May 24, 1960 P. M. G. TOULON 2,938,135

SOLID STATE DISPLAY SCREENS

Filed April 24, 1958 2 Sheets-Sheet 1

Fig.1.

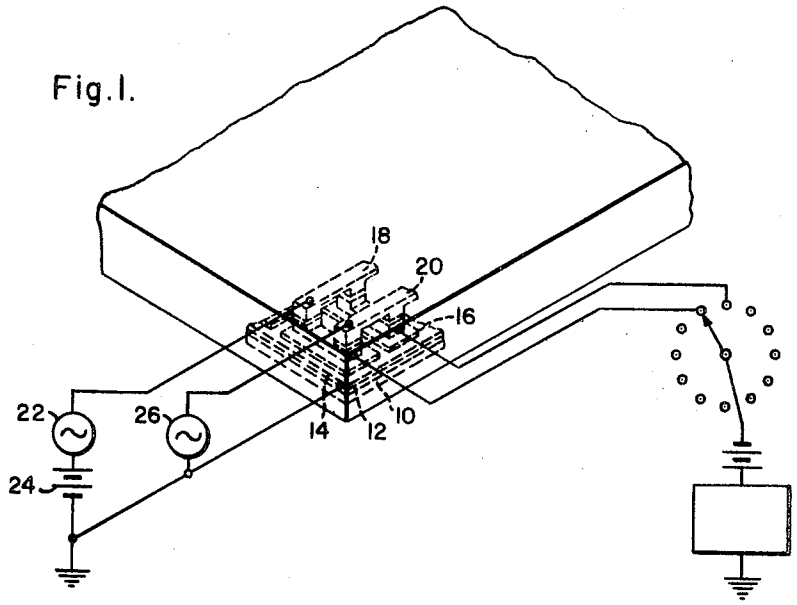
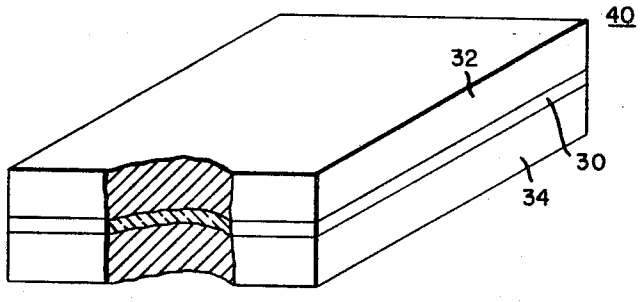


Fig.2.



WITNESSES

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Fig. 3.

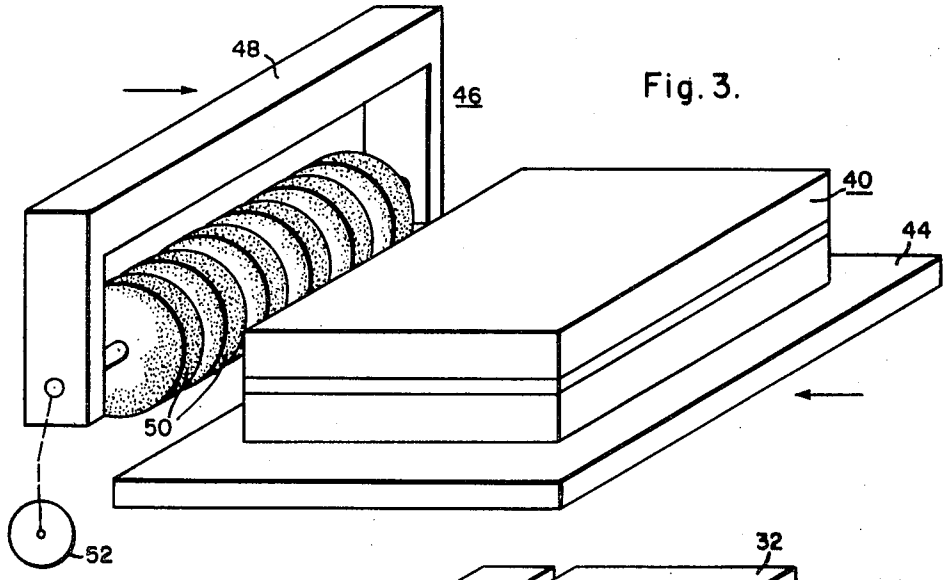


Fig. 4.

