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Haberland et al.

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[54] **GAS PANEL FABRICATION**

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[73] Assignee: **International Business Machines Corporation,** Armonk, N.Y.

[22] Filed: **Oct. 10, 1973**

[21] Appl. No.: **405,205**

Related U.S. Application Data

[63] Continuation of Ser. No. 214,348, Dec. 30, 1971, abandoned.

[52] **U.S. Cl.** ..... **316/20,** 29/25.13, 29/625, 313/220, 315/169 TV

[51] **Int. Cl.** **H01j 9/38,** H01j 9/18, H01j 9/26

[58] **Field of Search** ... 313/220, 221; 29/251, 25.11, 29/25.13, 25.16, 25.19, 472.5, 472.9, 625, 631; 316/17, 19, 20; 65/36, 59, 154, 147, 138, 139, 23; 117/201; 315/169, 169 TV, 165

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Primary Examiner—C. W. Lanham
Assistant Examiner—Joseph A. Walkowski

[57] **ABSTRACT**

A method is disclosed for the fabrication of a gas panel which includes depositing parallel lines as electrical conductors on a pair of glass plates, providing a protective coating of glass over the parallel lines, placing a sealing material between the glass plates around the periphery thereof, spacing the glass plates a given distance apart, firing the assembly in an oven to seal the glass plates together with a chamber therebetween, evacuating the chamber, filling it with an illuminable gas, and exposing each parallel lines at one end of each glass plate as an electrical contact.

27 Claims, 7 Drawing Figures

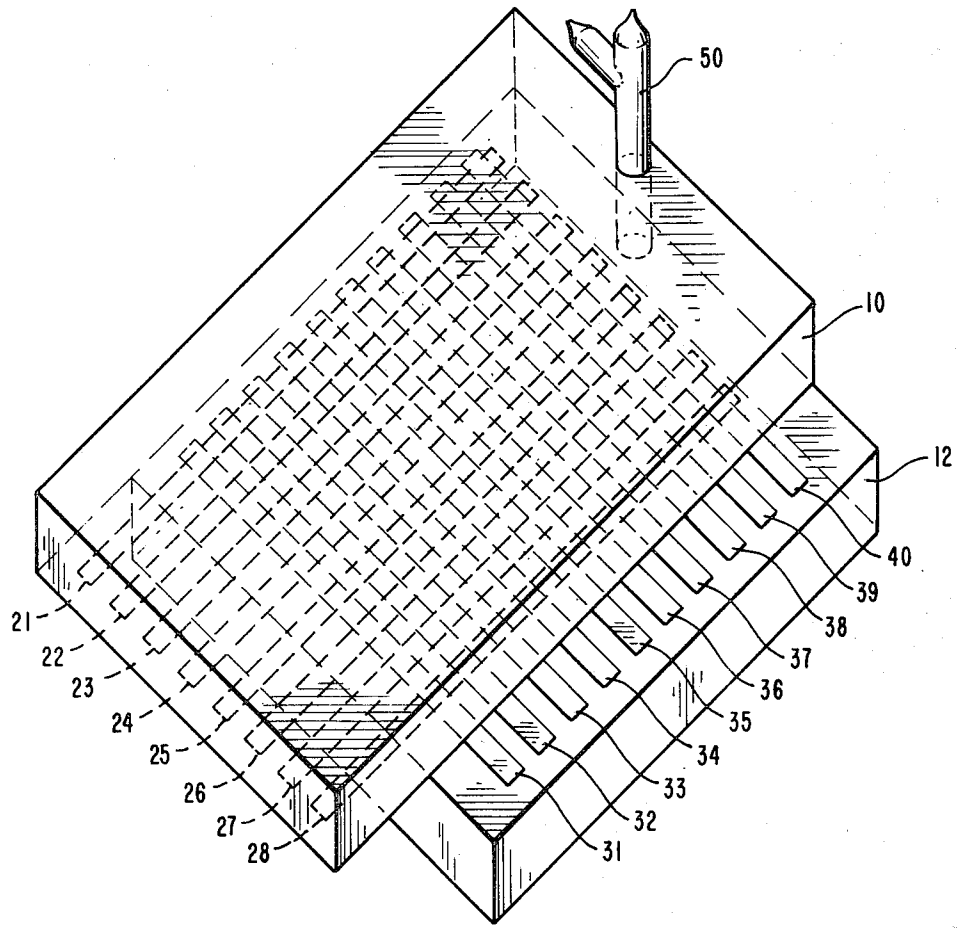


FIG. 1

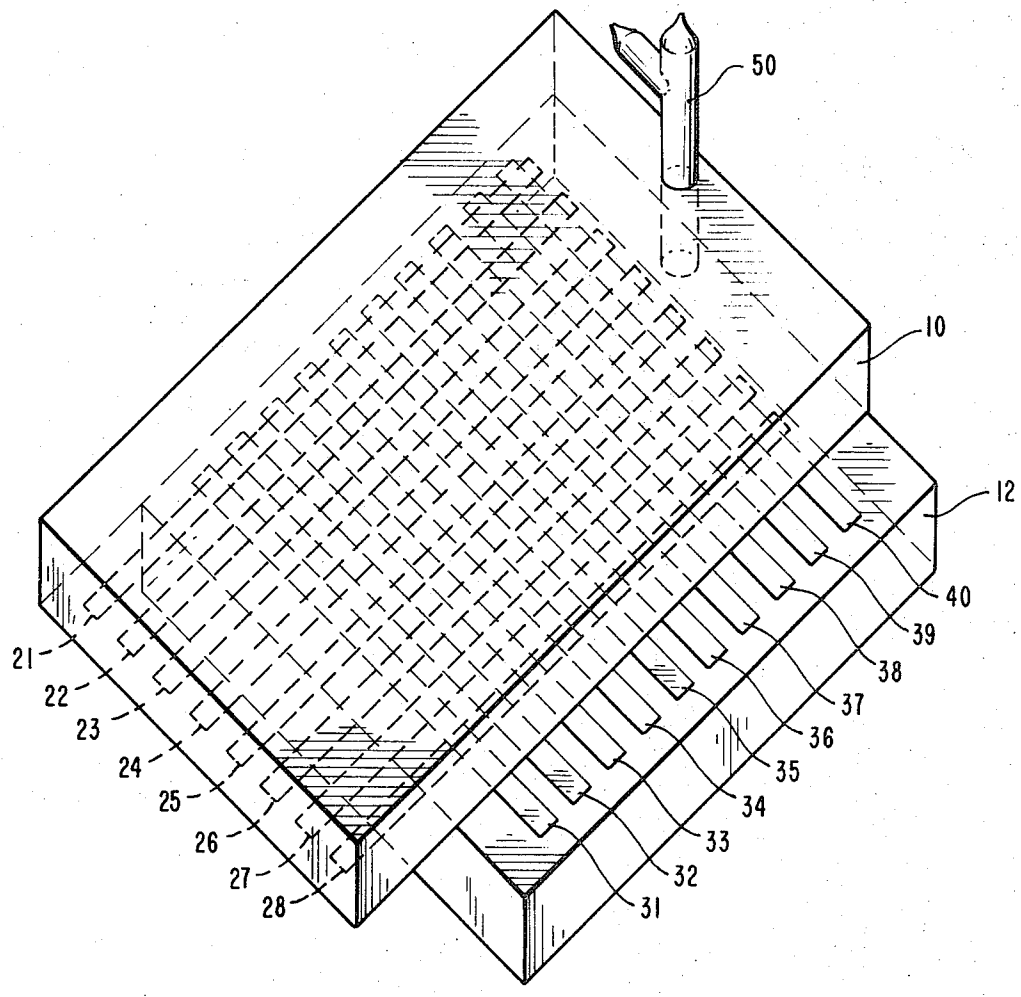
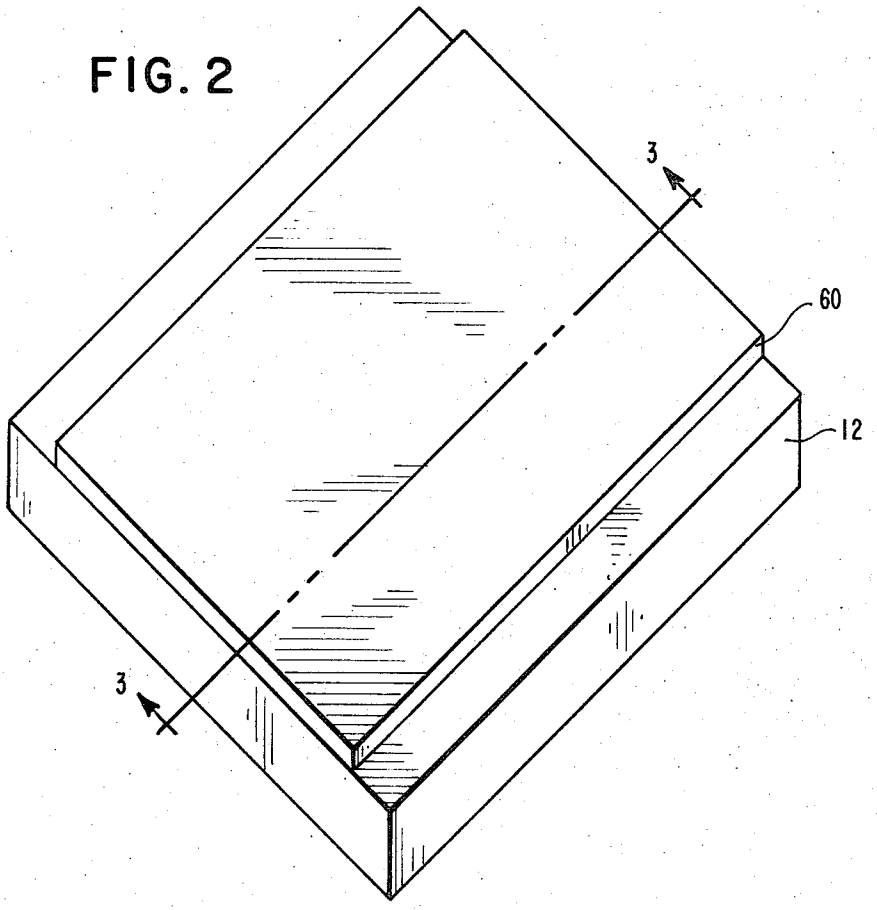


