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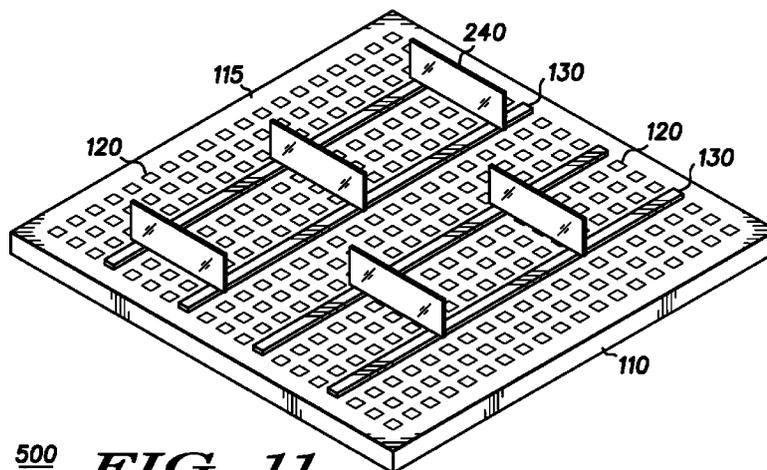
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(54) Method for affixing spacers in a flat panel display

(57) A method for affixing a plurality of spacers (240) in a flat panel display (700) includes the steps of: (i) patterning a bonding agent (130) on the inner surface of a display plate (110) of the flat panel display (700), (ii) forming spacer bundles (245, 246) within a spacer jig (210) (iii) contacting the contact planes of the spacer bundles (245, 246) with the bonding agent (130), (iv) selectively bonding a portion of the spacers (240) to

bonding regions (140) of the bonding agent (130), and (v) thereafter removing the spacer bundles (245, 246) from the display plate (110) so that the selectively bonded spacers (240) are removed from the spacer bundles (245, 246) and remain affixed to the display plate (110).



500 **FIG. 11**

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Description

Field of the Invention

The present invention pertains to a method for affixing spacers in a large area flat panel display and more specifically to a method for affixing spacers in a field emission display.

Background of the Invention

Spacers for flat panel displays, such as field emission displays, are known in the art. A field emission display includes an envelope structure having an evacuated interspace region between two display plates. Electrons travel across the interspace region from a cathode plate (also known as a cathode or back plate), upon which electron-emitter structures, such as Spindt tips, are fabricated, to an anode plate (also known as an anode, cathodoluminescent screen, or face plate), which includes deposits of light-emitting materials, or **phosphors**. Typically, the pressure within the evacuated interspace region between the cathode and anode plates is less than or equal to 10^{-6} Torr.

The cathode plate and anode plate are thin in order to provide low display weight. If the display area is small, such as in a 1" diagonal display, and a typical sheet of glass having a thickness of about 0.04" is utilized for the plates, the display will not collapse or bow significantly. However, as the display area increases, the thin plates are not sufficient to withstand the pressure differential in order to prevent collapse or bowing upon evacuation of the interspace region. For example, a screen having a 30" diagonal will have several tons of atmospheric force exerted upon it. As a result of this tremendous pressure, spacers play an essential role in large area, light-weight displays. Spacers are structures incorporated between the anode and the cathode plate to provide standoff. The spacers, in conjunction with the thin, lightweight plates, support the atmospheric pressure, allowing the display area to be increased with little or no increase in plate thickness.

Several schemes have been proposed for providing spacers. Some of these schemes include the affixation of glass rods or posts to one of the display plates by a pick-and-place method, wherein each spacer structure is individually handled and positioned in an appropriate orientation while it is affixed to the inner surface of one of the display plates. This method has several drawbacks, such as requiring tight tolerances, being very time-consuming, and failing to consistently provide perpendicularity of the spacer with the inner surface of the display plate.

Thus, there exists a need for a method for affixing spacers within a flat panel display which provides perpendicularity of the spacers with the inner surface of the display plate to which it is being bonded and which

results in high throughput. There further exists a need for a method for affixing spacers in a flat panel display which avoids the tight tolerance requirements typical of pick-and-place methods.

Brief Description of the Drawings

Referring to the drawings:

FIG. 1 is an isometric view of a structure realized by performing various steps of an embodiment of a method for affixing spacers in a flat panel display in accordance with the present invention.

FIG. 2 is a side-elevational view of a structure realized by performing various steps of an embodiment of a method for affixing spacers in a flat panel display in accordance with the present invention.

FIG. 3 is a top plan view of the structure depicted in FIG. 2.

FIG. 4 is a top plan view of a structure realized by performing various steps of another embodiment of a method for affixing spacers in a flat panel display in accordance with the present invention.

FIGs. 5 and 6 are side elevational views of structures realized by performing various steps of an embodiment of a method for affixing spacers in a flat panel display in accordance with the present invention and including the structures depicted in FIGs. 1 and 2.

FIG. 7 is a sectional view of FIG. 5 taken along section line 7 - 7.

FIG. 8 is a bottom plan view of a structure depicted in FIG. 6.

FIGs. 9 and 10 are side elevational views of structures realized by performing various steps of another embodiment of a method for affixing spacers in a flat panel display in accordance with the present invention.

FIG. 11 is an isometric view of a structure realized by performing additional steps of a method upon the structure of FIG. 10 in accordance with the present invention.

FIG. 12 is a side elevational view and schematic depiction of a structure realized by performing various steps of another embodiment of a method for affixing spacers in flat panel display in accordance with the present invention.

FIG. 13 is a cross-sectional view of a schematic depiction of a field emission display realized by performing various steps of a method for fabricating a field emission display in accordance with the present invention.