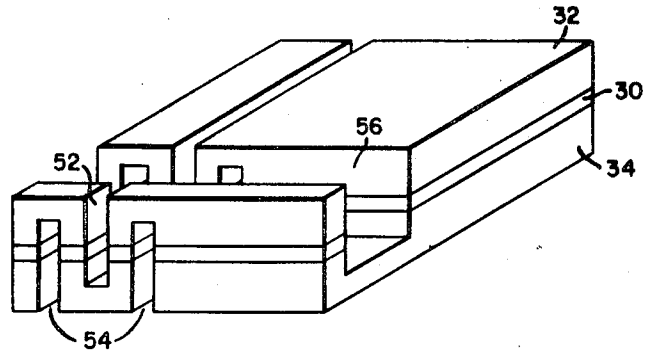
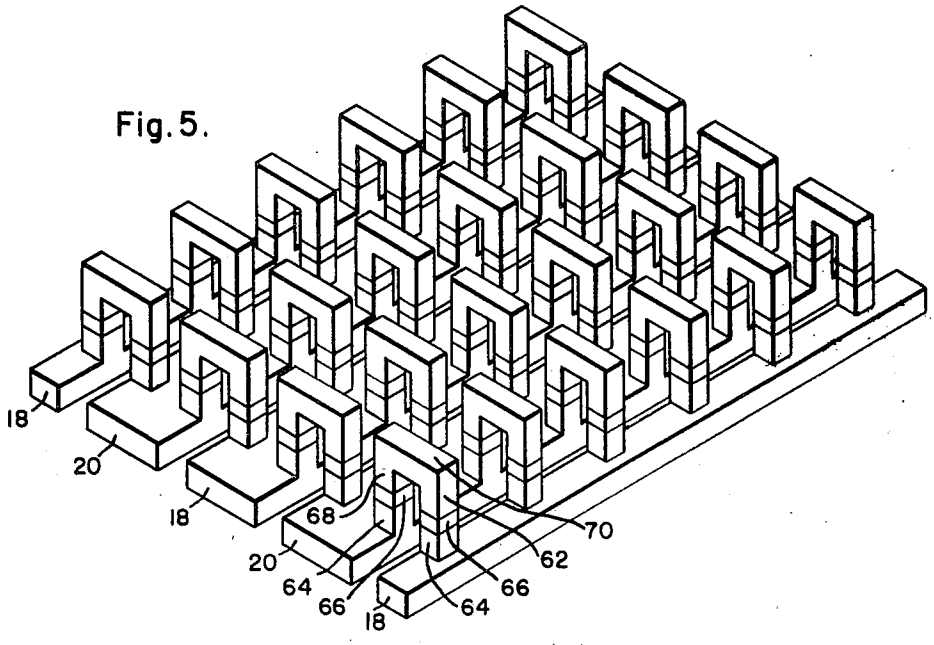


Fig. 5.



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SOLID STATE DISPLAY SCREENS

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8 Claims. (Cl. 313—108)

This invention relates to display devices and, more particularly, to methods of fabricating multielementary solid state display devices. Recent developments in panel type light amplifiers utilizing electroluminescent phosphors have given rise to the possibility of utilizing such devices as a display screen. The various disadvantages and inadequacies of the conventional display transducer, the cathode ray tube, are well known. Prominent among those which are generally cited are the grossly inconvenient shape and size, limited brightness, and susceptibility to flicker.