FIG. 2



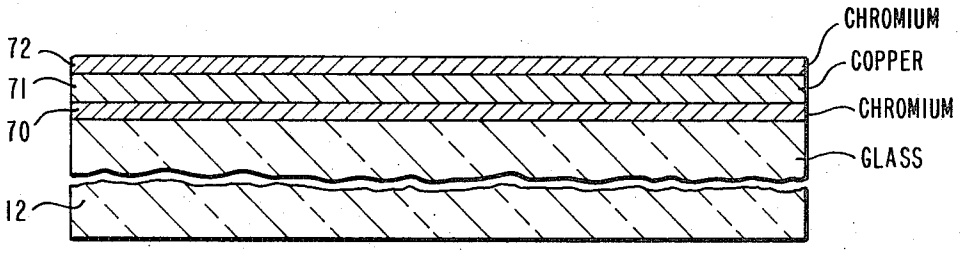


FIG. 3

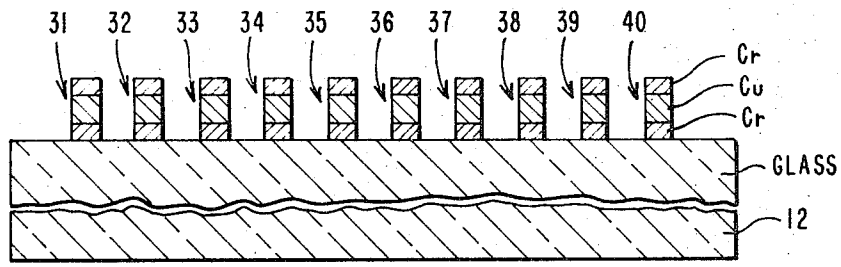
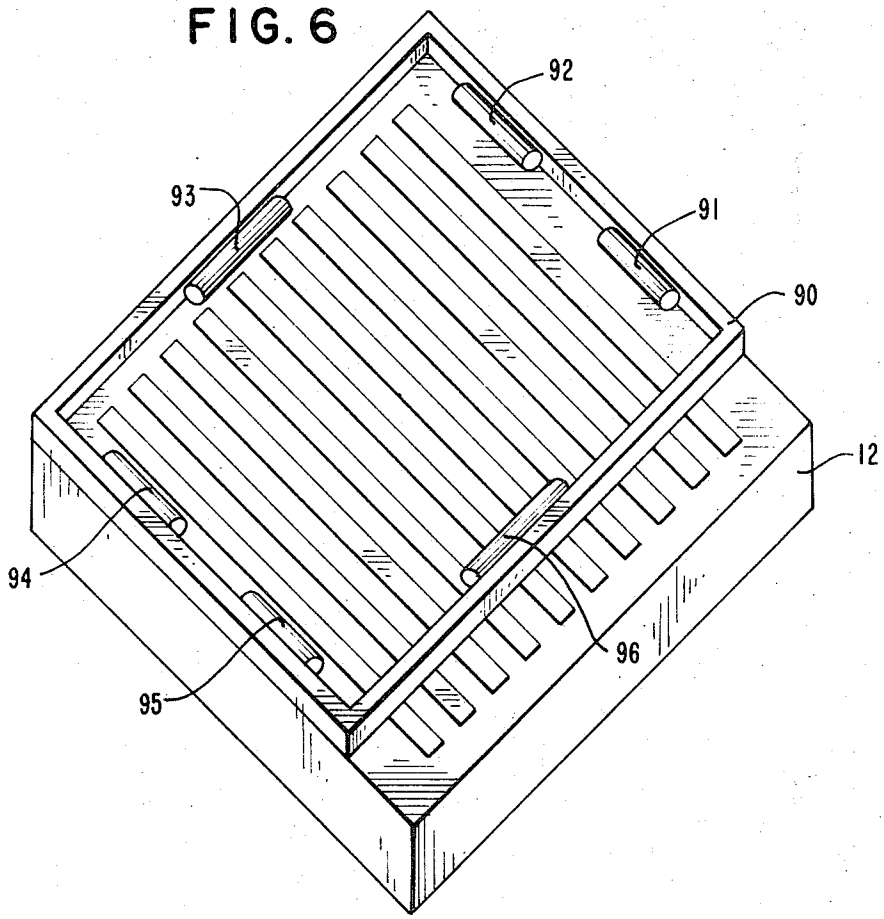


FIG. 4

FIG. 6



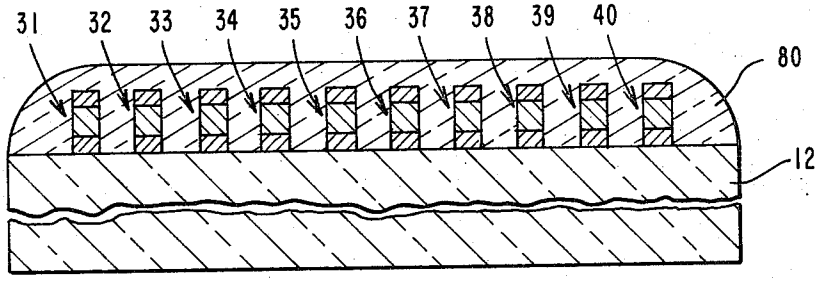
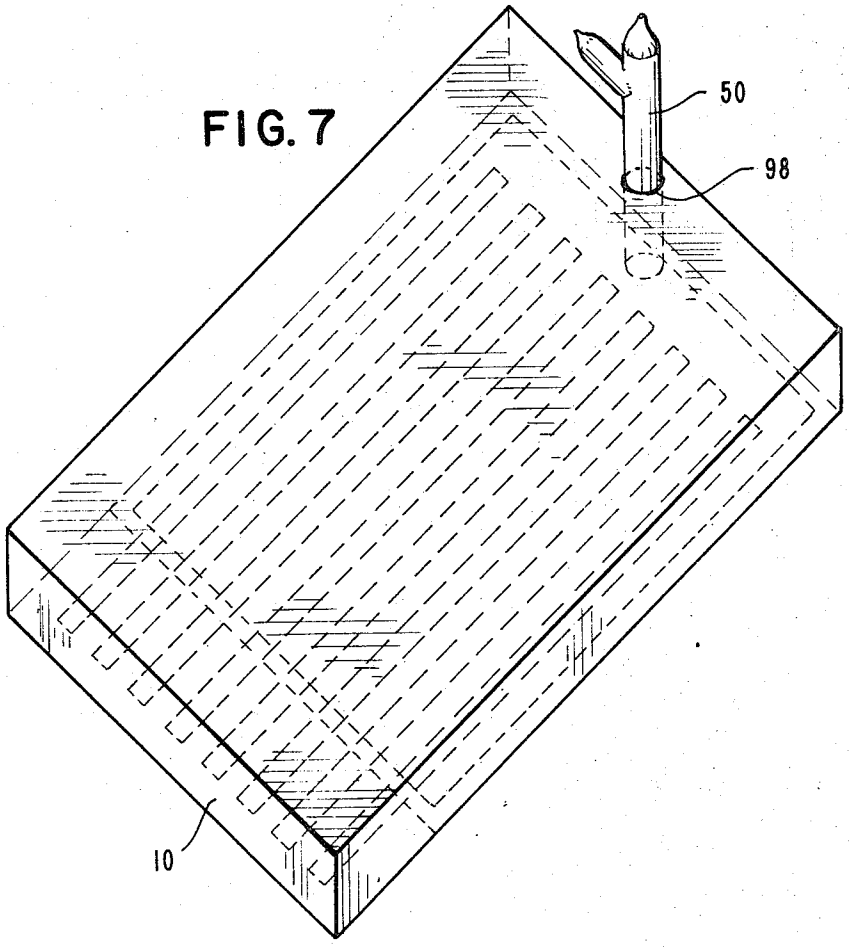


FIG. 5

FIG. 7



GAS PANEL FABRICATION

CROSS-REFERENCES TO RELATED APPLICATIONS

This is a continuation, of application Ser. No. 214,348 filed Dec. 30, 1972 and, now abandoned.