Description of the Preferred Embodiment

Referring now to FIG. 1, there is depicted an isometric view of a structure 100 realized by performing various steps of an embodiment of a method for affixing

spacers in a flat panel display in accordance with the present invention. Structure 100 includes a display plate 110 of a flat panel display. In this particular embodiment, display plate 110 includes either an anode plate or a cathode plate suitable for use in a field emission display, and preferably includes the anode plate. Display plate 110 has a major surface 115 upon which a plurality of pixels 120 are disposed. Pixels 120 include, in an anode plate, deposits of cathodoluminescent material which emit light upon excitation by electrons. Structure 100 further includes a patterned bonding agent 130, which is disposed on a portion of the regions available between pixels 120. The regions available between pixels 120 have widths within a range of about 50-250 micrometers. Bonding agent 130 must be present on those portions of major surface 115 of display plate 110 where it is desired to affix spacers. In the preferred embodiment, bonding agent 130 includes a glass frit, which is a low temperature solder-glass. One of various deposition techniques is used to deposit the glass frit onto display plate 110. These deposition techniques include, but are not limited to, the following examples, each of which is suitable for forming frit patterns having very fine line widths so that the patterns can be accommodated by the regions between pixels 120. First, frit can be deposited by using a microdispense machine capable of dispensing extremely small amounts of adhesive onto a substrate; the proper line-width is achieved by using the proper particle size distribution and viscosity. Photolithographic techniques can also be used wherein a photo-resist is added to the glass frit to provide a frit resist. A layer of the frit resist is deposited onto major surface 115 and thereafter exposed under a photo-mask to form a predetermined pattern on display plate 110. A third method suitable for frit deposition includes electrophoretic deposition. In this method, a conductive metal, such as aluminum, is first deposited onto display plate 110. The metal is then patterned to have the predetermined pattern for bonding agent 130. Thereafter, display plate 110 is placed in an electrolytic frit suspension. A potential is then applied to the metal so that the frit particles are attracted, and adhered, to the metal, thereby depositing frit particles onto the patterned metal. Another technique suitable for depositing the patterned frit includes physically stamping the frit onto major surface 115 by, for example, using a finely edged stamp. The stamp may include a plurality of extremely fine wires having a configuration which is the same as the predetermined pattern of bonding agent 130. In this particular deposition method, the fine wire is coated with a frit having a fine particle-size, stretched taut across an area corresponding to the predetermined frit pattern, and then brought into physical contact with major surface 115 of display plate 110, thereby leaving extremely fine lines of frit on display plate 110. These techniques differ from standard frit-deposition practices, which typically deposit much larger patterns than those required for bonding agent 130. When display plate 110

includes an anode plate of a field emission display, the deposition methods described above are also advantageous because they reduce disturbance of the phosphor material, which is typically not tightly held to the anode plate. Standard methods of screen-printing frit would probably destroy these loosely-held phosphor deposits. However, it is feasible to form the frit pattern on an anode plate by utilizing a very finely meshed screen in a screen-printing technique if the phosphor deposits are disposed within holes formed in the major surface of the anode plate; being protected within these holes, the phosphor is not displaced by the screen-printing method. The very fine mesh of the screen would provide the predetermined line width of the pattern. Because bonding with frit requires an oxidizing environment, in order to affix spacers in a field emission display, this particular embodiment requires that display plate 110 include the anode plate of the field emission display. The anode plate is not affected by the oxidizing environment, while the cathode plate contains elements, such as molybdenum electron-emitting structures, which are deleteriously affected by oxidation. In other embodiments of the present method, one of which is described below with reference to FIG. 12, an oxidizing environment is not required; in these particular embodiments for affixing spacers in a field emission display, display plate 110 may include the cathode plate of the field emission display. In the preferred embodiment of the present method, bonding agent 130 has line-widths which are thinner than the spacers. The predetermined pattern of bonding agent 130, as depicted in the preferred embodiment of FIG. 1, includes a plurality of parallel, regularly-spaced strips. For a typical anode, which includes a substrate of 1.1 mm thick glass, a spacing of about 15 mm between spacers is believed to be adequate, for load-bearing purposes, to withstand the pressure exerted by the atmosphere on the final evacuated display. When spacers are affixed so that their length is parallel to the length of the strips, as will be described in greater detail with reference to FIG. 8, a suitable spacing between the strips of bonding agent 130 is therefore also about 15 mm. Other suitable patterns for bonding agent 130 are possible and depend upon parameters such as the thickness of display plate 110 and the relative positioning of the spacers with respect to bonding agent 130.

Referring now to FIGs. 2 and 3, there are depicted side-elevation and top plan views, respectively, of a structure 200 realized by performing various steps of an embodiment of a method for affixing spacers in a flat panel display in accordance with the present invention. Structure 200 includes a plurality of spacers 240 which are stacked on a major surface of a jig 210 to form a pair of spacer bundles 245, 246. In this particular embodiment, spacer bundle 246, which is identical to spacer bundle 245, is parallel to spacer bundle 245 and is separated therefrom by a center divider 260. In other bundle/jig structures in accordance with the present

invention, single or multiple spacer bundles, having more than two spacer bundles, are employed. Jig 210 includes a base plate 220, including the major surface, a jig support member 230 disposed in slideable relationship to the major surface, and a movable arm 250, which can be used to move jig support member 230 laterally along the major surface of base plate 220. Spacers 240 are made from a dielectric material, such as glass. In the preferred embodiment, each of spacers 240 includes a plate of glass having a high aspect ratio and a height equal to the distance between the inner surfaces of the display into which spacers 240 are incorporated. To fit in the regions available between pixels 120, the width of each of spacers 240 is within a range of 10-250 micrometers and is uniform among all of spacers 240; to provide the necessary spacing between the display plates, the height of each of spacers 240 is within a range of 200-2000 micrometers and is uniform among all of spacers 240. Spacers 240 are parallel to one another and stacked in abutting engagement with one another so that, in conjunction with jig support member 230, spacers 240 are maintained in an upright position within jig 210. The lateral positioning of support member 230, along the major surface of jig 210, is adjustable and is changed by moveable arm 250 so that support member 230 is in abutting engagement with the outermost of spacers 240 within bundle 245 and no gaps exist between adjacent spacers 240. Spacers 240 have first and second opposed edges. The first opposed edge of each of spacers 240 lies within a single contact plane, and the second opposed edge rests on the major surface of jig 210. Center divider 260 includes means to provide adjustment of its length. For example, center divider 260 may include: (1) two hollow elongated members, one of which can be encased by the other so that both are slideable with respect to each other, and (2) a spring disposed within the hollow portions of center divider 260 to facilitate adjustment of its length. The benefit of an adjustable length will become more apparent in the discussion with respect to FIG. 6. The length of each of spacer bundles 245, 246 depends on the dimensions of display plate 110 or on the dimensions of the portion of display plate 110 to which it is desired to affix a portion of spacers 240, as will be described in greater detail with reference to FIG. 5.