The utilization of a solid state display screen utilizing an electroluminescent phosphor could foster advances in the electronic image systems which have heretofore been impeded by said serious inadequacies of the cathode ray tube.

In the prior art, several proposals have been made in utilizing an electroluminescent phosphor which is sandwiched between two areas of mutually perpendicular conducting strips for displaying a scanned image. In this type of system, the electrical excitation on any element of the display must be in the form of a very short pulse applied once every frame. On the present performance of electroluminescent materials, it would appear that this and similar schemes are not practical as display devices. It is impossible to transfer sufficient energy to the phosphor with such an arrangement to yield adequate screen brightness. In order to utilize electroluminescence in a practical display, it is necessary to provide means by which the excitation is applied to each element for a major fraction of the frame time. This process is called storage, since it involves means for storing the control signal that sets the brightness of the element for one or more frame periods.

In my copending application Serial No. 727,916, filed April 11, 1958, entitled "Display Systems," now U.S. Patent No. 2,875,380, there is disclosed a solid state display screen which utilizes nonlinear capacitors as the storage means in controlling the light from the electroluminescent phosphor. This type of display screen provides the obvious advantage over conventional display of high brightness and minimum flicker. The one disadvantage of the structure disclosed in the previously mentioned application is the complex nature of the control structure. In building these structures, it is necessary to provide one or more of these nonlinear capacitors for each light-producing element in the display screen. In a device like the conventional television system, the structure might require more than 250,000 elements.

The control structure which may consist of one or more capacitors performs the same function regardless of the structure. The electroluminescent element associated with each control structure emits light in accordance with an alternating or time varying potential appearing across it while the nonlinear capacitor arrangement causes this potential to be altered in accordance with the applied video control potential.

Accordingly, the object of this invention is to provide

a method and process of building such complex structures which are adaptable to mass production.

It is another object to provide an economical process and method of fabricating a solid state display screen in which individual storage elements are provided for each display element desired.

It is another object to provide demountable type units which provide ease of manufacture and also ease in removal and replacement in case of breakdown.

It is another object to provide a method of forming a structure in one unit for applying potentials to any light-producing screen.

These and other objects are effected by this invention as will be apparent from the following description taken in accordance with the accompanying drawings throughout which like reference characters indicate like parts, and in which:

Figure 1 is a partial, perspective, schematic view of a display screen made in accordance with the principles of my invention;

Figs. 2 through 4 are perspective views showing steps in the formation of the display screen structure according to the teachings of my invention; and

Fig. 5 is an enlarged, perspective view of a portion of the control structure made in accordance with the present invention.

Referring in detail to Fig. 1, there is shown a structure constructed in accordance with the teachings of my invention. The structure illustrated in Fig. 1 consists of a light transmitting support member **10** which may be of glass. The area of the support member **10** would be the size of the entire screen or display device. Deposited on one surface of the supporting member **10** is a continuous coating **12** of a light transmitting electrically conductive material, such as stannic oxide, which serves as the front electrode of the light emitting or producing portion of the screen structure. Any other suitable light transmitting material having suitable electrical properties may be utilized.

Deposited on the electrically conductive layer **12** is a continuous coating **14** of a suitable phosphor material, such as zinc sulfide, copper and manganese activated, or zinc sulfide, copper activated. The phosphor layer **14** may be deposited in any suitable manner.

One specific method is to utilize a finely divided phosphor material, such as zinc sulfide activated with copper admixed with a solvent such as butyl acetate and with a polyvinyl chloride lacquer. The proportions of the constituents are not critical and may be varied within wide limits, but as a specific example, three parts by weight of phosphor may be mixed with 50 parts by weight of thinner and 35 parts by weight of polyvinyl chloride lacquer. The foregoing admixture may be sprayed in a plurality of coatings, for example four, according to the desired thickness, and the coating dried between each coating operation. Other dielectrics and solvents may be substituted for the foregoing specific examples, as is well known.

