June 28, 1955 K. R. HOYT 2,711,983

PRINTED ELECTRIC CIRCUITS AND METHOD OF APPLICATION

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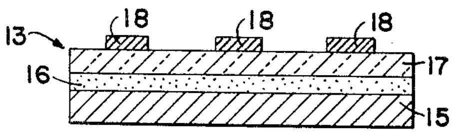

FIG. 1.

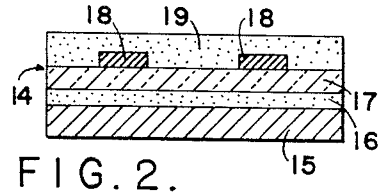

FIG. 2.

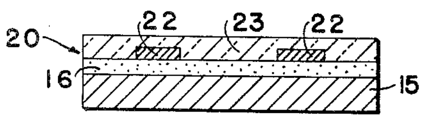

FIG. 3.

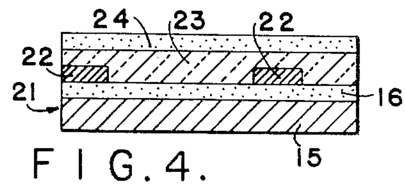

FIG. 4.

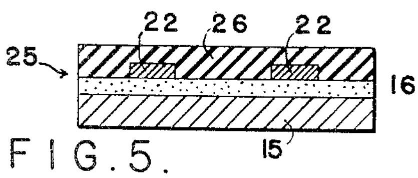

FIG. 5.

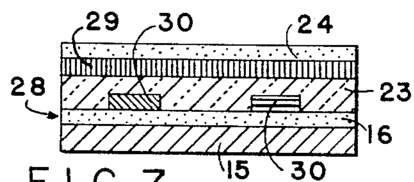

FIG. 7.

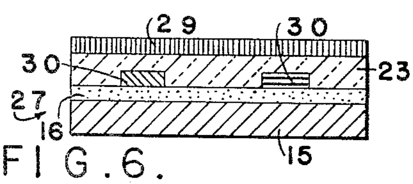

FIG. 6.

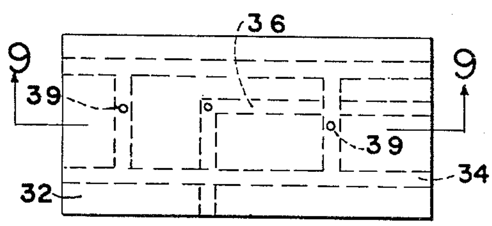

FIG. 10.

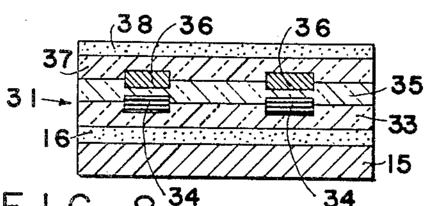

FIG. 8.

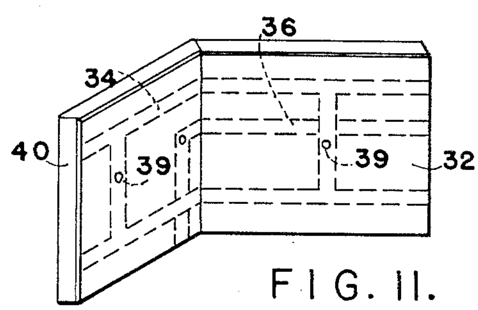

FIG. 11.

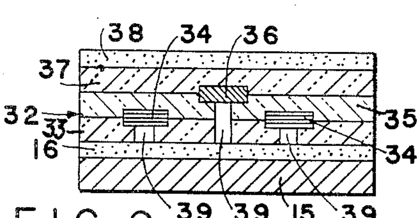

FIG. 9.

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PRINTED ELECTRIC CIRCUITS AND METHOD OF APPLICATION

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6 Claims. (Cl. 154—95)

This invention relates to the type of electric circuits commonly called printed circuits, in that they are substantially two-dimensional delineations or patterns of electric circuits upon supporting surfaces, although they may be painted, inlaid, electrolytically deposited, or otherwise applied to said surfaces.