Referring now to FIG. 4, there is depicted a top plan view, similar to FIG. 3, of a structure 200'. Structure 200' includes a plurality of spacers 240' having circular cross-sections. Spacers 240' include a plurality of rods or fibers positioned upright and held in abutting engagement in a jig having a support member 230', in a fashion similar to that described with reference to FIG. 2. A particular configuration of pixels on a display plate may make preferable the use of spacers 240' having circular cross-sections. In such an application, the use of structure 200' is preferable.

Referring now to FIGs. 5-8, there are depicted side elevational (FIGs. 5 and 6), sectional (FIG. 7), and bot-

tom plan (FIG. 8) views of structures realized by performing various steps of an embodiment of a method for affixing spacers in a flat panel display in accordance with the present invention. FIG. 5 illustrates a structure 300, which includes structures 100 and 200 of FIGs. 1 and 2, respectively. A sectional view of FIG. 5, taken along section line 7 - 7, is illustrated in FIG. 7, which is included to facilitate understanding of the alignment of spacer bundles 245, 246 with respect to bonding agent 130. Structure 300 is realized by aligning structure 200 with structure 100 so that a portion of spacers 240 can be selectively bonded to portions of bonding agent 130, which comprise a plurality of bonding regions 140. By employing spacer bundles 245, 246, in a single alignable structure 200, only one highly accurate alignment step is required, whereas a pick-and-place technique requires alignment of each spacer individually. In other embodiments of the present method, display plate 110 can be partitioned into a few regions to which the bonding procedure described herein is applied. By significantly reducing the number of alignment steps, yield of the displays is also improved. Additionally, handling of bundles 245, 246 and structure 200 is much simpler than the handling of individual spacers, which have extremely small dimensions. The uniformity of spacers 240, in conjunction with the function of jig 210 in maintaining the parallel relationship among spacers 240, allow the contact planes of spacer bundles 245, 246 to be placed within the plane of major surface 115 of display plate 110. These factors also insure that spacers 240 are perpendicular to the major surface of display plate 110. In this manner, the first opposed edges of a portion of spacers 240 are brought into abutting engagement with bonding regions 140 of bonding agent 130. If jig support member 230 is ever brought into a position opposing major surface 115 of display plate 110, the height of jig support member 230 must be less than that of spacers 240 so that spacers 240 are not prevented from making physical contact with display plate 110 by the excessive height of jig support member 230. If the width of bundles 245, 246 is always, during the steps of the present method, greater than that of display plate 110, the height of jig support member 230 can be made greater than that of spacers 240. In this particular embodiment, and as illustrated in FIGs. 7 and 8, each of spacers 240 which is bonded to display plate 110, is bonded over its entire length to a portion of a strip of bonding agent 130, a bonding region. To provide room for some alignment error, bonding agent 130 is deposited into strips having a width which is less than the width of each of spacers 240, the width of each strip being within a range of 10-90% of the width of each of spacers 240. This also prevents partial bonding of multiple spacers to one bonding region, the partial bonding possibly causing in the partially bonded spacers to overlap portions of pixels 120, thereby interfering with their functioning, or possibly introducing weakly bonded spacers which are subsequently dislodged and

released into the active region of the display. The uniformity of the width of spacers 240 provides the advantage of repeated use of structure 200 to affix spacers in multiple displays, as will be described in greater detail below. The spacing between adjacent strips of bonding agent 130 is suitable to provide proper alignment with a spacer at each bonding region 140. In this particular embodiment, this spacing is equal to a whole number multiple of the width of a single spacer, to insure appropriate alignment with a spacer at each bonding region 140. After structure 200 is aligned with display plate 100, bonding agent 130 is suitably activated to form bonds between the portion of spacers 240 which are in abutting engagement with bonding agent 130 and bonding regions 140. In this particular embodiment the suitable activation of bonding agent 130 includes heating the frit. This can be accomplished by placing structure 300 within an oven and heating it to a frit sealing temperature characteristic of the particular glass frit employed. In order to minimize differences in expansion rates of materials during the heating process, it is preferable that the material of base plate 220 be the same as the material of spacers 240. Differences in expansion rates can cause base plate 220 to slide or move relative to spacers 240. Providing equal expansion rates ensures that the perpendicularity and predetermined alignment of spacers 240 is maintained during the bonding/heating step. Structure 300 is heated for a sufficient amount of time to form the frit bonds. Thereafter, display plate 110 is moved away from jig 210, as illustrated by opposed arrows in FIG. 6. Simultaneously, support member 230 can be moved in a direction away from spacers 240, by the action of movable arm 250, thereby relieving the compressive force exerted upon spacers 240. This reduces the chance of weakening or breaking any of the bonds formed between spacers 240 and display plate 110 during the removal step. A structure 400, including structure 100 and the portion of spacers 240 which are affixed thereon, is thereby realized and is illustrated in FIG. 6. A bottom plan view of structure 400 is depicted in FIG. 8. After structure 400 is removed, the action of movable arm 250 can be used to provide a compressive force to support member 230, toward the remaining spacers 240 to close the gaps and simultaneously compress center divider 260. The bonding process described with reference to FIGs. 1-8 can then be repeated with another display plate. This is made possible because the width of spacers 240 is uniform, and, therefore, the compressed bundle will provide the same spacer configuration for alignment purposes with a subsequent display plate having the same pattern for bonding agent 130 as that of structure 100. By providing spacer bundles 245, 246 having lengths exceeding the length of display plate 110, the bundle/jig structure can be reused repeatedly until it no longer has the desired length.