Deposited on the exposed surface of the phosphor layer **14** is a mosaic coating made up of a plurality of elemental areas **16** of suitable electrically conductive material, such as silver or aluminum. The elements **16** are separated so as to provide suitable insulation for any voltages applied so as to provide separately controllable light-producing elements. The number of the conductive elements **16** will depend on the amount of resolution and display elements desired in the image device. The conductive elements **16** which are the back electrodes of the light-producing screen may be deposited by evaporating a suitable material through a mesh, as is well known in the art. The resulting structure provides a plurality of separate controllable light-producing elements or cells

which are discussed more fully in an article entitled "Electroluminesence and Related Topics" by G. Destriau and H. F. Ivey in the December 1955 issue of the Proceedings of the I.R.E.

By way of explanation, electroluminescence was first completely disclosed by G. Destriau in London, Edinburgh and Dublin Philosophical Magazine, series 7, volume 38, No. 285, pages 700–735 (October 1947), article titled "The New Phenomenon of Electrophotoluminescence." In the phenomenon of electroluminescence, selected phosphor materials are placed within the influence of an electric field, such as by sandwiching the phosphor material between two spaced electrodes and applying an alternating potential between these electrodes. The resulting electric field which is created across the electrodes excites the phosphor material to luminescence, and the phosphor materials which display this electroluminescence are thus termed "field responsive." Such phosphor materials are normally admixed with a dielectric material or a separate layer of dielectric material which is included between the electrodes in order to prevent any arcing thereacross which would short out the electroluminescent cell, but a separate dielectric material is only desirable and not mandatory for the cells may be operated under some conditions without any dielectric where the applied electric field is as high as 100 kv. per centimeter. Normally, the spaced electrodes are parallel, but they need not be, as where graded field intensities are desired.

A control or storage portion which includes a nonlinear capacitor is associated with each of the elements **16** to provide the desired control of the individual light cell in response to a video or control signal. The control portion of each display area or light-producing element of the screen in the specific embodiment shown consists of a bridge-type circuit utilizing two nonlinear dielectric capacitors connected in series. The center of the bridge is connected to the back electrode **16** of the light-producing screen and the other leads of the capacitors are connected to two separate bus bars **18** and **20** for providing the necessary light-producing voltage. The bus bar **18** is connected through a suitable voltage source **22** of time varying frequency and a direct current voltage bias source **24** to ground. The other bus bar **18** is connected through a suitable voltage source **26** of time varying frequency to ground. The front electrode **12** is also connected to ground. The sources **22** and **26** are connected to provide two oppositely phased voltages in comparison with the common ground connection. The frequency of the power sources **22** and **26** is of about 10,000 cycles per second. A more detailed description of the bridge circuit is given in my previously mentioned Patent 2,875,380.

The method of fabricating the electroluminescent phosphor or light-producing portion of the screen has been described. As previously pointed out, to attempt to assemble separately a control portion for each light-producing element would be next to impossible. It is necessary to fabricate the control portions for all the light-producing elements as a single unit or at least a small number of sections. In order to form the control portions for a plurality of the light-producing elements as a single unit, it is necessary to first form a sheet of nonlinear dielectric material of substantially the same area as the display screen and which has suitable mechanical rigidity. A suitable sheet of nonlinear dielectric material may be of about 10 mils in thickness. To form the dielectric sheet, a quantity of a suitable resin such as melamine formaldehyde is added to water in liquid form. The proportion of such mixture is not critical and may, for example, be about twenty-five parts water and one part resin by weight. This mixture is stirred and heated to about 70° C. A suitable nonlinear dielectric such as a ferroelectric material of barium titanate is then added to the solution in powdered form. Fine particles of the order of 3 microns may be used but size is not critical and particles up to 20 microns may be readily used. One part by weight of ferroelectric powder to three parts of the water-resin solution forms a suitable mixture. After thorough stirring, the solution is poured and allowed to settle on a film of polyvinylidene chloride. The film with the deposited mixture is then heated to about 140° C. and held at that temperature for about one hour in order to evaporate the water and polymerize the resin contained in the mixture. After such treatment, the ferroelectric material and resin material is placed on a slab of zirconia (ZrO_2) or other refractory material of low reactivity. It makes no essential difference whether the film of polyvinylidene chloride is still attached. The zirconia slab is then placed in a furnace where it is heated to about 1200–1450° C. This high temperature causes the resin material to be burned off and results in a strong, dense sheet of the ferroelectric material. Such a sheet is generally called a ferroelectric ceramic sheet **30** and is illustrated in Fig. 2.