Application Ser. No. 214151 filed on Dec. 30, 1971 for Improved Method of Gas Panel Construction by Thomas J. Murphy et al, now U.S. Pat. No. 3,804,609.

Application Ser. No. 214150 filed on Dec. 30, 1971 for Method of Protecting Electrical Conductor Terminations during Gas Panel Fabrication by Peter R. Wagner, et al, now U.S. Pat. No. 3,778,901.

BACKGROUND OF THE INVENTION

1. This invention relates to gas panels and more particularly to a method of constructing gas panels.

2. The introduction of gas panels for use as display devices or storage devices has lead to an increased demand for them particularly where they are reliable in operation and reasonable in cost and upkeep. It is highly desirable for both display and storage purposes to have a large number of cells per unit area of the gas panel. When used in conjunction with other devices, display panels must be uniform in their optical and electrical characteristics whereby they readily may be interchanged. For example, if the characteristics of the gas vary widely from one panel to another, then standard electrical signals from other devices may operate one panel but not another. Such inconsistency or lack of uniformity may result in unreliable operation in some instances. If the electrical conductors are pitted, eroded, or broken in the fabrication process, an unreliable gas panel results. Defective gas panels must be discarded, and as the number of such defective gas panels increases ina production operation, the cost of producing acceptable gas panels increases accordingly. A method of fabrication is needed, therefore, for the production of gas panels having uniformity in their mechanical, electrical and optical characteristics. Such method of construction preferably should provide gas panels which are relatively less expensive to manufacture, maintain, and operate.

It is to this end that the present invention is directed.

SUMMARY OF THE INVENTION

It is a feature of this invention to provide an improved method of mass producing reliable gas panels thereby to reduce the per unit cost of manufacture.

It is a feature of this invention to provide an improved fabrication technique for the reproduction of gas panels each of which has substantially the same mechanical, electrical, and optical characteristics whereby such gas panels may be employed interchangeably.

It is a feature of this invention to provide an improved technique for constructing gas panels wherein the parts thereof are not pitted, eroded, broken, or defaced in the fabrication process.

In a preferred embodiment of the method according to this invention two glass plates are cut to appropriate dimensions, and a laminate preferably of chromium-copper-chromium is disposed on one side of each glass plate. The laminate is terminated back a given distance from the ends of each glass plate. The photoresist material is disposed on the laminate and dried. The photoresist material is exposed to a light pattern of artwork having alternate light and dark parallel lines. The two glass plates are immersed in a developer until the exposed photoresist is removed. The remaining photoresist in the form of parallel lines. Each plate is cleaned and then immersed in a solution which etches away the laminate from regions not protected by the parallel lines of photoresist material. This etching process leaves a plurality of laminated parallel lines having an outer coating of unexposed photoresist. This photoresist is exposed and placed in a developer until it is removed. The resulting laminated parallel lines terminate a given distance from the edges at both ends of each glass plate. The two glass plates are heated in a forming gas atmosphere and water vapor to oxidize the exposed surface of the outer chromium layer thereby to render the laminated parallel lines passive during a subsequent dielectric coating operation. A glass frit is sprayed over the conductive parallel lines of each glass plate. The glass frit preferably is a lead glass which is applied to a uniform depth by precision spraying. The glass plates then are fired in an oven to reflow the glass frit whereby a glass coating covers the laminated parallel lines. The two glass plates are spaced apart a given distance and sealed around the periphery thereby to form a chamber therebetween for holding an illuminable gas. Thereafter the chamber between the two glass plates is evacuated and refilled with an illuminable gas under less than atmospheric pressure. The dielectric coating and the outer chromium layer are removed from the end regions of the parallel lines at one end of each glass plate so that electrical connections can be made to the exposed copper lands. The dielectric coating may be removed by immersion in an etching solution such as hydrochloric acid, and the outer chromium layer may be removed by immersion in an etching solution such as potassium ferricyanide. The fabrication of the panel is complete, and it may be operated by applying electrical signals to selected parallel lines on each plate thereby to ignite gas cells defined by the coordinate intersections of such parallel lines which are disposed orthogonally to each other.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a gas panel constructed according to this invention.

FIG. 2 is a perspective view of one glass plate during the fabrication process.

FIG. 3 is a cross-sectional view, with parts not shown to scale, taken on the line 8—3 in FIG. 2.

FIG. 4 is a cross-sectional view, with parts not shown to scale, of one plate after the parallel conductors are formed thereon.

FIG. 5 is a cross-sectional view, with parts not shown to scale, of a plate showing a protective coating disposed on the laminated parallel lines.

FIG. 6 is a perspective view of a lower plate with a frame seal and spacers disposed thereon.

FIG. 7 is a perspective view of an upper plate which includes tubulation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A gas panel constructed according to the novel method of this invention is illustrated in FIG. **1**, and it includes an upper glass plate **10** separated from and sealed to a lower glass plate **12** with an intervening chamber which is filled with an illuminable gas. Electrically conductive parallel lines **21** through **28** are disposed on the lower side of the glass plate **10**, and they serve as an electrode for supplying a given electrical signal to a selected gas cell. Electrically conductive parallel lines **31** through **40** are disposed on the upper side of the glass plate **12**, and they serve as an electrode for supplying a given electrical signal to the other side of a selected gas cell. Gas cells are defined as the region of the illuminable gas disposed between the coordinate intersections of the upper parallel lines **21** though **28** and the lower parallel lines **31** through **40**. A selected gas cell is ignited by supplying a given electrical signal to one of the parallel lines **21** through **28** and applying a given electrical signal to a selected one of the parallel lines **31** through **40**. The gas cell at the coordinate intersection of the pair of selected lines is ignited.

The fabrication of the gas panel in FIG. **1** according to the method of this invention involves numerous operations. In the ensuing description the basic method steps are outlined first, and thereafter the various operations involved in the basic steps of the method are described in detail. The basic steps are summarized as follows:

1. Two plates of glass which may be soda-lime-silica glass are cut to the appropriate dimensions according to the desired size of the gas panel. The plates are overlapped as shown in FIG. **1**, and the overlap area serves as the display or storage portion of the panel.

2. A first thin film of chromium approximately 1,000 Angstroms thick is deposited on one side of each glass plate. A second thin film of copper approximately 10,000 Angstroms thick is deposited on the first thin film composed of chromium of each glass plate. A third film composed of chromium approximately 1,000 Angstroms thick is deposited on the second thin film composed of copper of each glass plate. The deposition of these thin films to form a laminate preferably is done by vacuum metalization techniques. The laminate terminate a given distance from the edges of the glass plates for reason explained later.

3. A photolithographic process is used to convert the laminate into a plurality of parallel lines which serve as electrical conductors. A liquid photoresist material is applied, preferably by roller, over the outer thin film of chromium and baked dry. The photoresist material is exposed to a light pattern of art work having the desired shape of parallel lines to be formed. After the exposure of the photoresist material is made, the two plates are immersed in a developer until the exposed resist material is removed. The unexposed areas of the photoresist remain undisturbed. Each glass plate is cleaned and then immersed in a solution which etches away the chromium-copper-chromium laminate from regions not protected by the resist material. This etching process leaves a plurality of parallel lines with each line being composed of a chromium-copper-chromium laminate having an outer coating of unexposed resist. This resist is exposed and placed in a developer until it is removed. The resulting parallel lines terminate a given distance from the edges of the glass plates.

4. The two glass plates are heated in a forming gas atmosphere composed of 90 percent nitrogen and 10 percent hydrogen and eater vapor. The outer surface of the third thin film composed of chromium thereby is oxidized, and the chromium oxide surface prevents a subsequent coating operation from dissolving the laminated parallel lines. This step is referred to as passivation since it renders the laminated parallel lines passive during a subsequent dielectric coating operation.

