. Either one of the conductors or wires can be insulated and the other uninsulated in the device described immediately above. Alternatively, both of the conductors or wires can be insulated.

A more detailed description of a specific embodiment of my invention is given below with reference to the attached drawing, wherein:

FIG. 1 is a schematic elevational view drawn to a greatly enlarged scale showing the construction of one embodiment of the electroluminescent strand of the invention;

FIG. 2 is an end view of the embodiment shown in FIG. 1 showing the relationship of the two conductors and the phosphor in the strand;

FIG. 3 is a schematic elevational view showing a frame employed for manufacturing electroluminescent strand of the type shown in FIGS. 1 and 2;

FIG. 4 is a schematic elevational view drawn to a greatly enlarged scale showing conductor ends of the electroluminescent strand of FIGS. 1 and 2 prepared for electrical connection.

FIG. 5 is a schematic elevational view drawn to a greatly enlarged scale showing the construction of a preferred embodiment of the electroluminescent strand of the invention;

FIG. 6 is an end view of the embodiment shown in FIG. 5 showing the arrangement of the two conductors and the phosphor coating in the electroluminescent strand;

FIG. 7 is a view similar to that of FIG. 5, showing the construction of an electroluminescent strand made of two wires coated with dielectric material; and

FIG. 8 is a similar view showing an additional embodiment of my invention.

Reference to FIGS. 1 and 2 will show that in the embodiment of the electroluminescent strand shown therein, two conductors 10 and 11 are spaced a predetermined, uniform distance with respect to each other. A parallel spacing of a small distance preferably is established between the conductors along their lengths, as shown. A phosphor 12 is filled in the space established between the two conductors 10 and 11. A method of making this embodiment of electroluminescent strand of FIGS. 1 and 2 will be described in more detail below.

Upon applying a varying voltage across the conductors 10 and 11 the phosphor 12 is excited and produces an electroluminescent light. Either one of the conductors 10 or 11 is provided with a coating of dielectric or insulating material, such as varnish, Teflon, Kel-F, etc. If properly made, the electroluminescent strand shown in FIGS. 1 and 2 possesses some degree of flexibility in the plane perpendicular to the plane of the two conductors. Care must be taken in bending or shaping strands of this type to prevent any separation of the conductors 10 and 11 from the phosphor 12. If slight separations occur between conductors 10 and 11 and phosphor 12, uneven light results along the length of the electroluminescent strand. Appreciable separations result in total failure to produce light in the region of such separations.

Electroluminescent strand of the type shown in FIGS. 1 and 2 can conveniently be made by the use of a frame 13 of the type shown in FIG. 3. A frame 13 made of welded aluminum and provided with fixed hooks 14 at one side thereof and adjustable hooks 15 at the other side proved quite satisfactory. The hooks 14 and 15 are relatively much smaller than shown in FIG. 3 and are positioned close together on each side 17 and 18, respectively, of frame 13 depending upon the spacing desired between conductors 10 and 11. A length of a single wire conductor of a suitable diameter, such as about 0.002 in., for example, and made of a suitable metal, such as copper, silver, nickel, molybdenum, etc., is fastened to the uppermost fixed hook 14 and passed horizontally of the frame 13 through the eye of uppermost adjustable hook 16. From uppermost adjustable hook 16, the wire conductor is passed horizontally back across the opening of frame 13 and through the eye of the second fixed hook 14. This cycle of operations is repeated until the desired number of horizontal lengths of wire have been strung into frame 13.

Starting with the first two, or two uppermost, horizontal lengths 21 and 22 of wire, which are spaced closer...
together than the desired predetermined spacing of conductors 10 and 11 in the finished electroluminescent strand, the uppermost adjustable hook 16 is urged outwardsly of side 18 of frame 13 by tightening a nut 19 threadedly mounted on hook 16, as shown. This action tightens the wire lengths 21 and 22, and is continued until the desired degree of tightening is attained. Each successive pair of wire lengths is tightened in similar manner by urging a corresponding adjustable hook 16 outwardsly of side 18 of frame 13 by tightening a corresponding nut 19.

26. When the wire lengths have been properly tightened, each pair of these lengths, such as lengths 21 and 22, is spaced apart a desired, predetermined distance, such as about 0.010 in., for example. This can be done by urging a spacer, such as a short length of wire of the desired diameter, for example, between the lengths 21 and 22 at each end thereof, and at spaced points between the ends, if desired. A hardenable electroluminescent phosphor slurry of the desired composition and consistency is applied in the space between adjacent lengths of wire, such as lengths 21 and 22, of each pair of spaced lengths. This phosphor application is conveniently made by dipping a small brush into the phosphor slurry and painting the paste between the wire lengths. Because of the action of the surface tension of the slurry it flows into the space between the adjacent spaced lengths of wire and forms a continuous fluid mass.

After this fluid mass of phosphor has dried and hardened to the desired degree, the spaces are removed from between the lengths of the wire pairs and the hardened phosphor retains the wire lengths in the desired, spaced relationship. Any empty spaces left after removal of the wire spacers are filled in with phosphor slurry. The resulting strands, having the structure shown in FIGS. 1 and 2, are based on the frame 13 at the desired temperature for a suitable time to complete the processing of the phosphor. After baking and cooling, the electroluminescent strands are cut from hooks 14 and 16 by wire cutters. The resulting processed electroluminescent strands are formed into the desired shapes, such as numerals, letters, words, arrows, etc. One end of the shaped strand is prepared for electrical contact as shown in FIG. 4. A length of the phosphor 12 is removed from the end of the strand and the exposed lengths of wires 10 and 11 are bent apart. A button or bead of suitable plastic potting compound is cast at the juncture of wires 10 and 11 with phosphor 12 to fix the relationship of these elements for ease in electrically connecting wires 10 and 11 to a source of varying voltage.