Additional information on the preparation of ferroelectric ceramics may be found in an article in the Bulletin of the American Ceramic Society, 33, No. 5 (May 1954), page 131, "Preparation of Reproducible Barium Titanate," by R. M. Callahan and J. F. Murray.

The ceramic sheet **30** of ferroelectric material resulting from the previous treatment should be planar and may be a square six inches on a side and about 10 mils in thickness. The ceramic sheet **30** is next positioned between two electrically conductive layers **32** and **34** of similar area. The layers or sheets **32** and **34** should also be planar and may be of a thickness of about 125 mils. It is necessary to bind the sheets **30**, **32** and **34** together into a unitary structure **40**. It is necessary to provide a good electrical and mechanical bond between the sheets. One specific method of accomplishing this is by dipping the ceramic sheet **30** into a suitable paint, such as one containing silver particles and a glass frit in a binder of a plastic such as ethyl cellulose in a solvent such as toluol. The paint may also be sprayed or applied by other suitable means. The paint is air dried during which time the solvent evaporates and the binder sets. The treated layer is then heated in air at 750° C. for about thirty minutes and the glass frit becomes molten and reacts with the silver and the ceramic to provide a good mechanical and electrical contact after cooling. It is required to have such a bond in order to withstand the later machining operations. Both sides of the ceramic sheet are then tinned with a suitable solder, such as 36% lead, 62% tin and 2% silver having a melting point of 230° C. The addition of 2% silver to an ordinary lead-tin solder is desirable in order that the silver deposited from the previously applied silver paint will not dissolve into the solder and thus destroy the mechanical bond.

The two sheets **32** and **34** of electrically conductive material which may be of a material such as brass or copper-graphite, are also tinned on one side with a similar solder as that used on the ceramic sheet **30** to assure good contact and the ceramic sheet **30** is then positioned between the tinned surfaces of the brass sheets **32** and **34**. The sandwich of the two brass sheets **32** and **34** with the inner ceramic sheet **30** is heated to a temperature of about 230° C. and then is cooled. This melts the solder binding agent and when the solder solidifies bonds the laminated structure **40** consisting of the sheets **30**, **32** and **34** into a unitary structure. This is only one suitable process for bonding the laminated structure and other methods may be used which provides a good electrical and physical bond.

The stacked structure **40**, shown in Fig. 2, is then placed in a suitable machine **46** for cutting, as illustrated in Fig. 3. The machine **46** illustrated in Fig. 3 shows only a table **44** and a cutting head **48**. The stacked structure **40** is positioned on the table and retained