Referring now to FIG. 9, there is depicted a side elevational view of an apparatus 350 suitable for per-

forming various steps of another embodiment of a method for affixing spacers 240 in a flat panel display in accordance with the present invention. Apparatus 350 includes an infrared laser head 280 for producing a directional beam of infrared radiation. Infrared laser head 280 is movably connected to an x-y table 290 for alignment purposes. Apparatus 350 further includes structure 300 (FIGs. 5 and 7) disposed in operable relation to infrared laser head 280. In this particular embodiment, base plate 220 of jig 210 is made from a material transparent to infrared radiation. The material of spacers 240 is similarly transparent to infrared radiation. Apparatus 350 is useful for the localized heating of the frit comprising bonding agent 130, so that heating and bonding are caused to occur only at bonding regions 140, where it is desired to selectively affix spacers 240 to display plate 110. Apparatus 300 must be heated to some degree to minimize stresses at the spacer/substrate interface. However, the heating is less than that required for a uniform heating of structure 300 to provide the frit sealing, as described with reference to FIG. 5. In the use of apparatus 350, x-y table 290 is first aligned with structure 300. Then, infrared laser head 280 is sequentially aligned beneath each of bonding regions 140. After infrared laser head 280 is aligned with a bonding region, it is caused to emit a beam of directed infrared radiation through base plate 220 and the spacer which is in registration with the given bonding region. The laser is on for a period of time sufficient to realize the appropriate sealing temperature of the glass frit. Each of spacers 240 which are bonded are similarly affixed. This laser bonding method provides several benefits, such as allowing a low temperature bonding technique. Also, by causing the frit to melt only at certain portions, there is less likelihood of elements sliding, or moving, relative to each other, thereby assuring tight tolerances.

Referring now to FIGs. 10 and 11, there are depicted side elevational and isometric views, respectively, of an apparatus 375 (FIG. 10) and a structure 500 (FIG. 11) suitable for performing various steps of another embodiment of a method for affixing spacers 240 in a flat panel display in accordance with the present invention. All elements of apparatus 375 are the same as those in apparatus 350 (FIG. 9). However, the orientation of display plate 110 is rotated 90 degrees relative to the orientation shown in FIG. 9 and within the plane of display plate 110. Uniform heating of the frit is not suitable in this particular embodiment because it would result in the affixation of spacers to portions other than at bonding regions 140 of bonding agent 130. The localized heating action of infrared laser head 280, as described above with reference to FIG. 9, provides selective bonding along the length of bonding agent 130. Spacers 240 are selectively affixed onto display plate 110 in the manner described with reference to FIG. 9. After the frit bonds are formed display plate 110 is moved away from the spacer bundles in the manner

described with reference to FIG. 6, and structure 500 is realized. An isometric view of structure 500 is illustrated in FIG. 11.

It will be apparent from the above descriptions that the selective bonding of spacers 240 to display plate 110, to provide a pre-determined spacing of the bonded spacers, is achieved by providing an appropriate pattern of bonding agent 130 upon display plate 110, and/or it is achieved by the particular method utilized to create the bonding between the selected spacers and major surface 115 of display plate 110.

Referring now to FIG. 12, there is illustrated a side elevational view and schematic depiction of an apparatus 600 suitable for performing various steps of another embodiment of a method for affixing spacers 240 in a flat panel display in accordance with the present invention. Apparatus 600 includes structure 300 (FIG. 5) wherein bonding agent 130 is made from an anodic bonding metal, such as aluminum, rather than frit, and base plate 220 includes a conductive plate, made from, for example, stainless steel. The aluminum is deposited by using one of a number of standard metal film deposition techniques, known to one skilled in the art. The thickness of the anodic bonding metal is in a range of 0.005 to 2 micrometers. The anodic bonding metal is deposited at least at those locations on the inner surface of display plate 110 where a portion of spacers 240 are to be affixed in a configuration predetermined to provide adequate standoff in the flat panel display. In this particular embodiment of the present method, the step of bonding a portion of spacers 240 to bonding regions 140 of bonding agent 130 includes forming anodic bonds between the contacting surfaces of the edges of spacers 240 and the physically contacted portions of metallic bonding agent 130. To form these anodic bonds, apparatus 600 further includes a fixture 610 for holding display plate 110. Fixture 610 is connected to electrical ground. Base plate 220 is electrically coupled to a voltage source 630. Spacers 240 are aligned with display plate structure 100, in the manner described with reference to FIG. 5, and are brought into physical contact with bonding agent 130. A potential difference within a range of 500-2000 volts, preferably 1000 volts, is applied over apparatus 300 thereby providing the potential difference over the contacting surfaces of spacers 240 and bonding agent 130. The voltage is applied so as to positively bias metallic bonding agent 130 with respect to spacers 240. Concurrent with the step of applying the potential difference, structure 600 is heated in an oven to a temperature within a range of 300-500 degrees Celsius, preferably about 400 degrees Celsius. At 1000 volts and about 400 degrees Celsius, the duration of the bonding steps is about 15 minutes. The suitable bonding time is determined by the value of the potential difference and the temperature to which the contacting surfaces are heated, and it is sufficient to form an anodic bond. After a suitable bonding time has elapsed, the applied potential difference is

removed and structure 600 is cooled. Display plate 110 is lifted away from jig 210. In this particular embodiment, the surface of bonding agent 130 must substantially conform to the surface of the contacting edge of spacers 240. This surface substantially conforms when the extent of subsequent bonding at bonding regions 140 is sufficient to permanently attach spacers 240 to display plate 110 and maintain selectively bonded spacers 240 in a perpendicular orientation with respect to the inner surface of display plate 110. This substantial conformation precludes bonding of only a portion or portions of the edge of each spacer, due to poor physical contact. In this particular embodiment, the contacting surfaces of bonding agent 130 substantially conform to the first edges of spacers 240 because the exposed surface of the deposited aluminum is flat, and the first edges of spacers 240 are also flat. Thus, during the subsequent bonding steps, bonding occurs over the entire surface of the first edges of spacers 240. Providing uniform perpendicularity among selectively bonded spacers 240 is important to assure that bonded spacers 240 subsequently make physical contact, at their opposing second edges, with the inner surface of the display plate which subsequently opposes display plate 110 in the flat panel display and can thereby bear the load due to atmospheric pressure. Jig 210, and the uniformity of the height of spacers 240, provide this perpendicularity. In this particular embodiment, for the formation of a field emission display, display plate 110 may include an anode plate or a cathode plate of a field emission display because the bonding may be performed in a non-oxidizing environment. This prevents the deleterious oxidation of elements of the cathode display plate, such as field emitters which are typically made from an oxidizable metal, such as molybdenum. When display plate 110 includes the cathode plate of a field emission display, the bonding steps (including heating and applying a potential difference) must be performed in an inert atmosphere, such as an argon atmosphere or a nitrogen atmosphere which does not contain oxygen. Also during the bonding steps, all components of the cathode display plate are preferably electrically coupled to maintain a uniform voltage throughout cathode display plate. This prevents the formation of potential differences within the cathode display plate which may cause ionic migrations within the dielectric layers of the cathode display plate. These ionic migrations may damage the dielectric properties of those dielectric layers.