5. A glass frit is applied over the electrically conductive parallel lines of each glass plate. The glass frit preferably is a lead glass. The glass frit is applied to a uniform depth over each glass by precision spraying. The two glass plates are then fired in an oven to a temperature sufficient to reflow the glass frit whereby a glass coating covers completely the parallel lines. The parallel lines terminate a given distance from the edges of each glass plate, as pointed out above, and since the lead glass coating extends beyond the ends of these parallel lines, it follows that the ends, sides and top of each of the parallel lines are coated over by the lead glass coating. The covering of the ends of these parallel lines is done to prevent a reaction in subsequent firing steps of the process from attacking and destroying end regions of these lines. The lead glass coating serves also to prevent the electrically conductive parallel lines from directly contacting the illuminable gas when such gas is inserted in the completed gas panel. The lead glass coating serves as a dielectric material which collects a wall charge when the parallel lines are used subsequently as electrodes for operating the gas panel. Furthermore, the lead glass coating provides mechanical strength and support for the thin laminated conductors which enables them to withstand thermal and mechanical stress and stock during and after the fabrication process.

6. The two glass plates are spaced apart a given distance and sealed around the periphery thereby to form a chamber therebetween for holding an illuminable gas. The sealing material preferably is lead glass finely ground and disposed in a cellulose binder which is cut in the form of a rectangular frame. The inner periphery of the rectangular frame represents the desired dimensions of the chamber for holding the illuminable gas. The frame is disposed on one of the glass panels on top of the dielectric coating, and this glass plate is heated in an oven until the cellulose binder is baked out of the sealing material. The binder is baked out of the sealing material to avoid blistering or darkening of the sealant. The bake out is done also to remove possible contaminates which subsequently might invade the illuminable gas. Glass rods of suitable diameter to maintain proper chamber width are disposed at given intervals around the inner periphery of the sealing material. The spacer rods are placed approximately one-sixteenth of an inch from the inner periphery of the sealing material. The remaining glass plate is disposed on top of the spacer rods with the lead glass dielectric coating face down engaging the sealant and spacer rods. A hollow glass tube is inserted in a hole in the upper plate, and sealing material is placed around the glass tube. The assembly is placed in an oven, leveled, and fired until the lead glass sealing material reflows. The glass plates are sealed to

each other, and the glass tube is sealed to the upper glass plate.

7. The hollow glass tube is connected to a vacuum pump. The chamber between the two glass plates is evacuated, and simultaneously the panel is backed thereby to remove moisture from the chamber and gasses which escape from the lead glass sealing material. After the chamber is evacuated and the bake off is complete, the chamber is filled with an illuminable gas. The illuminable gas may be any one or a combination of several well known gasses used for this purpose. One suitable conbination is an illuminable gas composed of 99.9 percent neon and 0.10 argon. The evacuated chamber is filled with the illuminable gas until the pressure in the chamber reaches a range of 600 to 700 torrs.

8. The dielectric coating and the outer or third thin film composed of chromium are removed in the end regions of the parallel lines on each plate so that electrical connections can be made to the exposed copper lands. The dielectric coating may be removed by immersion in an etching solution containing hydrochloric acid, and the third layer composed of chromium may be removed by immersion in a solution of potassium ferricyanide. The construction of the panel is complete, and it may be operated by applying electrical signals to the parallel conductors.

The foregoing summary of the basic steps according to this invention lays the foundation for a more detailed description of the basic steps given next. The steps of the succeeding detailed description are numbered to correspond with the basic method steps summarized above.

1. The glass plates **10** and **12** in FIG. **1** are cut to appropriate dimensions thereby to provide an overlap area of a desired size for use as a display device or a storage device. The upper plate **10** extends beyond the left edge of the lower plate **12** and this extension provides support for the electrical conductors **21** through **28.** The conductors **21** through **28** are not extended to the left edge of the glass plate **10** for reasons pointed out subsequently. The glass plate **12** extends beyond the right edge of the plate **10,** and this extension provides support for the electrical conductors **31** through **40.** The electrical conductors **31** through **40** likewise are not extended to the right edge of the lower glass plate **12** for reasons pointed out subsequently.

The glass plates **10** and **12** preferably are made of a soda-lime-silica which is one-fourth inch thick and free of chips or scratches. Lightly scratched plates are acceptable if scratches exist on one side only. The scratched surfaces are disposed outwardly so that the unblemished surface is used for depositing the conductors. The plates **10** and **12** should be checked for flatness, and the flatness should be 50 millionths or better. A hole is drilled in the upper plate **10** to permit the subsequent insertion of a hollow tube **50** which is bifurcated as shown. Tubulation is essential to permit subsequent evacuation of the chamber and insertion of an illuminable gass.

The glass plates are thoroughly cleaned. The cleaning may include degreasing in Freon TF for about 5 minutes, scrubbing in a detergent, rinsing in tap water, and placing in Freon vapor for 5 minutes. Precise measurements are then made for thickness and flatness of the plates. After the measurements are made they are cleaned again. This cleaning may include placing the plates in a detergen cleaner at 160° Farenheit, applying ultrasonic energy for thirty minutes, rinsing in hot water for 5 minutes, and spray rinsing in distilled water for 2 minutes. Further cleaning may include placing the plates in chromate solution at 160° Farenheit for 15 minutes, rinsing in hot water for 5 minutes, rinsing in distilled water for 2 minutes, placing in 10 percent hydrochloric solution for 15 minutes, rinsing in hot water for 5 minutes, rinsing in distilled water for 2 minutes, and placing in Freon TF vapors for 5 minutes. The plates are then ready for deposition of the electrodes.

2. The electrodes preferably are formed on the plates **10** and **12** in FIG. **1** by successive depositions which form a laminate. The laminate extend over the entire area of each glass plate out to the point where the electrodes in FIG. **1** terminate which is about one-fourth of an inch from the left and right edges of each glass plate. This is illustrated in FIG. **2** for the lower plate **12.** The laminate **60** covers the entire upper surface of the glass plate **12** except the regions to the left and right of the electrodes **31** through **40** in FIG. **1.** The laminate **60** is made by depositing a layer of chromium 1,000A thick on the glass plate **12.** This chromium deposition on the glass plate **12** is shown as the layer **70** in FIG. **3.** FIG. **3** is a cross sectional view taken on the line **3—3** in FIG. **2.** Next copper is deposited on the chromium layer **70.** This is shown as the layer **71** in FIG. **3,** and the copper layer is about 10,000A. Another layer of chromium is deposited on the copper layer **71,** and this is shown as the layer **72** in FIG. **3.** The chromium layer **72** is about 1,000A thick. This completes the laminate **60** in FIG. **2** for the plate **12.** A similar laminate is deposited on the lower side of the plate **10** in FIG. **1.** The deposition of the various layers of the laminate **60** may be accomplished by any one of various well known techniques, and vacuum metalization is particularly suitable. If this techique is used, each layer of the laminate is deposited by inserting the glass plates in a bell jar, evacuating the bell jar, and heating the metal to be deposited in a crucible until it vaporizes. The metal vapor condenses on the plates to form a thin layer of the laminate. This procedure is repeated for each layer of the laminate.

3. A photolithographic process is used to form the parallel lines on each glass plate from the laminate **60.** A liquid photoresist coating is applied over the surface of the laminate **60** in FIG. **2** of glass plate **12,** and a similar coating is applied over the laminate of the plate **10.** Before the photoresist coating is applied, the plates **10** and **12** are pre-baked in an oven for 30 minutes at 180° Farenheit. The plates are allowed to cool to room temperature. The photoresist material is rolled on by a precision coater. It is preferable that the pressure of the roll applying the photoresist material be approximately 18 lbs. per square inch and that the viscosity of the photoresist material be adjusted to dry in 50 to 55 seconds. After the photoresist coating is applied, the plates **10** and **12** are baked in an oven for 1 hour at 190° Farenheit.

The plates **10** and **12** are then placed in a printer and aligned with the art work. Exposure of the photoresist material is made under a vacuum of 10 lbs. per square inch. The light patterns projected onto the photoresist material are in the form of alternate light and dark parallel rows.

The glass plates **10** and **12** are immersed in developer which removes the exposed photoresist. This takes

about 8 minutes. The plates **10** and **12** are rinsed in tap water, a gentle spray for 30 seconds, again is distilled water, and finally in a gentle spray for 30 seconds. Nitrogen is blown on the laminate **60** of each plate until it is dry. Any broken lines in the photoresist material may be touched up by a fine camel's hair brush dipped in photoresist material. The plates are again baked in an oven for 30 minutes at 180° Farenheit.

Each plate is immersed in a solution of 50 percent hydrochloric acid with zinc activation, and this etches the portions of the upper chromium layer **72** in FIG. **3** not protected by the remaining photoresist material on both plates. The plates are continuously observed, and when all of the upper chromium layer **72** is removed, the plates are withdrawn and rinsed in cold tap water for about 1 minute. The plates are then immersed in a solution containing 681 grams of ammonium persulphate per gallon of distilled water. This etches the exposed copper from the layer **71** in FIG. **3** of both plates. The plates are constantly observed, and when the copper is removed, the plates are withdrawn and rinsed in cold tap water for about 1 minute.