thereon by suitable means such as clamps or cement. The cutting head **48** consists of a plurality of cutting wheels of a suitable material such as silicon carbide. The cutting wheels **50** may have a diameter of 2 to 3 inches and a thickness of about 5 to 10 mils. The grooves which are cut in the stacked structure **40**, as illustrated in Fig. 4, normally have a thickness of 5 to 10 mils and correspond to the thickness of the wheel **50**. The cutting wheels **50** are rotated by a suitable driving means **52**, such as an electrical motor. In the normal cutting operation, the grinding wheels **50** will rotate at a speed of about 3500 revolutions per minute. The cutting head **48** may be provided with a sufficient number of wheels **50** and of such a spacing so as to provide the necessary grooves in one pass. In most cases, it will be necessary to index the machine so that a plurality of passes are made in order to cut grooves in the entire structure **40**. In the first operation, the grooves **52**, illustrated in Fig. 4, are made by movement of either the cutting head **48** or the table **44** of the machine so that the cuts or grooves 10 mils wide and spaced apart 30 mils are made in one direction and of a depth such that the grooves **52** extend through the conductive layer **32** and the ceramic layer **30**, and into the other conductive layer **34**. The sandwich **40** is then moved with respect to the cutting head so that additional cuts or grooves **54** are made in the opposite surface of the stacked structure parallel to the grooves **52** in the opposite surface and also spaced intermediate the grooves **52**. The grooves **54** are 10 mils in width and also spaced 30 mils apart.

It is then necessary to make a plurality of cuts **56** in the same surface as the cuts **52** of similar depth but at 90° with respect to the grooves **52**. The cuts **56** are made 30 mils in width and spaced apart 10 mils. The resulting structure is illustrated in Fig. 5. The parallel elements **18** and **20** are electrically conductive bus bars formed from the layer **34**. The bridge circuit control elements **62** are connected between bus bars **18** and **20**. The element **62** is U-shaped with the end portions **64** of the legs of the U-shaped member formed from the layer **34**. A ceramic layer **66** is provided next in each leg which is formed from the ceramic layer **30**. The remainder of portion **68** of the element **62** is formed from the layer **32**. The portion **68** provides the contact area **70** which is pressed onto the individual areas **16** and retained by a suitable conductive varnish. The conductive varnish also provides a good electrical contact therebetween. The resulting structure is encased in a suitable plastic material as illustrated in Fig. 1.

It is also normally necessary to fill the grooves in the first surface cut with a plastic resin, such as phenol-formaldehyde or urea-formaldehyde, in order to improve the mechanical strength of the structure before the grooves are cut in the other side of the structure. It also may be desirable in some cases to space the cutting wheels such that the distance is of the order of 30 mils so that it is necessary to make a second pass to provide the intermediate grooves. This procedure may be necessary in those cases where the structure is extremely fragile.

While I have shown my invention in only one form, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various other changes and modifications without departing from the spirit and scope thereof.

I claim as my invention:

1. In the process of manufacturing a solid state display device, the steps comprising coating a sheet of nonlinear dielectric material with a first material to provide good electrical and mechanical contact and applying thereover a second coating of a solder, placing the treated dielectric sheet between two sheets of electrically conductive material to form a sandwich, heating said sandwich to form an integral body through said solder, and thereafter removing material from one of the exterior surfaces of said integral body to form a plurality of grooves extending through one electrically conductive sheet and the intermediate sheet of dielectric material and terminating in the body of the remote electrically conductive sheet.

2. In the process of manufacturing a solid state display device, the steps comprising coating both faces of a sheet of nonlinear dielectric material with a heat responsive binding agent, placing the coated sheet between two sheets of electrically conductive material to form a sandwich, heating said sandwich to cause said binding agent to unite said sandwich to form an integral body, and thereafter removing material from the exterior surfaces of said integral body to form a plurality of grooves extending through the electrically conductive sheet and the intermediate sheet of dielectric material, said grooves terminating in the body of the remote electrically conductive sheet.

3. In the process of manufacturing a solid state display device, the steps comprising coating both faces of a sheet of nonlinear dielectric material with a heat responsive binding agent, placing the treated dielectric sheet between two sheets of electrically conductive material to form a laminated structure, heating said laminated structure to cause said binding agent to unite said sheets to form an electrical and mechanical bond, and thereafter cutting a plurality of grooves in one surface of said laminated structure extending through the electrically conductive sheet and the dielectric sheet and into the remote electrically conductive sheet.