Referring now to FIG. 13, there is depicted a cross-sectional view of a schematic depiction of a field emission display (FED) 700 realized by performing various steps of a method for fabricating a field emission display in accordance with the present invention. FED 700 includes structure 400 (FIG. 8), wherein display plate 110 includes an anode display plate of a field emission display. Display plate 110 includes pixels 120 made from cathodoluminescent material. Spacers 240 are affixed to display plate 110 by performing the steps

according to one of several embodiments of a method for affixing spacers 240 in a flat panel display in accordance with the present invention. Some of these embodiments are described with reference to FIGs. 1-12 above. After spacers 240 are thereby affixed, a cathode display plate 710 and side walls 720 are attached to display plate 110, and hermetically sealed thereto, to define an envelope 730. Envelope 730 is evacuated to provide therein a pressure less than 1×10^{-6} Torr. Cathode display plate 710 includes a plurality of field emitters 740, which are schematically depicted by sharp-pointed tips in FIG. 13. Field emitters 740 are formed on an inner surface of cathode display plate 710. The inner surface of cathode display plate 710 is brought into abutting engagement with the second, non-bonding edges of spacers 240. The first edge of each bonded spacer is bonded to a bonding region of bonding agent 130; the opposing second edge is in abutting engagement with a portion of the inner surface of cathode display plate 710, in the region between field emitters 740. Cathode display plate 710 and anode display plate 110 also include the appropriate conductive elements and are operably coupled to suitable electronics, in a manner known to one skilled in the art, to provide for the selective addressing of field emitters 740 and to appropriately guide emitted electrons from cathode display plate 710 toward anode display plate 110. Spacers 240 extend between cathode display plate 710 and anode display plate 110 for maintaining a predetermined spacing there between. This predetermined spacing is typically within a range of 200-2000 micrometers. Spacers 240 are located within envelope 730. Preferably, spacers 240 include glass plates having a width within a range of 10-250 micrometers and a height within a range of 200-2000 micrometers. In this particular embodiment, spacers 240 are made from soda-lime silicate glass, and the substrates of display plate 110 and cathode display plate 710 are also made from soda-lime silicate glass. Because they are all made from the same materials, spacers 240, anode display plate 110, and cathode display plate 710 have the same thermal expansion coefficients so that they expand and contract at the same rate during thermal treatments of FED 700, thereby precluding cracking and breakage due to differing expansion and contraction rates. In other embodiments, different materials are used for spacers 240 and display plates 110, 710; these materials, however, must have thermal expansion coefficients which are substantially the same to prevent breakage and cracking during thermal cycles in the fabrication of FED 700. Also, in other embodiments of the present invention, the spacers include structures other than thin plates, such as rods, posts, or fibers. Anode display plate 110 and cathode display plate 710 each have a thickness of about 1 millimeter. The necessary configuration of, and total number of, spacers 240 within envelope 730 is dependent upon these thicknesses. For a thickness of about 1 millimeter, a distance between adjacent spacers of

about 15 millimeters is believed to be suitable.

While we have shown and described specific embodiments of the present invention, further modifications and improvements will occur to those skilled in the art. We desire it to be understood, therefore, that this invention is not limited to the particular forms shown, and we intend in the appended claims to cover all modifications that do not depart from the spirit and scope of this invention.

Claims

1. A method for affixing spacers (240, 240') in a flat panel display (700), the method including the steps of:

providing a plurality of spacers (240, 240') having first and second opposed edges;
 providing a display plate (110) of the flat panel display (700), the display plate (110) having a major surface;
 patterning a bonding agent (130) on the major surface of said display plate (110) to provide a plurality of bonding regions (140);
 providing a spacer jig (210);
 forming within the spacer jig (210) a spacer bundle (245, 246) comprising the plurality of spacers (240, 240') having their first opposed edges within a contact plane, the spacer jig (210) maintaining the plurality of spacers (240, 240') in an upright position and parallel to one another;
 placing the contact plane of the spacer bundle (245, 246) within the plane of the major surface of the display plate (110), the plurality of bonding regions (140) being in abutting engagement with the first opposed edges of a portion of the plurality of spacers (240, 240');
 bonding the portion of the plurality of spacers (240, 240') to the bonding regions (140) to provide a plurality of affixed spacers (240, 240'); and
 thereafter removing the spacer bundle (245, 246) from the display plate (110) so that the plurality of affixed spacers (240, 240') are removed from the spacer bundle (245, 246) and remain bonded to the display plate (110).

2. A method for affixing spacers (240, 240') as claimed in claim 1 wherein the display plate (110) is chosen from a group consisting of an anode plate and a cathode plate suitable for use in a field emission display (700).

3. A method for affixing spacers (240, 240') as claimed in claim 1 wherein the bonding agent (130) includes glass frit and wherein the step of bonding the portion of the plurality of spacers (240, 240') to

the bonding regions (140) includes heating the glass frit at the bonding regions (140) for a sufficient amount of time to form bonds between the portion of the plurality of spacers (240, 240') and the glass frit comprising the bonding regions (140).

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4. A method for affixing spacers (240, 240') as claimed in claim 3 wherein the step of patterning the bonding agent (130) includes physically stamping the glass frit onto the major surface of said display plate (110).

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5. A method for affixing spacers (240, 240') as claimed in claim 1 wherein the plurality of spacers (240, 240') are made from glass.

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6. A method for affixing spacers (240) as claimed in claim 1 wherein the plurality of spacers (240) include a plurality of plates.

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7. A method for affixing spacers (240') as claimed in claim 1 wherein the plurality of spacers (240') include a plurality of rods.

8. A method for affixing spacers (240') as claimed in claim 1 wherein the plurality of spacers (240') include a plurality of fibers.