Both plates are then immersed again in the 50 percent hydrochloric acid solution which etches the exposed regions of the chromium layer **70** in FIG. **3** of both plates. The plates are continuously observed, and when the chromium layer **70** is removed, the plates are withdrawn and rinsed in cold tap water for about 1 minute. The plates are then immersed in a solution containing one pound of potassium ferricyanide and 17 grams of sodium hydroxide per gallon of distilled water. The plates are removed after about 7 seconds, rinsed in distilled water for 2 minute, and then blown dry with nitrogen.

The plates **10** and **12** are placed in the printer again, and the remaining photoresist material is exposed. The plates are then immersed in developer which removes the remaining photoresist material after which they are removed, rinsed in water and dried with nitrogen. The laminate regions are wiped with acetone, rinsed in water, sprayed with isopropyl or ethyl alcohol and then dried with nitrogen. At this point in the process the laminate **60** of the glass plate **12** in FIG. **2** has been converted to laminated parallel lines as shown in cross-section in FIG. **4.** The copper layers in FIG. **4** serve as electrically conductive parallel lines which form the electrode on the plate **12** in FIG. **1.** The copper layers **31** through 40 in FIG. **4** are checked at this point to determine if there are any open copper lines and to assure adequate deposition of copper throughout each line. Reference is made to copending Application Ser. No. 214,250 filed on Dec. 30, 1971.

For Method of Protecting Electrical Conductor Terminations During Gas Panel Fabrication by Peter R. Wagner et al for additional description concerning the parallel conductors in the fabrication process.

4. The glass plates **10** and **12** are heated in a forming gas atmosphere composed of 90 percent nitrogen, 10 percent hydrogen and water vapor. The temperature of the gas is raised 8.5° centigrade per minute until the temperature rises to 525° centigrade. That temperature is held for 80 minutes. This keeps the parts of the plate at the temperature of 525° centrigrade for about 50 minutes. This atmosphere is then cooled at the rate of 3.2° centigrade per minute to 300° centigrade at which point cooling may be accelerated, but care should be exercised to avoid cracking of the glass plates or oven structure. This operation is done to oxidize the upper surface of the chromium strips disposed on the copper strips **31** through **40** in FIG. **4.** It is done to passivate or render inactive the upper chromium strips in FIG. **4** during a subsequent dielectric coating operation.

5. The laminated lands in FIG. **4** are covered with lead glass which is a dielectric material (1) that protects these parallel lines from reacting in subsequent steps of the panel fabrication, (2) that isolates the electrically conductive copper strips from contact with the illuminable gas when the panel later is operated with electrical signals, and (3) that provides mechanical support which enables these lines to survive greater shock and stress. The manner of adding this coating is described next.

The laminated parallel lines in FIG. **4** are covered with a glass frit. This covering is preferably done by using a precision spray gun which has a regulated constant blower pressure, constant vapor pressure and regulated constant speed which provides accurate control of the thickness of the dielectric coating. The spray gun is loaded with a mixture of finely ground lead glass frit and suspension vehicle. The suspension vehicle is commercially available from Corning Glass Company under the name suspension vehicle, and it is composed of a nitrocellulose polymer binder in a solvent of amyl acetate. The lead glass frit is a powder which is sufficiently fine to permit spraying. This powder may be made from small lead glass beads disposed in a jar with alumina balls, and the jar may be rotated to cause the alumina balls to break up the glass beads. The process continues until the glass beads are reduced to a very fine powder sufficiently small to pass through the nozzle of the spray gun. The mixture used in the spray gun is a slurry which in includes 110 grams of the powdered lead glass and 110 grams of the Corning suspension vehicle. They may be blended by mixing in a blender at medium speed for three minutes or so. The mixture is added to the spray gun equipment, and the mixture is applied uniformly throughout the area of the parallel conductors on both plates **10** and **12.**

The spray gun is operated in a class **100** clean stage or enclosure having a highly clean atmosphere. A freon vapor generator preferably is used to provide freon vapor as the propellent for the spray gun. Liquid freon is heated to produce the vapor, and the pressure of the vapor to the spray head is regulated to be constant. Freon is preferable to air as a propellent since it contains little, if any, contamination. Compressed air from a compressor, on the other hand, has various contaminants chief of which is oil. In addition to regulated blower pressure the spray gun has a regulated constant speed of movement relative to the upper surface of the glass plates. The thickness of the coating sprayed on the upper surface of the glass plates is preferably 1.8 mils thick but the thickness of the coating may be varied as desired. Spraying provides a uniform depth of the coating on the upper surface of the glass plate because there is uniform dispersion of powdered glass frit particles per unit volume of the slurry, and the coating is deposited at a constant rate by regulating and maintaining constant the speed of the sprayhead relative to the surface of the glass plates.

The preparation of the powdered lead glass is described next. The lead glas is received in granular form and milled before use. The milling is preferably one with alluminum oxide balls. The balls are cleaned first.

This may be done by placing the alluminum oxide balls in a ceramic jar and immersing them in a solution of 10 percent distilled water and 90 percent hydrochloric acid for 15 minutes. This solution is removed, and the jar is rinsed first with water and then ethyl alcohol. The jar with the balls therein is placed in an oven with the top of the jar removed, and the assembly is baked at 110° centrigrade for one hour at which time the jar is removed and allowed to cool in air. Next 200 grams of granular lead glass and 200 grams of alcohol are added to the jar which may contain 200 alluminum oxide balls, for example. A rubber gasket is placed on the top of the jar, and the cover is placed on the jar and tightened to form a tight seal with the rubber gasket. The ceramic jar is placed on a ball mill and rotated for about 24 hours thereby to mill the granular lead glass to a fine powder. The constant of the jar is poured into a 400 mesh sieve which passes all particles having a diameter of 0.0015 of an inch or less. The sieved material is dried overnight at 50° centrigrade in an exhaust hood. The powdered frit is placed in a clean pyrex dish and baked at 250° centigrade for 3 hours to assure dryness. It is then placed in an oven and covered with a clean glass plate and maintained at 240° Farenheit until used. The powdered frit thus remains completely dry until ready to be mixed with a suspension vehicle for a spraying operation.

The spray gun is disassembled and thoroughly cleaned in an ultrasonic cleaner after each spraying operation is completed. The parts are then rinsed in acetone and dried. The inside of the spray gun equipment is cleaned with lint-free paper soaked in acetone. The paper is removed and replaced with clean paper taped down with masking tape to prevent contamination. The filters of the spray gun equipment are replaced when dirty. Various types of spray gun equipment may be used, and one suitable type is zicon equipment which is commercially available from Zicon Corporation of Mt. Vernon, New York. Their R-3 nozzle and RB-5 spreader are adequate for spraying powdered glass frit, for example. The jet size of the spray head is 0.030 of an inch in diameter.

After the lead glass frit coating is sprayed on the laminated lands forming the parallel lines on the plates **10** and **12,** they are dried for approximately 20 minutes at room temperature. The edges of the glass plates **10** and **12** are wiped after the drying operation with a lint-free cloth or paper to remove any dielectric from the edges, and the tubulation hole in the upper plate **10** in FIG. **1** is wiped to remove any of the spray.

Both plates are placed in an oven on polished lava plates which previously have been leveled with a machinist's level. Grade "A" lava plates are preferred which are adjusted to be flat and parallel within 0.0002 inches per inch or better. The polished lava plates are wiped with a lint-free cloth soaked in acetone before use.

The plates **10** and **12** are fired in the oven which is programmed to provide a temperature rise of 6° centrigrade per minute to 200° centigrade, then 1° centigrade per minute to 604° centrigrade, then holding the temperature at 604° centigrade for one hour, and thereafter decreasing the temperature 1 centigrade per minute to room temperature. This cycle is about twelve hours. This operation results in a dielectric coating **80** as shown in cross-section in FIG. **5,** and this coating preferably is 1.8 mils thick. The parts are not shown to scale in FIG. **5.** Reference is made to copending Application Ser. No. 214,151 filed on Dec. 30, 1971 for "Improved Method of Gas Panel Construction" by Thomas J. Murphy et al for additional description concerning this dielectric coating operation.

6. The next step is to separate the glass plates a given distance and seal them around the periphery to form a chamber therebetween for holding an illuminable gas. A sealing material composed of powdered glass disposed in a cellulose binder is used. It is preferably preformed in a frame configuration of the desired size. A pre-formed seal frame **90** is illustrated in FIG. **6,** and it is disposed on the dielectric coating of the glass plate **12.** Glass spacer rods **91** through **96** are disposed around the inner periphery of the seal frame **90,** and these rods are spaced about one-sixteenth of an inch from the inner periphery of the sealed frame. The glass rods have the same diameter, and this diameter represents the desired chamber space between the glass plates **10** and **12** in FIG. **1.** The number of the glass rods used as spacers can be increased or diminished as needed in order to provide uniform spacing between the plates **10** and **12.**

The glass plate **12** is placed in an oven on a polished lava plate which has been leveled with a machinist's level. The oven is operated to increase temperature at the rate of 6° centrigrade per minute to 70° centigrade, then 1° centrigrade per minute to 400° centigrade, then maintaining at 400° centigrade for one hour, then decreasing temperature at 1° centigrade per minute to room temperature. The cycle is about 12 hours. This bakeout removes the cellulose binder from the frame **90** in FIG. **6.** The cellulose binder is baked out of the sealing material to avoid blistering and darkening of the sealant as well as remove possible contaminates which subsequently might invade the illuminable gas.