4. In the process of manufacturing a solid state display device, the steps comprising coating both faces of a nonlinear dielectric material with a heat responsive binding agent, placing the treated dielectric sheet between two sheets of electrically conductive material to form a laminated structure, heating said laminated structure to cause said binding agent to unite said sheets to form an electrical and physical bond, and thereafter cutting a plurality of grooves in one surface of said laminated structure extending through the conductive sheet and the dielectric sheet into the remote electrically conductive sheet, and cutting a second plurality of grooves in the other surface of said laminated structure extending through the electrically conductive sheet and the dielectric sheet into the remote electrically conductive sheet.

5. In the process of manufacturing a solid state display device, the steps comprising coating both faces of a nonlinear dielectric material with a heat responsive binding agent, placing the treated dielectric sheet between two sheets of electrically conductive material to form a laminated structure, heating said laminated structure to cause said binding agent to unite said sheets to form an electrical and physical bond, and thereafter cutting a plurality of grooves in one surface of said laminated structure extending through the electrically conductive sheet and the dielectric sheet into the remote electrically conductive sheet, cutting a second plurality of grooves in the other surface of said laminated structure extending through the electrically conductive sheet and the dielectric sheet into the remote electrically conductive sheet to form a control structure and attaching said control structure to an electroluminescent light-producing structure.

6. In the process of manufacturing a solid state display device, the steps comprising placing a nonlinear dielectric sheet between two sheets of electrically conductive material to form a laminated structure, providing a binding agent material between said sheets, heating said laminated structure to cause said binding agent to unite said sheets to form an electrical and physical bond, and thereafter cutting a first group of spaced parallel grooves in one surface of said body extending through the electrically conductive sheet and the dielectric sheet and into the remote electrically conductive sheet, cutting a second group of grooves in the same surface transverse to said first grooves to provide a plurality of projections on the remote electrically conductive sheet including a portion of said remote sheet, the dielectric sheet and the other

electrically conductive sheet, and cutting a third group of grooves in the opposite surface of said body parallel to said first group of grooves to provide a groove spaced between adjacent grooves of said first group.

7. In the process of manufacturing a solid state display device, the steps comprising placing a nonlinear dielectric sheet between two sheets of electrically conductive material to form a laminated structure, providing a binding agent material between said sheets, heating said laminated structure to cause said binding agent to unite said sheets to form an electrical and physical bond, and thereafter cutting a plurality of spaced parallel grooves in one surface of said body extending through the electrically conductive sheet and the dielectric sheet to the remote electrically conductive sheet, cutting a plurality of grooves in the same surface transverse to said first grooves to provide a plurality of projections on the remote electrically conductive sheet including a portion of said remote sheet, the dielectric sheet and the other electrically conductive sheet, cutting a plurality of grooves in the opposite surface of said body parallel to and alternately spaced with said first grooves for a control structure, providing an electroluminescent layer having a continuous conductive layer on one side and a mosaic of conductive elements on the other side and binding each of said projections on said control structure to one of said conductive elements of said mosaic to provide intimate electrical contact therewith.

8. In the process of manufacturing a storage display structure in which a light display screen of a layer of electroluminescent phosphor is utilized having a continuous conductive coating on one surface of said electroluminescent phosphor layer and a plurality of electrically conductive elements on the other surface of said electroluminescent phosphor layer, the steps comprising coating both faces of a sheet of nonlinear dielectric material with a heat responsive binding agent, placing said treated dielectric sheet between two sheets of electrically conductive material to form a laminated structure, heating said laminated structure to cause said binding agent to unite said sheets to form a good electrical and physical bond and thereafter removing a first group of grooves of material in one surface of said laminated structure extending through the electrically conductive sheet and the dielectric sheet into the remote electrically conductive sheet, cutting a second group of grooves in a direction transverse to said first group and in the same surface thereof to provide a plurality of elements similar in number to the number of conductive elements in said plurality of conductive elements on said phosphor layer, and attaching said elements to said conductive elements on said phosphor screen to provide separate controls for each of the light producing elements of the electroluminescent screen.

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