The art of making printed or painted electric circuits on supporting surfaces has been highly developed, but has either involved much hand labor, as when the circuits are painted in electro-conductive paint, or has been restricted to flat surfaces adaptable to printing or stencilling processes. Irregular surfaces, convex or concave, with flanges or with external or internal angles, have not hitherto been considered as available as supports, by mass production methods, of two-dimensional circuits. For example, if a circuit was to cross a corner from one wall of a box to the adjacent wall, the walls forming the corner could not be an integral unit made by stamping or bending but were separate flat pieces, each individually receiving its individual part of the circuit, then joined in a corner, and the individual circuit parts connected by hand-applied paint or solder. Printing, stencilling, or photographic processes necessarily limited the applied circuits to areas of sizes workable according to the chosen process; a continuous circuit extending the length of the fusilage of an aeroplane was impractical even in the improbable event that the long supporting surface was smooth.

Insulation problems further complicated the hitherto existing art. Individual layers of insulation, wiring, and more insulation, had to be applied successfully, and often in difficult situations to the supporting surfaces. For this reason, even on surfaces themselves of insulating material, the application of complex crossed circuits by any of the known methods was, if not impossible, excessively expensive.

It is an object of this invention to provide simple and inexpensive means for applying printed circuits to supporting surfaces which may be flat or uneven or angular or curved, and which may be of much greater extent than has hitherto been found practicable.

It is a further object of this invention to provide means prepared in advance for applying electric circuits of great length and complexity so as to largely eliminate the hand-labor hitherto necessary in connecting small sections applied by the photographic, electrolytic or inlaying processes.

Another object of the invention is to provide means for applying insulation at the same time that the circuits are applied.

Still another object is to provide means for applying a large number of crossed or overlying circuits concurrently in a manner providing for insulating the circuits from one another.

A further object of the invention is to provide prepared circuits which can be intimately bonded to the supporting surfaces.

Yet another object of the invention is to provide oxidation-proof means for applying printed circuits which in

the course of fusing to a supporting surface or in subsequent usage would ordinarily subject to oxidation and deterioration, thus permitting the use of inexpensive electro-conductive metals.

In broad terms, I attain the foregoing objects, and others which will appear as the following specification proceeds, by applying the printed circuit or circuits to a base surface by means of a flexible decalcomania in which said circuit or circuits are incorporated, and which also includes a layer or layers of insulating material in a form which is flexible at the time the decalcomania is applied. The circuit or circuits may be embedded between layers of insulation or they may be left uncovered by the insulation, and the insulation may be applied to the supporting surface to insulate the circuit or circuits therefrom, or if the base surface is of itself of insulating material, the insulating material of the decalcomania may be used as exterior protection. The variety of forms in which my invention may be embodied makes possible the use of either "press-on" or "slide-off" techniques in applying the decalcomania. It also permits either cold or hot techniques in the application and subsequent curing or drying of the decalcomania, although I prefer when possible to use a method of curing in which the applied decalcomania is gradually baked at successively rising temperature levels, whereby volatile or decomposable elements of the decalcomania are successively removed, the ordinary elements of a decalcomania being removed first and the insulation material being fused to the supporting surface in a final step when no intervening elements remain.

In the accompanying drawing, illustrative of a number of suitable decalcomania arrangement but not intended to be all-inclusive of possible modifications of my invention,

Fig. 1 shows in cross-section a decalcomania having insulation on only one side of the printed circuits and suitable for application by the "slide-off" technique.

Fig. 2 shows in cross-section a decalcomania having insulation only on one side of the printed circuits but suitable for application by either the "slide-off" or "press-on" technique.

Figs. 3 and 4 show in cross-section decalcomanias in general similar respectively to those shown in Figs. 1 and 2, but having insulation only on the opposite sides of the circuits.

Fig. 5 is a view similar to Fig. 3, but showing the circuits protected by a different type of insulation.

Figs. 6 and 7 are cross-sectional views showing decalcomania circuits of different colors separated by transparent insulating material;

Fig. 8 shows in cross-section the use of a plurality of layers of insulating material in which a plurality of circuits are embedded.

Fig. 9 illustrates in cross-section a decalcomania having insulating layers which are discontinuous by reason of pre-formed perforations giving access to the embedded circuits.

Fig. 10 is a plan view of a decalcomania having crossed circuits and access perforations in the manner shown in Fig. 9; and

Fig. 11 shows such a decalcomania applied to an angulated supporting surface.