Next tubulation is added to the glass plate **10.** This plate is placed on a piece of lint-free paper or cloth with the dielectric coated side down as shown in FIG. **7.** The tubulation **50** is cleaned and dried. The cleaning operation may be that described above for the glass plates **10** and **12.** Next powdered glass and suspension vehicle are mixed with a clean glass rod, and the mixture should have a heavy cream consistency. This mixture may be stored for future use. A powdered glass of 325 mesh is preferred, and one suitable type commercially available is Corning 7,570 powdered glass available from Corning Glass Company. A bead of this mixture is applied to a step of the hollow tube **50,** and if there is no step, the paste is applied near the end of the tube **50.** The tube is then placed in the hole of the plate **10** and rotated a small amount to flow the paste slightly. The bead of paste is shown generally by the reference numeral **98** in FIG. **7.** The tubulation paste is allowed to dry in air for 15 minutes.

The top plate **10** in FIG. **7** is placed on the bottom plate **12** in FIG. **6** in the manner shown in FIG. **1.** The parallel electrical conductors **21** through **28** on the lower side of the top plate **10** extend orthogonally with respect to the parallel electrical conductors **31** through **40** on the top of the lower plate **12.** The plates **10** and **12** in FIG. **1** are separated a given distance from each other by the glass spacer rods **91** through **96** in FIG. **6.**

This assembly is placed in an oven on a polished lava plate which has been leveled with a machinist's level. A glass weight is placed on the top plate **10** to yield a

pressure of up to 0.5 lbs. per square inch throughout the sealing area or overlapped regions of the plates **10** and **12** in FIG. **1.** The oven is operated to raise the temperature 6° centigrade per minute to 200° centigrade, then 1° centigrade per minute to 500° centigrade, holding at 500° centigrade for 1 hour, and then decreasing temperature 1° centigrade per minute to room temperature. The cycle is about 12 hours. This operation causes the glass in the seal frame **90** of FIG. **6** to reflow and unite the upper plate **10** and the lower plate **12** in FIG. **1** in a spaced relationship as determined by the spacer rods **91** through **96.** These glass plates are hermetically sealed throughout the region of the seal frame **90** in FIG. **6.**

It is pointed out that when this firing operation takes place, the glass coating **80** protects the laminated parallel lines **21** through **28** of the plate **10** and the laminated parallel lines **31** through **40** of the plate **12** from being eroded. If the glass coating **80** were omitted during this firing operation, then the left ends of the copper layer of the parallel lines **21** through **28** of the plate **10** and the right ends of the copper layer of the parallel lines **31** through **40** of the plate **12** in FIG. **1** would be pitted or eaten away. This is undesirable because it would reduce the end area of copper strip used as an electrical connector, and in some cases there might not be sufficient copper left at the ends of some of these lines to make an electrical connection. The glass coating thus serves the important function of protecting and preserving the ends of the copper strip which are exposed during this firing operation.

7. The assembly is placed in an oven again, and the bifurcated hollow glass tube 50 in FIG. 1 is connected through one branch to a vacumn pump and through the other branch to a source of illuminable gas. The source of illuminable gas is isolated from the tube 50. This may be done by closing an outlet valve. The vacuum pump is operated in the chamber between the glass plates 10 and 12 in FIG. 1. The pressure in the chamber between the glass plates 10 and 12 is reduced to 1×10^{-6} Torr. This low pressure is reached after about one hour. The oven is fired and programmed to increase temperature 1° centigrade per minute to 400° centigrade. This temperature is held for 5 hours, and the oven then is programmed to decrease temperature 1° centigrade per minute to room temperature. The cycle is about 17 hours. This evacuation and bakeout operation removes moisture and gasses which escape from the lead glass sealing material and the dielectric coating. This insures that the the illuminable gas subsequently inserted will remain free of contamination from the sealing material and the dielectric coatings which form the chamber walls for the gas panel.

With the chamber pressure still at 1×10^{-6} torrs the vacuum pump is sealed off from the tube **50,** and low pressure in the chamber persists. An illuminable gas is then admitted through one branch of the tube **50** to the chamber, and backfilling with the illuminable gas continuous until the pressure of 600 to 700 torrs is reached. The illuminable gas is passed slowly to the chamber, and this may take approximately **20** minutes to completely backfill to the desired pressure. The tube **50** is then tipped off with a gas-oxygen flame thereby to seal the chamber completely with the illuminable gas at the given low pressure. A check on the gas within the chamber may be made with the use of a spectrometer.

8. The laminated parallel lines **21** through **28** of the top plate **10** in FIG. **1** and the laminated parallel lines **31** through **40** of the lower plate **12** are covered with the dielectric glass coating as explained above. It is necessary to remove portions of these coatings as well as the upper chromium coating of the laminate in order to expose the copper strips on the top of plate **12** in FIG. **1** and the bottom of plate **10** for electrical connection purposes. The dielectric coating is removed by dipping the right end of the glass plate **12** in FIG. **1** in a solution of hydrochloric acid and water in equal parts for about 30 seconds. The depth of insertion in this acid bath should be enough to remove the dielectric coating from the edges of the conductors **31** through **40** in FIG. **1,** but the insertion depth should not be enough for the acid to reach the plate **40.** The panel is removed and dipped in tap water. the dielectric coating is inspected. If it is not gone, the panel again is dipped in the acid bath, removed and rinsed in water. If the dielectric coating is not removed, this dipping continues until it removed. Caution should be exercised by watching closely to prevent attack of the outer chromium layer of the laminated parallel lines **31** through **40.** This is evidenced by bubbles, and this process should be terminated when bubbles appear.

Next the right side of the lower plate **12** in FIG. **1** is dipped in a solution consisting of one gallon of distilled water, **17** grams of sodium hydroxide, and one pound of potassium ferricyanide to the same depth as in the acid bath above. The panel is gently moved back and forth in the solution until all of the chromium in the outer layer of the laminated parallel lines **31** through **40** is gone. This may take about three hours. The panel is removed, rinsed with water and blown dry with nitrogen or air. This leaves exposed the end regiono of the copper strips of the laminated lines **31** through **40** of the plate **12** in FIG. **1,** and electrical connection can be made to these exposed copper strips. The preceding two operations are repeated to remove the dielectric glass coating and the outer chromium coating from the laminated parallel lines **21** through **28** on the lower left face of the upper plate **10** in FIG. **1.** The fabrication of the gas panel is complete.

The panel is operated in a test made by applying electrical signals of 180 to 200 volts to all of the lines **21** through **28** of the upper panel **10** and all of the lines **31** through **40** of the lower panel **12.** This will ignite all gas cells. Thereafter electrical signals are applied to selected ones of the lines on the plates **10** and **12** to ignite selected gas cells defined by the coordinate intersections of the parallel lines **21** through **28** and **31** through **40** in FIG. **1.**

Some of the operations in steps **1** through **7** of the method according to this invention may be varied, and the order may be changed in many instances without departing from the essence of the invention. The fabrication method lends itself to mass production techniques.

It is seen therefore that a novel fabrication technique is provided according to this invention for producing gas panels having uniformity in their mechanical, electrical, and optical characteristics. The fabrication according to this invention may be adapted to mass production techniques thereby making the gas panels relatively less expensive to manufacture. The gas panels, moreover, are relatively inexpensive to operate as display or storage devices. While the method of this inven-

tion has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of fabricating a gas panel, said method including the steps of:

1. cutting a pair of glass plates to appropriate dimensions to provide an overlap area of a desired size for the gas panel,
2. disposing parallel lines as electrical conductors on each glass plate with the electrical conductors terminating a given distance from each end of each glass plate,
3. heating each glass plate in an atmosphere which oxidizes the exposed surface of each parallel line thereby to render each parallel line passive during a subsequent protective coating operation,
4. spraying a mixture of glass frit in a suspension vehicle over the parallel lines of each glass plate with precision spray equipment thereby to deposit the mixture with a uniform depth on each glass plate,
5. firing each glass plate on a level surface in an oven to reflow the glass frit whereby a protective glass coating completely covers the parallel lines,
6. placing on one of the glass plates a sealing material composed of glass frit in a binder prefabricated in the form of a rectangle, and placing spacers at selected locations near the sealing material on said one glass plate,
7. heating one said glass plate to bake the binder out of the sealing material,
8. placing the other glass plate on said one glass plate with the parallel lines on said one glass plate extending orthogonally to the parallel lines on the other glass plate,
9. heating the assembly in an oven on a level surface to reflow the glass frit that was in a binder and seal the two glass plates together spaced apart a given distance thereby to form a chamber therebetween,
10. heating the assembly in an oven and simultaneously evacuating the chamber, thereafter backfilling the chamber with an illuminable gas, and sealing the illuminable gas in said chamber under less than atmospheric pressure, and
11. exposing each parallel line at one end of each glass plate as an electrical contact.