It will be understood that an electroluminescent strand of the type shown in FIGS. 1 and 2 can be produced continuously by any suitable means, such as by continuously leading two spaced wires 21 and 22, while continuously maintained in predetermined spaced relationship with respect to each other, from spools or other supplies of the wires, continuously passing the spaced wires through a bath or baths of phosphor slurry or slurries, continuously passing the spaced, phosphor coated wires through a wiping orifice or die, continuously passing the wire strand through a baking zone, or zones, and continuously passing the baked strand onto a spool, or through wire cutting means, to produce a supply of finished electroluminescent strand product.

A method of embedding the flexible electroluminescent strand according to my invention is shown in FIGS. 5 and 6. It is constructed by procuring a suitable coated wire 23, such as a copper wire 24 having a suitable diameter, such as a diameter of about 0.002 in., for example. The wire 24 is coated with a suitable high dielectric coating 26, a coating of Teflon, for example, about 0.003 in. thick. Wire 23 is wound over a bare, uncoated wire 27 having a suitable diameter, such as about 0.007 in., for example. Wire 23 is wound in the form of a helix having a suitable pitch, such as about 2/3 of an inch, for example.

In actual practice, coated wire 23 is wound around uncoated wire 27 by the use of a continuous wind bobbin machine. This equipment results in very rapid, efficient and low cost production of a uniform product. The straight, inner wire 27 serves as the main conductor, whereas the helically wound, outside wire 23 acts as a secondary. Such a construction means which helps to retain the phosphor coating 16 as a continuous shell covering both conductors. It will be understood that the wire dimensions and pitch dimension given are not fixed but can be varied in accordance with the results desired. In general, the smaller wire and pitch dimensions produce brighter light and, of course, result in a flexible cord of smaller overall size.

The electroluminescent phosphor coating 28 is applied over the exposed surfaces of inner bare wire 27 and between the helical windings of coated wire 23, as best shown in FIG. 5. The phosphor coating 28 preferably is applied in the form of a slurry and can be painted onto the structure with a soft brush, sprayed thereon with a spray gun, or coated onto the structure by dipping the same into a body of the slurry. In the latter case, the excess slurry is wiped from the structure by any suitable means, such as by passing the slurry-dipped strand through an orifice of suitable diameter. After the phosphor coating 28 is applied and wiped, it is baked at a suitable temperature for a predetermined time. A transparent protective coating of varnish, shellac, plastics, etc., can be applied to the baked phosphor, if desired. Such coating protects the phosphor from wear and atmospheric effects.

The electroluminescent strand of my invention, shown in FIGS. 5 and 6, represents an important improvement over the electroluminescent strand shown in FIGS. 1 and 2. It will be noted that electroluminescent strands of the type shown in FIGS. 5 and 6 have peculiar cross-sections. This type of strand is very flexible and can be bent in all directions and not just in a particular plane. This is an important advantage because in many applications it is necessary that the wire be capable of being bent at any desired angle, and in any desired direction. Furthermore, the type strand shown in FIGS. 5 and 6 generates illumination equally entirely around its cylindrical surface and not principally along certain longitudinal portions thereof, as is the case with the type strand shown in FIGS. 1 and 2.

In an alternative method, two insulated wires, such as two Teflon-coated wires, can be used, as shown in FIG. 7. The straight, outer wire 32 is electrically insulated from the inner, similar Teflon-coated wire 30 in the manner described above in describing the embodiment shown in FIGS. 5 and 6. A phosphor coat 31 also is applied in the manner described above in the embodiment of FIGS. 5 and 6. In an additional alternative method, the two wires, both coated, or one coated and one uncoated, can be twisted helically around each other as shown in FIG. 8, to form an electroluminescent strand in the form of a twist strand. A phosphor coating 34 is applied to the twist strand structure in the manner described above in connection with the description of the embodiment of FIGS. 5 and 6.

It will again be understood that electroluminescent strands of the types shown in FIGS. 5 and 6, FIG. 7, and FIG. 8, respectively; can be produced continuously by any suitable methods, as pointed out above in connection with the discussion of the type electroluminescent strand shown in FIGS. 1 and 2. For example, the outer wire can be continuously supplied to a helical winding, twisting or the like, machine and the wires can be continuously wound, twisted, etc., the resulting strand is continuously passed through a bath or baths of phosphor slurry, or slurries, continuously passed through a wiping orifice or die, continuously passed through a baking zone, or zones, and continuously wrapped onto a spool to produce a supply of finished electroluminescent strand product suitable to be cut and formed or shaped, as desired, depending upon the use to which it is to be applied.
The electroluminescent wire of my invention has many important applications where illumination is desired in the form of a fine line or in the form of a symbol, numeral, word, etc., spelled out by a thin line of light, such as in read-out devices, gauges, recorders, computers, panels, displays, etc.

Obviously many other modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention can be practised otherwise than as specifically described.

What is claimed is:

1. A flexible electroluminescent strand consisting essentially of a first copper wire having a diameter of about 0.007 in., a second copper wire having a diameter of about 0.002 in. coated with a high dielectric material and wound around the first wire, and an electroluminescent phosphor coating applied to the surface of the first wire and engaging the surface of the dielectric coating of the second wire.

2. A flexible electroluminescent strand consisting essentially of a first copper wire having a diameter of about 0.007 in., a second copper wire having a diameter of about 0.002 in. coated with a high dielectric material wound in the form of a helix having a pitch of about \( \frac{3}{8} \) in. around the first wire, and an electroluminescent phosphor coating applied to the surface of the first wire and engaging the surface of the dielectric coating of the second wire.

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