Having reference to the details of the illustrations, in each of Figs. 1–9, there is shown the usual removable paper backing **15**, coated with a layer of soluble binder material **16**, which may be a water-soluble gelatin. Gelatins are readily available for the purpose which volatilize or decompose at temperatures of around 250 degrees Fahrenheit, and a binder material of such quality is preferably employed. In the decalcomanias **13** and **14** shown in Figs. 1 and 2, a layer of insulating material **17** is applied to the layer of binding material

16 and the circuit or circuits 18 are printed on the layer 17. The insulating material 17 is shown in Figs. 1 and 2 as being vitreous and may be a composition of finely ground glass particles, carried in a suitable lacquer. A fineness of about 300 mesh is suitable for the glass particles. Numerous lacquers having in themselves good dielectric properties are available, and preferably I select one which volatilizes or otherwise decomposes at a temperature considerably higher than the volatilizing point of the gelatin layer 16 but considerably lower than the fusing point of the ground glass. The circuits 18, on the other hand, may be printed in electro-conductive paint, such as silver paint, having a fusing point higher than the glass fusing point. For example, the gelatin as aforesaid may be selected to volatilize at about 250 degrees, the lacquer in the layer 17 may be selected to volatilize at about 650 degrees, the ground glass to fuse as about 970 degrees, and the silver paint to fuse at about 1100 degrees.

It will be seen that the decalcomania 13 of Fig. 1 is suitable for application by the "slide-off" technique, having gelatin 16 only adjacent to the paper backing 15. The decalcomania 14 shown in Fig. 2 has a second layer of gelatin 19 covering the circuits 18 and may be applied by either the slide-off or press-on techniques. Either of these decalcomanias may be applied to a conductive surface by the slide-off technique, then having their respective insulating layers 17 between the surface and the circuits 18, and of course they may be applied to non-conductive surfaces.

Because the ground glass in lacquer is quite flexible, the decalcomanias should be carefully smoothed after having been applied, in order to assure the closest adhesion to the supporting surface, to carry the circuits over and around any unevennesses, curves, or angles in the supporting surfaces, and to avoid air-pockets. In many instances they may be applied cold, as the ground glass and lacquer layers 17 do not have to be fused in order to provide good insulation for low voltages. Where, however, either the voltages are high or the surfaces to which the decalcomanias are affixed are subject subsequently to bending, I prefer to heat-treat the affixed decalcomanias in order at least to remove volatile fractions therefrom, thus improving the dielectric qualities of the layers 17, and usually to fuse the residual ground glass, particularly when the supporting surface is of material to which the glass will fuse. In heat-treating the applied decalcomanias, I increase the heat in a series of steps, each step being designed to create a new condition requisite to the most satisfactory completion of the following step. I will for example, after of course removing the paper backing 15, first bake the applied decalcomania at about 250 degrees Fahrenheit to drive off the gelatin layer 16, or the layers 16 and 19. It will be apparent that this step will bring the insulation layer 17 into intimate contact with the supporting surface. After a time sufficient for the generated vapors and gases to escape, so as to leave no gas pockets, the temperature is raised to the vaporizing point of the lacquer in the layer 17, which may be about 650 degrees, and held there until, again, generated vapors have escaped. As a final step the temperature may be raised to the fusing point of the glass, about 970 degrees and the glass fused to the supporting surface. It is quite important to allow sufficient time between successive increases of temperature to permit escape of vapor and not to over-heat during either of the first two named steps, as otherwise vapor pockets will be formed by too rapid generation of vapor.

The decalcomanias 20 and 21, shown in Figs. 3 and 4, are respectively similar to the decalcomanias 13 and 14 except that their circuits 22 are placed on the side of the insulation layers 23 next to the gelatin layers 16 and the paper backing 15. It will be apparent that either of the decalcomanias 20 and 21 may be applied to non-

conductive supporting surfaces by the slide-off technique and the circuits 22 will then not be exposed but will be covered by the insulation layers 23. It will also be apparent that if the decalcomania 21 is applied by the press-on technique by means of the gelatin layer 24, it will result in the same relative arrangement as the application of either of the decalcomanias 13 or 14 by the slide-off technique.