2. The method of claim **1** wherein the spraying of step 4 is performed by using a regulated constant blower pressure and a regulated constant speed of relative movement between the spray equipment and the glass plates.

3. The method of claim **2** including the further step of using freon vapor as a propellent in the spray equipment.

4. The method of claim **1** wherein the sprayed mixture of step 4 is a slurry prepared by adding finely ground glass frit to a suspension vehicle composed of a solution of nitrocellulose polymer binder in amyl acetate, and mixing thoroughly to disperse the finely ground glass frit uniformly throughout the solution to form the slurry.

5. The method of claim **1** wherein each of the parallel lines in step 2 is a laminate made by depositing a first layer composed of chromium on each glass plate, depositing a second layer composed of copper on the first layer, deposting a third layer composed of chromium on the second layer, applying a coating of photoresist on the third layer, exposing the photoresist with art work having a light pattern of alternate light and dark lines, developing the exposed photoresist material, etching the laminate between the remaining regions of photoresist material, exposing the remaining photoresist material and developing again to remove the remaining of the exposed photoresist material.

6. The method of claim **5** wherein the heating operation of step 3 is performed in an atmosphere composed of 90 percent nitrogen, 10 percent hydrogen, and water vapor thereby to form a layer of chromium oxide on the outer surface of the third layer composed of chromium whereby the outer layer of chromium oxide renders the laminated parallel lines passive or non-reactive to subsequent high temperature operations.

7. A method of fabricating a gas panel, said method comprising the steps of:

1. cutting two glass plates to appropriate dimensions for the desired size of a gas panel,
2. depositing parallel lines as electrical conductors on each glass plate with the electrical conductors terminating a given distance from each end of each glass plate, each parallel line being a laminate composed of a first layer composed of chromium deposit on each glass plate, a second layer composed of copper deposited on the first layer and a third layer composed of chromium, deposited on the second layer,
3. heating each glass plate in an atmosphere composed of 90 percent nitrogen, 10 percent hydrogen, and water vapor to form a layer of chromium oxide on the outer surface of the third layer composed of chromium whereby the outer layer of chromium oxide renders the laminated parallel lines passive or non-reactive to subsequent firing operations,
4. spraying a slurry composed of a finely ground glass frit, uniformly dispersed in a suspension vehicle, on each glass plate to cover the laminated parallel lines on each glass plate with a uniform depth of such slurry.
5. firing each glass plate on a level surface in an oven to reflow the glass frit whereby a protective glass coating completely covers the laminated parallel lines.
6. placing on one of the glass plates a sealing material composed of glass frit in a cellulose binder prefabricated in the form of a frame or rectangle, placing spacers at selected locations near the sealing material on said one glass plate, and heating said one glass plate to bake the cellulose binder out of the sealing material,
7. placing the outer glass plate on said one glass plate with the parallel lines of one plate extending orthogonally to the parallel lines of the other glass plate,
8. heating the assembly in an oven thereby to seal the two glass plates together spaced a given distance apart and forming a chamber therebetween,
9. evacuating the chamber and simultaneously baking the assembly in an oven, thereafter backfilling the chamber with an illuminable gas under less

than atmospheric pressure, and sealing the illuminable gas in said chamber, and

10. removing the protective glass coating and the upper layer of chromium from the end regions of the laminated parallel lines at one end of each glass plate, thereby exposing the copper layer of each parallel line as an electrical contact.

8. The method of claim **7** wherein step **4** is performed using spray gun equipment with regulated constant blower pressure and regulated constant speed of relative movement between the spray gun and the surface of the glass plates thereby to provide accurate control of the thickness of the slurry sprayed over the laminated parallel lines, ane using freon vapor as a propellent for the spray gun.

9. A method of fabricating a gas panel, said method including the steps of:

1. cutting first and second glass plates to appropriate dimensions to provide an overlap area of a desired size for the gas panel, and making a hole in the first glass plate,
2. disposing parallel lines as electrical conductors on each glass plate with the electrical conductors terminating a given distance from each end of each glass plate,
3. heating each glass plate in an atmosphere which oxidizes the exposed surface of each parallel line thereby to render each parallel line passive during a subsequent protective coating operation,
4. spraying a mixture composed of glass frit in a suspension vehicle, over the parallel lines of each glass plate with precision spray equipment thereby to deposit the mixture with a uniform depth on each glass plate,
5. firing each glass plate on a level surface in an oven to reflow the glass frit whereby a protective glass coating completely covers the parallel lines,
6. placing on the second glass plates a sealing material composed of a glass frit in a cellulose binder prefabricated in the form of a frame or rectangle, and placing spacers at selected locations near the sealing material on the second glass plate,
7. heating the second glass plate to bake the cellulose binder out of the sealing material,
8. applying a bead of a mixture of glass frit and suspension vehicle on one end of a tubulation and placing such end in the hole on the first glass plate,
9. placing the first glass plate on the second glass plate with the parallel lines on the first glass plate extending orthogonally to the parallel lines on the second glass plate,
10. heating the assembly in an oven on a level surface to seal the two glass plate together spaced apart a given distance thereby to form a chamber therebetween.
11. heating the assembly in an oven and simultaneously evacuating the chamber through the tubulation, thereafter backfilling the chamber through the tubulation with an illuminable gas, and tipping off the tubulation thereby sealing the illuminable gas in said chamber under less than atmospheric pressure, and
12. exposing each parallel line at one end of each glass plate as an electrical contact.

10. The method of claim **9** wherein the spraying of step **4** is performed by using a regulated constant blower pressure and a regulated constant speed of relative movement between the spray equipment and the glass plates.

11. The method of claim **10** including the further step of using freon vapor as a propellent in the spray equipment.

12. The method of claim **10** wherein the sprayed mixture of step **4** is a slurry prepared by adding finely ground glass frit to a suspension vehicle composed of a solution of nitrocellulose polymer binder in amyl acetate, and mixing thoroughly to disperse the finely ground glass frit uniformly throughout the solution to form the slurry.

13. The method of claim **10** wherein each of the parallel lines in step 2 is a laminate made by depositing a first layer composed of chromium on the first and second glass plates, depositing a second layer composed of copper on the first layer, depositing a third layer composed of chromium on the second layer, applying a coating of photoresist on the third layer, exposing the photoresist with art work having a light pattern of alternate light and dark lines, developing the exposed photoresist material, etching the laminate between the remaining regions of photoresist material, exposing the remaining photoresist materal and developing again to remove the emainder of the exposed photoresist material.

14. The method of claim **13** wherein the heating operation of step 3 is performed in an atmosphere composed of 90 percent nitrogen, 10 percent hydrogen, and water vapor thereby to form a layer of chromium oxide on the outer surface of the third layer composed of chromium whereby the outer layer of chromium oxide renders the laminated parallel lines passive or non-reactive to subsequent high temperature operations.

15. A method of fabricating a gas panel, said method comprising the steps of:

1. cutting first and second glass plates to appropriate dimensions to provide an overlap area of a desired size for the gas panel, and providing a hole in the first glass plate,
2. depositing a first layer composed of chromium on the first and second glass plates with said first layer terminating a given distance from each end of the first and second glass plates, depositing a second layer composed of copper on the first layer, depositing a third layer composed of chromium on the second layer, thereby to form a laminate, applying a coating of photoresist on the third layer, exposing the photoresist with art work having a light pattern of alternate light and dark lines, developing the exposed photoresist, etching the laminate between the remaining regions of photoresist, exposing the remaining photoresist, and developing again to remove the remainder of the exposed photoresist, whereby laminated parallel lines which serve as electrical conductors are formed on the first and second glass plates,
3. heating the first and second glass plates in an atmosphere composed of 90 percent nitrogen, 10 percent hydrogen, and water vapor thereby to form a layer of chromium oxide on the outer surface of the third layer composed of chromium whereby the outer layer of chromium oxide renders the laminated parallel lines passive or non-reactive to subsequent high temperatuere operations,

