

April 5, 1966

P. G. SCHMIDT

3,245,023

HEATING DEVICE

Filed March 29, 1963

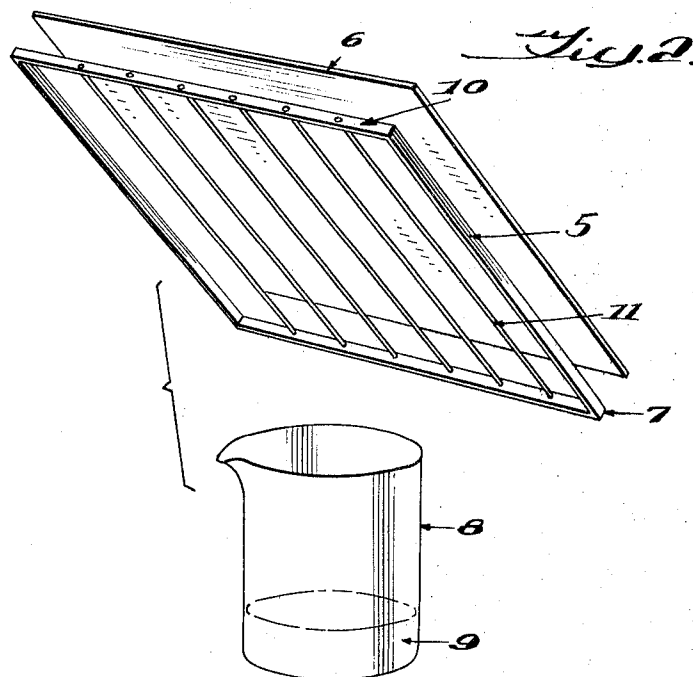
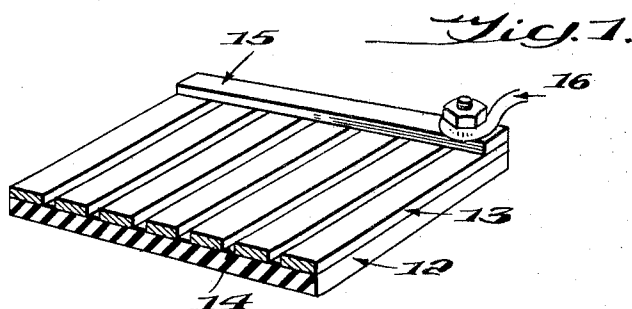
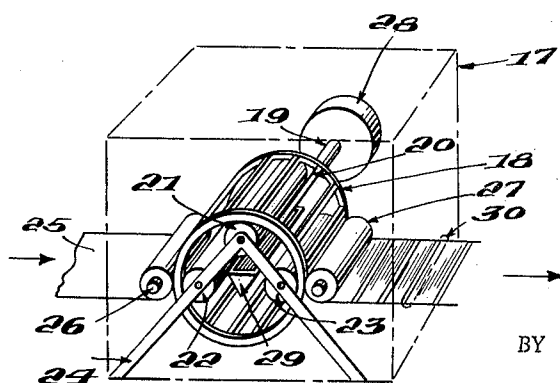


*Fig. 3.*



INVENTOR  
PAUL GORDON SCHMIDT,

BY

*Robert W. Black*

ATTORNEY

1

3,245,023

## HEATING DEVICE

Paul Gordon Schmidt, Wilmington, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed Mar. 29, 1963, Ser. No. 268,900

1 Claim. (Cl. 338-211)

This invention relates to electrical heating devices and more particularly to integral electrical heating devices having a plurality of electrically conductive coating pathways insulated from one another.

Electrical heating of panels by means of resistance coatings applied to insulating substrates for uses such as de-icing windshields or for food warming devices, offer many attractive possibilities if reliability can be achieved. These devices afford uniform area heating, can provide unobstructed vision, and the device can be of low cost and compact construction. However, the use of conductive coatings on non-conductive substrates for electrical heating devices is highly critical with respect to uniformity since small areas of high resistance or voids in the coatings can cause catastrophic failure of the entire device. This is a result of excessive heating in areas adjacent to a void which causes erosion of the coating around the void, which in turn causes growth of the void, resulting in rapid acceleration of the process of erosion and complete burnout of the device. This characteristic has put such rigorous requirements on quality control that production costs have been prohibitively high for many applications where this structure is useful.