In Fig. 5 is illustrated a decalcomania 25 of the same general construction as the decalcomania 20, but with the glass insulation layer 23 of the latter replaced by a layer of lacquer 26. Such a decalcomania is suitable for application to surfaces to which glass is not readily fusible, and may be applied cold or may be baked on at temperatures sufficient to dry the gelatin layer 16 without affecting the lacquer layer 26.

An advantage in the use of decalcomanias 14, 20, 21 and 25, is that the conduits 18 or 22 are within the decalcomanias, that is, between layers of protective material, and the decalcomanias may not only be prepared in advance of application but may be stored unused without damage to the thin printed circuits by scratching or oxidation. When the decalcomanias are applied in such manner that the insulating layers 17 continue to cover the circuits, being on the opposite side of the circuits from the supporting surfaces, oxidation is prevented even when the decalcomanias are baked or fused. Under these circumstances, such metals as copper or aluminum may be used for the circuits in place of silver.

The structure of plural circuits, including cross-over, is shown in Figs. 6, 7, 8, 9, and 10. In the decalcomanias 27 and 28 of Figs. 6 and 7, the structure is essentially the same as in Figs. 3 and 4, an additional circuit 29 being shown crossing the circuits 30 on the opposite side of the insulating layer 23. The circuits 29 and 30 may be printed in different colors, as indicated, so that they may readily be traced through the glass insulating layer 23. The modified decalcomanias 31 and 32 shown in Figs. 8 and 9 illustrate the use of plural insulating layers. An insulating layer 33 is placed upon the binder layer 16 and circuits 34 are printed thereon. Then another insulating layer 35 is spread upon the layer 33 and circuits 34, and circuits 36 are in turn printed thereon. This succession of insulating layers and circuits may be continued at length without stiffening the decalcomania to the point where it will no longer adhere to a surface angle, as many as eight layers of circuits insulated by insulation layers of a few thousandths of an inch in thickness having been found practicable. The decalcomanias may be topped off by exterior insulating layers 37 and binder layers 38 to make them applicable by either of the standard techniques and to conductive surfaces. As successive layers of insulation are built upon the original backing 15 and binder layer 16, masking strips or spot disks may be suitably placed to break the continuity of the insulating layers at points where access to enclosed circuits is desired, so as to provide access ports 39 for electrical connections to the circuits. With transparent glass insulating layers, the various circuits and access ports will appear on a flat decalcomania as shown in Fig. 10, and as in Fig. 11 when applied to an angulated support 40.

I claim:

1. In a decalcomania, in combination with a layer of removable backing material, and soluble binder material for affixing said decalcomania to a supporting surface: a plurality of layers of flexible insulation material containing elements destructible by heat and separated from said backing layer by a portion of said binder material and adapted to retain their insulating properties after said destructible elements have been destroyed, and a plurality of interconnected printed electric circuits between said insulation layers said entire decalcomania being a solid unit in cross section and having flexibility sufficient to permit it to extend around a sharp angle.

2. In a decalcomania, the combination set forth in claim 1, in which said binder material and insulating material are transparent.

3. In a decalcomania, in combination with a layer of removable backing material, and soluble binder material for affixing said decalcomania to a supporting surface: a layer of flexible insulation material containing elements destructible by heat and separated from said backing layer by a portion of said binder material, said material hardening upon the destruction of said destructible elements but then retaining its insulating properties, and a plurality of flexible printed electric circuits on opposite sides of said insulation layer.

4. In a decalcomania, the combination set forth in claim 3, in which said electric circuits are printed in electro-conductive material of different coloration.

5. In a decalcomania, the combination set forth in claim 3 in which said insulation material is substantially transparent.

6. The method of applying a plurality of printed electric circuits to a base surface which comprises: applying to said surface a decalcomania inclusive of volatile binding material, and insulating material containing finely ground glass and carrier material therefor volatilizing at a higher temperature relatively to said binding material, said circuits being printed on opposite side of said insulating material; smoothing said decalcomania on said surface to flex, when necessary, said circuits conformingly to irregularities of said surface; heating said decalcomania to a temperature and for a time sufficient to substantially decompose said binding material; further heating said decalcomania to a temperature and for a time sufficient to substantially decompose said carrier material; and further heating said decalcomania to a temperature and for a time sufficient to fuse said glass.

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