4. spraying on the first and second glass plates with a precision spray gun a slurry prepared by adding finely ground glass frit mixed thoroughly to disperse the finely ground glass frit uniformly throughout a suspension vehcile composed of a solution of nitrocellulose polymer binder in amyl acetate, thereby to deposit the mixture with a uniform depth on the first and second glass plates,
5. firing the first and second glass plates on a level surface in an oven to reflow the glass frit thereby to form a protective glass coating which covers completely the ends, sides and top of the parallel lines,
6. placing on the second glass plate a sealing material composed of a glass frit in a cellulose binder prefabricated in the form of a frame or rectangle the inner periphery of which represents the desired dimensions of a chamber to be formed between the first and second glass plates.
7. heating the second glass plate to bake the cellulose binder out of the sealing material,
8. applying a bead of a mixture of glass frit and suspension vehicle on one end of a tubulation and placing such end in the hole on the first glass plate,
9. placing the first glass plate on the second glass plate with the parallel lines on the first glass plate extending orthogonally to the parallel lines on the second glass plate,
10. heating the assembled first and second glass plates in an oven on a level surface to seal the first and second glass plates together spaced apart a given distance as determined by said spacers thereby to form chamber therebetween, and cooling the assembly,
11. heating the assembly again in an oven and simultaneously evacuting the chamber through the tubulation, thereafter back-filling the chamber through the tubulation with an illuminable gas, and tipping off the tubulation thereby sealing the illuminable gas in said chamber under less thanatmospheric pressure, and
12. removing the protective glass coating and the third layer of chromium from the end regions of each parallel line at one end of the first and second glass plates, thereby to expose the second layer composed of copper as an electrical contact for each parallel line.

16. The method of claim **15** wherein the spraying in step 4 is done by regulating the blower pressure of the spray gun to be constant, regulating the speed of relative movement between the spray gun and the surface of the first and second glass plates to be constant thereby to provide accurate control of the thickness of the slurry sprayed over the laminated parallel lines of the first and second glass plates, and using freon vapor as a propellent for the spray gun thereby to minimize the presence of contaminants.

17. The method of claim **16** wherein the finely ground glass frit for the slurry is milled in a ball mill to form a powder, sifting the powder to obtain a particle size equal to or less than 0.0015 of an inch in diameter, and using a jet in the spray head which has a diameter of 0.030 of an inch, baking the finely ground glass frit to remove all moisture thereby to prevent cohesion of the glass frit particles before adding them to the suspension vehicle, whereby the small glass frit particles are prevented from collecting together in the suspension vehicle and forming group particle sizes which might clog the jet of the spray head.

18. A method of fabricating a gas panel, said method including the steps of:
1. depositing parallel lines as electrical conductors on a pair of glass plates with the parallel lines terminating a given distance from each end of each glass plate,
2. providing a protective cover over each one of the parallel lines on each glass plate,
3. providing a protective coating of glass over the ends, sides, and top of each parallel line on the glass plates,
4. placing on one of the glass plates a sealing material composed of glass frit in a cellulose binder prefabricated in the form of a frame or rectangle, placing spacers at selected locations near the sealing material on said one glass plate, and heating said one glass plate to bake the cellulose binder out of the sealing material,
5. placing the other glass place on said one glass plate with the parallel lines of one glass plate extending orthogonally to the parallel lines of the other glass plate.
6. heating the assembly in an oven thereby to seal the two plates together spaced apart a given distance to form a chamber therebetween,
7. evacuating the chamber and filling it with an illuminable gas, and
8. exposing each parallel line at one end of each glass plate as an electrical contact.

19. The method of claim **18** wherein the protective coating of step **3** is added by spraying a slurry composed of finely ground lead glass powder thoroughly mixed with a suspension vehicle composed of a solution of nitrocellulose polymer binder in amyl acetate, regulating the spray equipment to have a constant blower pressure, and regulating the spray equipment to have a constant speed of relative movement between the spray equipment and the glass plates.

20. The method of claim **19** including the further step of using freon vapor as a propellent in the spray equipment.

21. The method of claim **19** wherein the finely ground lead glass power is prepared by milling lead glass granules in a ball mill to produce a fine powder, sifting the powder to limit the maximum particle size to a given diameter, baking the sifted powder to remove all moisture until the sifted powder is mixed in the suspension vehicle.

22. The method of claim **18** including the further step of cutting off one side of each glass plate flush with the ends of the parallel lines.

23. The method of claim **18** wherein each one of the parallel lines in step **1** is a laminate made by depositing a first layer composed of chromium on each glass plate, depositing a second layer composed of copper on the first layer, depositing a third layer composed of chromium on the second layer, applying a coating of photoresist on the third layer, exposing the photoresist with art work having a light pattern of alternate light and dark lines, developing the exposed photoresist, etching the laminate between the remaining regions of photoresist, exposing the remaining photoresist, and developing again to remove the remainder of the exposed photoresist.

24. The method of claim 23 including the further step of heating each glass plate in an atmosphere composed of 90 percent nitrogen, 10 percent hydrogen, and water vapor thereby to form a layer of chromium oxide on the outer surface of the third layer composed of chromium whereby the outer layer of chromium oxide renders the laminated parallel lines passive or non-reactive to subsequent high temperature operations.

25. A method of fabricating a gas panel, said method including the steps of:

1. cutting a pair of glass plates to appropriate dimensions to provide an overlap area of a desired size for the gas panel,
2. disposing parallel lines as electrical conductors on each glass plate with the electrical conductors terminating a given distance from each end of each glass plate.
3. heating each glass plate in an atmosphere which oxidizes the exposed surface of each parallel line and thereby to render each parallel line passive during a subsequent protective coating operation,
4. spraying a mixture of glass frit in a suspension vehicle over the parallel lines of each glass plate with precision spray equipment thereby to deposit the mixture with a uniform depth on each glass plate,
5. firing each glass plate on a level surface in an oven to reflow the glass frit whereby a protective glass coating completely covers the parallel lines,
6. placing on one of the glass plates, a glass sealing material around the periphery thereof, and placing spacers at selected locations near the glass sealing material on said one glass plate,
7. placing the other glass plate on said one glass plate with the parallel lines on said one glass plate extending orthogonally to the parallel lines on the other glass plate,
8. heating the assembly in an oven on a level surface to reflow the glass sealing material and thus seal the two glass plates together spaced apart a given distance thereby to form a chamber therebetween,
9. heating the assembly in an oven and simultaneously evacuating the chamber, thereafter backfilling the chamber with an illuminable gas, and sealing the illuminable gas in said chamber under less than atmospheric pressure, and
10. exposing each parallel line at one end of each glass plate as an electrical contact.

26. A method of fabricating a gas panel, said method including the steps of:

1. cutting first and second glass plates to appropriate dimensions to provide an overlap area of a desired size for the gas panel, and making a hole in the first glass plate,
2. disposing parallel lines as electrical conductors on each glass plate with the electrical conductors terminating a given distance from each end of each glass plate,
3. heating each glass plate in an atmosphere which oxidizes the exposed surface of each parallel line thereby to render each parallel line passive during a subsequent protective coating operation,
4. spraying a mixture composed of glass frit in a suspension vehicle over the parallel lines of each glass plate with precision spray equipment thereby to deposit the mixture with a uniform depth on each glass plate,
5. firing each glass plate on a level surface in an oven to reflow the glass frit whereby a protective glass coating completely covers the parallel lines,
6. placing on the second glass plate a glass sealing material around the periphery thereof, and placing spacers at selected locations near the glass sealing material on the second glass plate,
7. applying a bead of a mixture of glass frit and suspension vehicle on one end of a tubulation and placing such end in the hole on the first glass plate,
8. placing the first glass plate on the second glass plate with the parallel lines on the first glass plate extending orthogonally to the parallel lines on the second glass plate,
9. heating the assembly in an oven on a level surface to seal the two glass plates together spaced apart a given distance by the spacers thereby to form a chamber therebetween.
10. heating the assembly in an oven and simultaneously evacuating the chamber through the tubulation, thereafter backfilling the chamber through the tubulation with an illuminable gas, and tipping off the tubulation thereby sealing the illuminable gas in said chamber under less than atmospheric pressure, and
11. exposing each parallel line at one end of each glass plate as an electrical contact.

27. A method of fabricating a gas panel, said method including the steps of:

1. depositing parallel lines as electrical conductors on a pair of glass plates with the parallel lines terminating a given distance from one end of each glass plate,
2. providing a protective cover over each one of the parallel lines on each glass plate,
3. providing a protective coating of glass over the ends, sides, and top of each parallel line on the glass plates,
4. placing on one of the glass plates a glass sealing material around the periphery thereof, and placing spacers at selected locations near the glass sealing material on said one glass plate,
5. placing the other glass plate on said one glass plate with the parallel lines of one glass plate extending orthogonally to the parallel lines of the other glass plate,
6. heating the assembly in an oven thereby to seal the two plates together spaced apart a given distance to form a chamber therebetween,
7. evacuating the chamber and filling it with an illuminable gas, and
8. exposing each parallel line at one end of each gas plate as an electrical contact.

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