This deficiency of conductive coated insulated substrates is especially apparent in structures which are subjected to flexing. Flexing can cause the occurrence of microscopic fissures in the coating, which upon application of electric power can grow and lead to catastrophic failure.

It is, therefore, an object of this invention to provide electrical heating devices which are not subject to the deleterious effect of small imperfections.

It is a further object of this invention to provide reliable, integral electrical heating devices having a plurality of electrically conductive coating pathways insulated from one another which can be continuously produced. These and other objects will appear hereinafter.

These and other important objects and advantages of the invention will become apparent as the same is more fully understood from the following description, which, taken in connection with the accompanying drawings, discloses preferred embodiments of the invention wherein:

FIGURE 1 is a cross-sectional perspective view of the heating device of the present invention.

FIGURE 2 illustrates a method for preparing the device of the present invention and

FIGURE 3 schematically shows an apparatus for the continuous production of the heating device of the present invention.

Before the heating device of the present invention is described in detail, an understanding of the mechanism of failure, due to a minor imperfection in the conductive coating on the surface of an insulating support, will be briefly discussed. In general, a heating device is composed of an insulating film support having coated thereon a conductive surface which is coupled to an external power source located at two opposite ends of the support.

By nature, the distribution of the current, in flowing from one end to the other over the conductive surface, is such that it will spread over the entire available conductive coating. As the current approaches a minor imperfection in the coating, such as a small scratch, an increment of the electrical pathway encounters a large resistance gradient. As the current passes around this non-conductive area, the current density immediately adjacent

2

the area increases enormously. Accordingly, the heating at the very edges of the imperfection can be excessive due to a large increase in current density. This heating effect increases very rapidly as it approaches the periphery of the imperfection, causing oxidation or other erosion of the surface or, in the case of organic film supports, gradual degradation of the film. Quite obviously, any effects which cause erosion of the coating on the surface will be cumulative, since as part of the area is lost, the circumference of the imperfection increases, with an increasing effect on the remaining area of the conductive surface. The effect has an exponential growth until the size of the imperfection traverses the entire width of the conductive path, at which time the unit fails.

The present invention eliminates or minimizes the deleterious effects of imperfections, by isolating the effects of individual imperfections and irregularities in the conductive coating on the film. This is accomplished by dividing the conductive coating into a plurality of substantially independent pathways or channels. The extent of subdivision into pathways determines the effectiveness in eliminating very small imperfections, therefore, the larger the number of divided pathways the more effective the isolation will be.

As FIGURE 1 illustrates, insulating substrate 12 has conductive coating 13, preferably of a material such as tin oxide, divided into parallel strips by separations 14. Terminal strip 15 is applied to the end of the panel by means of conductive paint such as conductive silver paint, or it can be a metal strip which is firmly secured to the heating panel. A similar strip is located at the opposite end of the structure. These strips distribute the current evenly through the conductive pathways. The terminal strips join the conductive pathways to an external electrical circuit through connection 16.

This invention is useful in improving the lifetime of surface conductive devices which carry substantial currents, that is, currents which are of a magnitude at least approaching that which causes heating. It is applicable to flexible insulating supports coated with conductive coatings such as titanium dioxide ( $\text{TiO}_2$ ), tin dioxide ( $\text{SnO}_2$ ), indium oxide ( $\text{In}_2\text{O}_3$ ), or cadmium oxide ( $\text{CdO}$ ). Other conductive coatings such as thin metal films and films of conductive carbon are also advantageously employed with the device of this invention. The preferred oxide coatings are transparent.

The device of the invention is useful preferably with heat-resistant films, such as films of polymeric polyimides prepared from dianhydrides and diamines (e.g. pyromellitic dianhydride and 4,4'-diaminodiphenyl ether as described in copending application Serial No. 169,120, filed January 26, 1962, and assigned to the assignee of the present invention). Likewise, the lifetime of very thin conductive coatings on rigid substrates such as glass or ceramics may be increased by use of the device of the present invention.

The segregated pathway conductive coating of this invention can be applied by adaptation of numerous methods known to the art; by masking the areas between the separate channels as shown in FIGURE 2, or by scribing parallel lines manually or with an engine such as a ruling engine.

As shown in FIGURE 2, film 6 is supported by framework 7 above vessel 8 which contains the conductive composition 9 to be coated on the film. Frame 7 which is used as a film support in coating and as a masking frame to divide the coating into parallel channels has end supports 10 to which are silver soldered a number of parallel nickel wires 11. Additional heavy bars 5 at each end of the framework tend to support the wires in parallel relationship. When film 6 and framework 7 are placed in the oven for application of the conductive

coating, film 6 rests firmly on the framework so that the wires 11 will provide an uncoated section on the film.