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9. A method for fabricating a flat panel display (700), the method including the steps of:

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providing first and second display plates (110, 710) of the flat panel display (700), each display plate (110, 710) having a major surface and a perimeter;

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providing a plurality of spacers (240, 240') having first and second opposed edges; patterning a bonding agent (130) on the major surface of the first display plate (110) to provide a plurality of bonding regions (140);

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providing a spacer jig (210); forming within the spacer jig (210) a spacer bundle (245, 246) comprising the plurality of spacers (240, 240') having their first opposed edges within a contact plane, the spacer jig (210) maintaining the plurality of spacers (240, 240') in an upright position and parallel to one another;

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placing the contact plane of the spacer bundle (245, 246) within the plane of the major surface of the first display plate (110), the plurality of bonding regions (140) being in abutting engagement with the first opposed edges of a portion of the plurality of spacers (240, 240');

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bonding the portion of the plurality of spacers (240, 240') to the bonding regions (140) to provide a plurality of affixed spacers (240, 240') on the first display plate (110);

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thereafter removing the spacer bundle (245, 246) from the first display plate (110) so that the plurality of affixed spacers (240, 240') are removed from the spacer bundle (245, 246) and remain bonded to the first display plate (110);

positioning the second display plate (710) in parallel spaced relationship to the first display plate (110), the major surface of the second display plate (710) opposing the major surface of the first display plate (110), the second opposed edges of the plurality of affixed spacers (240, 240') being in abutting engagement with major surface of the second display plate (710); and

providing a plurality of side walls (720) between the first and second display plates (110, 710) at their perimeters to provide an envelope (730), the plurality of affixed spacers (240, 240') being disposed within the envelope (730).

10. A method for fabricating a field emission display (700), the method including the steps of:

providing an anode display plate (110) and a cathode display plate (710) of the field emission display (700), each display plate (110, 710) having a major surface and a perimeter; providing a plurality of spacers (240, 240') having first and second opposed edges;

patterning a bonding agent (130) on the major surface of one of the display plates (110, 710) to provide a bonding display plate (110) having a plurality of bonding regions (140) and a non-bonding display plate (710);

providing a spacer jig (210);

forming within the spacer jig (210) a spacer bundle (245, 246) comprising the plurality of spacers (240, 240') having their first opposed edges within a contact plane, the spacer jig (210) maintaining the plurality of spacers (240, 240') in an upright position and parallel to one another;

placing the contact plane of the spacer bundle (245, 246) within the plane of the major surface of the bonding display plate (110), the plurality of bonding regions (140) being in abutting engagement with the first opposed edges of a portion of the plurality of spacers (240, 240'); bonding the portion of the plurality of spacers (240, 240') to the bonding regions (140) to provide a plurality of affixed spacers (240, 240') on the bonding display plate (110);

thereafter removing the spacer bundle (245, 246) from the bonding display plate (110) so that the plurality of affixed spacers (240, 240') are removed from the spacer bundle (245, 246) and remain bonded to the bonding display

plate (110);

positioning the non-bonding display plate (710) in parallel spaced relationship to the bonding display plate (110), the major surface of the non-bonding display plate (710) opposing the major surface of the bonding display plate (110), the second opposed edges of the plurality of affixed spacers (240, 240') being in abutting engagement with major surface of the non-bonding display plate (710);

providing a plurality of side walls (720) between the bonding and non-bonding display plates (110, 710) at their perimeters to provide an envelope (730), the plurality of affixed spacers (240, 240') being disposed within the envelope (730); and

evacuating the envelope (730) to provide therein a pressure less than 1×10^{-6} Torr.