In order to illustrate the improvement of lifetime effected by the above insulated band structure in use with an electric current sufficient to cause heating, the area around a small scratch made through the coating about halfway across a single band glowed red in the dark, and after about an hour this band is observed to have lost its conductivity, while the other bands are unchanged in resistance.

As mentioned hereinbefore, the heating panel of this invention is especially adapted to automatic production. An apparatus for production of this panel by automatic means is illustrated schematically in FIGURE 3. An oven 17 contains an open ended, cage-like masking device 18 over which the film passes as it is being coated with the conductive material.

Device 18 is driven by spindle 19 and is made of rigid blade-like structures 20 which pass axially along the periphery of the cage-like structure. This cage-like masking roller is supported by rollers 21 and 22 and 23 which in turn are mounted on bracket 24 so as to provide support to the open end of the cage-like structure.

Film 25 is guided over the cage-like mask by rollers 26 and 27 while the cage-like structure is driven by driver member 28 on the far side of the enclosure. The solution for the coating composition is fed into the enclosure to trough 29 where it is electrically heated and evaporated to cover the film which wraps on the upper side of the cage-like structure and travels at the same speed as the cage structure to insure even masking lines on the film. The coated film passes out through port 30 where it goes to windup or other processing.

It will be understood by those familiar with related art that this device requires frequent attention, to avoid the build-up of the coating material on the inside of the masking, cage-like structure. For this reason a non-adherent coating is preferably used on the structure to prevent the adherence of the coating composition to the mask rather than to the film. Even so, after long periods of time the device must be taken apart and cleaned to remove excessive deposits which occur on the masking structure.

The principal advantage of this device over those known to the prior art is its reliability and relatively long lifetime as effected by elimination of the pernicious effect of minor imperfections in the coating. A further advantage is its ability to be constructed by relatively cheap

methods as a result of relaxation of rigorous quality standards. A still further advantage is the ease at which it can be adapted to continuous production allowing mass production of heating elements which are essential to their widespread use. Yet another advantage is the fact that this is an integral unit, as opposed to heating panels and similar devices fabricated from metal strips which are embedded in and supported by asbestos or other insulating fabrics. This enables the device to be adapted to numerous uses where conformity to complex shapes is required.

What is claimed is:

A heating device comprising, in combination: a flexible polyimide film derived from a dianhydride of an aromatic tetracarboxylic acid and an organic diamine; a conductive metal oxide coating on one surface of said film, said conductive metal oxide coating selected from the group consisting of tin oxide, indium oxide, titanium dioxide and cadmium oxide and divided into a plurality of substantially parallel pathways of equal width transversely insulated from each other; and a pair of conductive silver paint strips disposed in a parallel manner and applied over each end of said pathways joining said pathways to an external electrical circuit, whereby the effect of discontinuities in the coating is minimized.

#### References Cited by the Examiner

##### UNITED STATES PATENTS

|           |         |                |           |
|-----------|---------|----------------|-----------|
| 2,473,183 | 6/1949  | Watson         | 338—308   |
| 2,475,379 | 7/1949  | Strong         | 338—309   |
| 2,489,643 | 11/1949 | Hunter         | 219—243   |
| 2,557,983 | 6/1951  | Linder         | 338—308   |
| 2,564,677 | 8/1951  | Davis          | 338—308   |
| 2,584,859 | 2/1952  | Gaiser         | 338—309 X |
| 2,641,675 | 6/1953  | Hannahs        | 174—68.5  |
| 2,682,483 | 6/1954  | Erbe           | 219—549 X |
| 2,712,591 | 7/1955  | Rogell         | 219—528 X |
| 2,715,668 | 8/1955  | Booker et al.  | 219—543 X |
| 2,739,083 | 3/1956  | Brown et al.   | 117—211   |
| 2,867,609 | 1/1959  | Edwards et al. | 260—78    |
| 2,934,736 | 4/1960  | Davis          | 338—308   |
| 2,961,522 | 11/1960 | Hammer         | 219—549 X |
| 3,063,881 | 11/1962 | Harwig         | 219—543 X |

ANTHONY BARTIS, *Acting Primary Examiner.*

RICHARD M. WOOD, *Examiner.*

V. Y. MAYEWSKY, *Assistant Examiner.*