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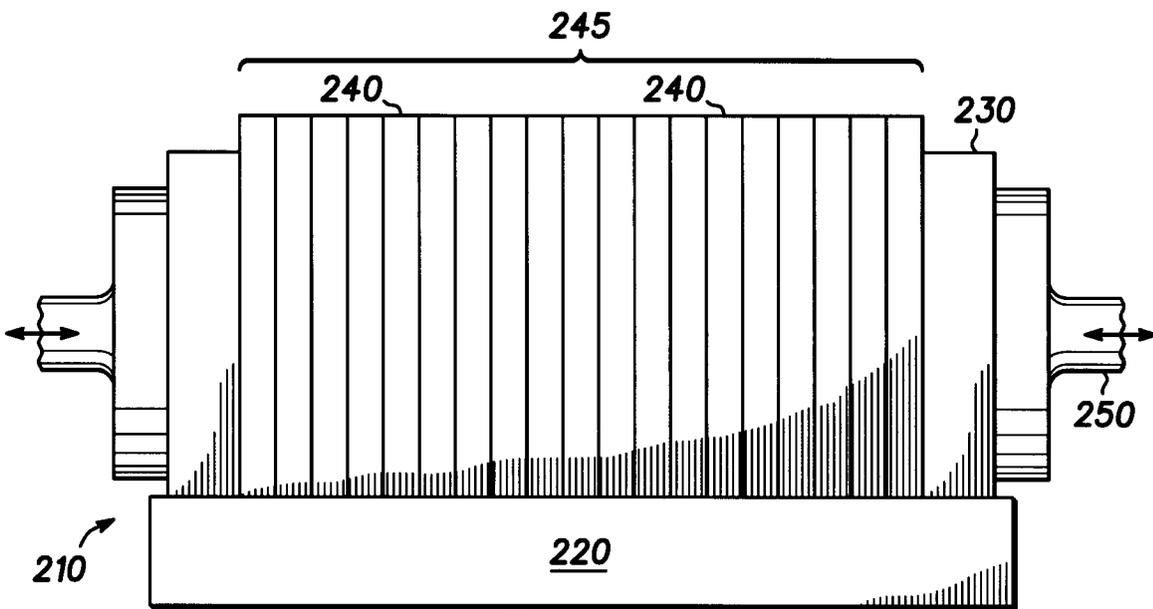
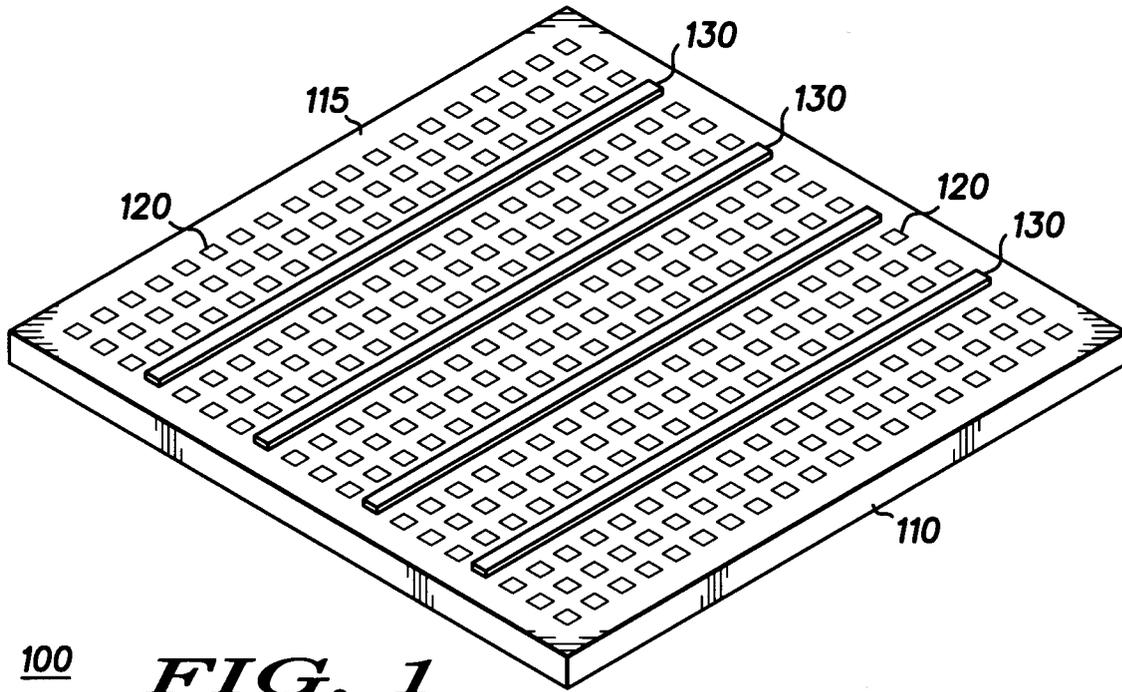
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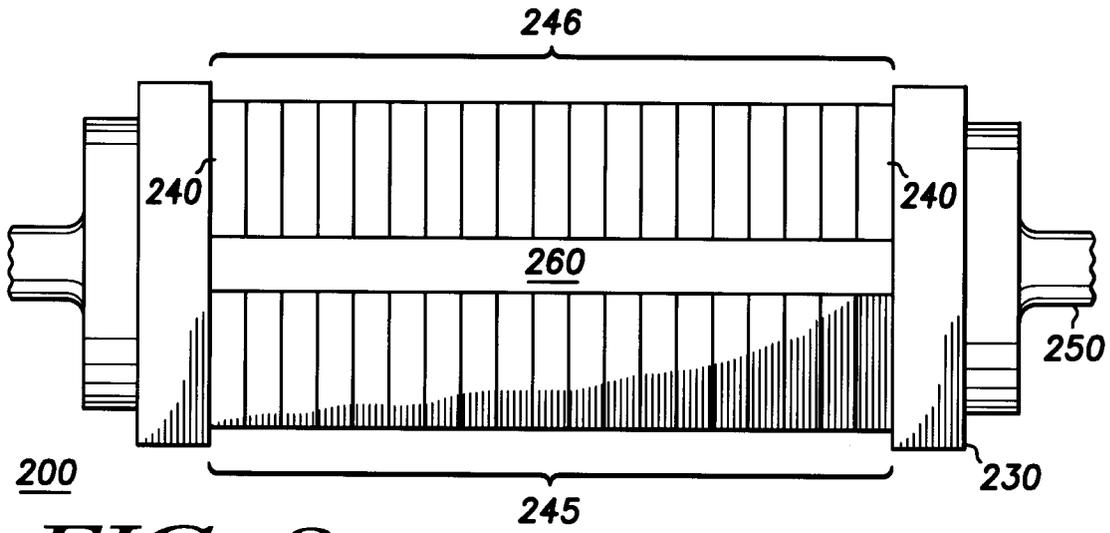


FIG. 3

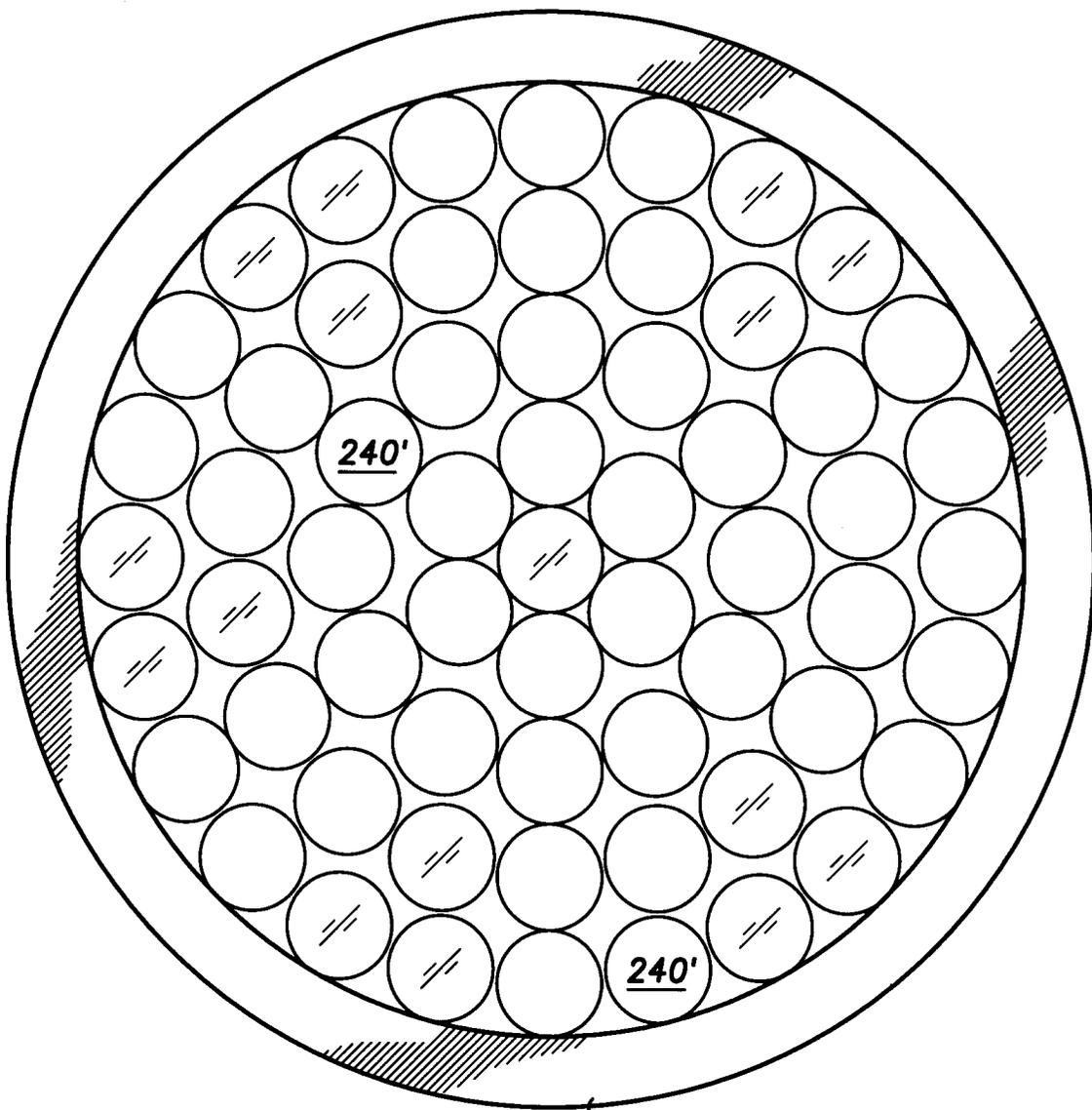
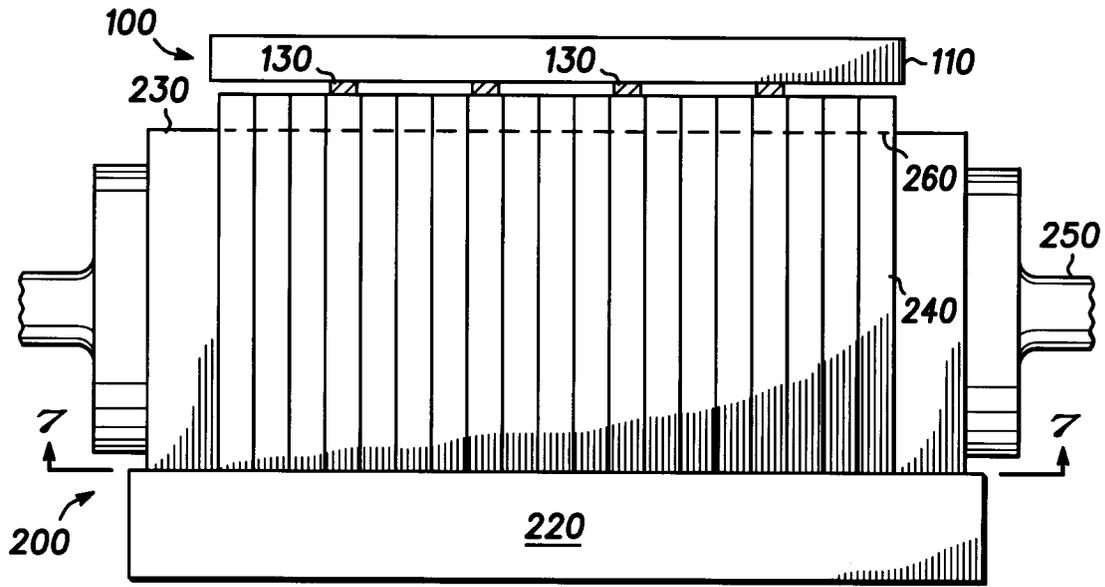
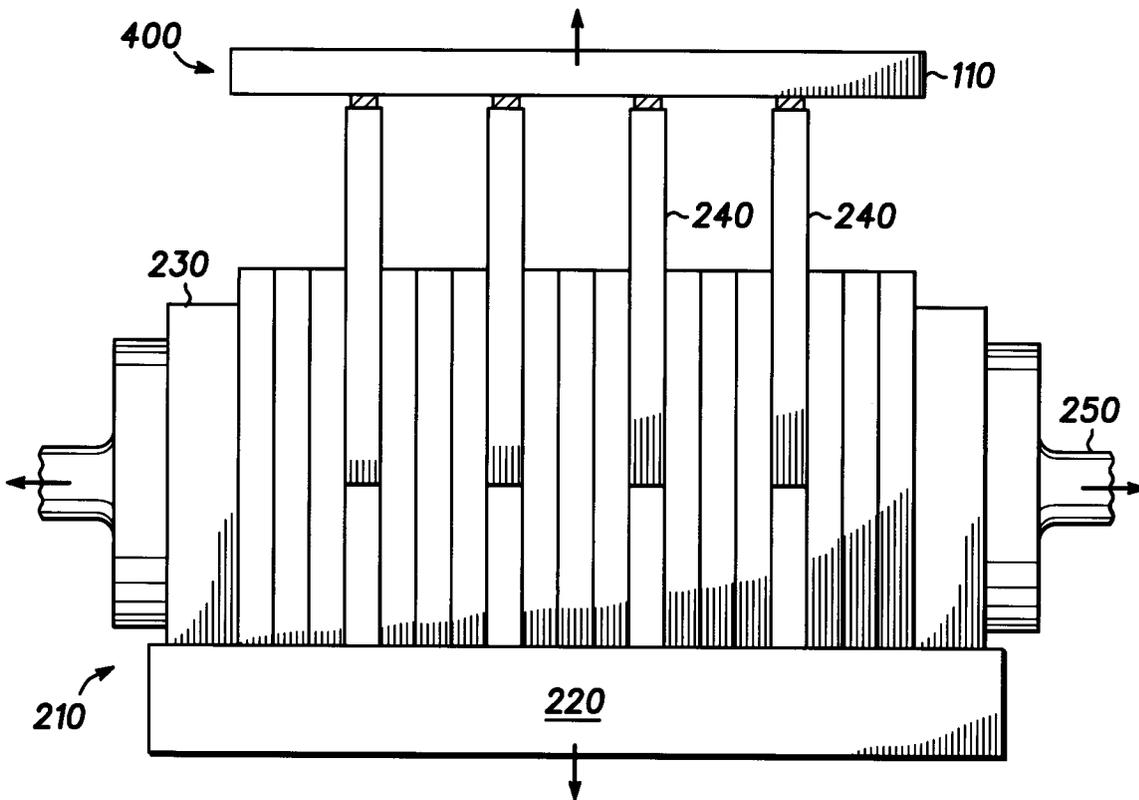


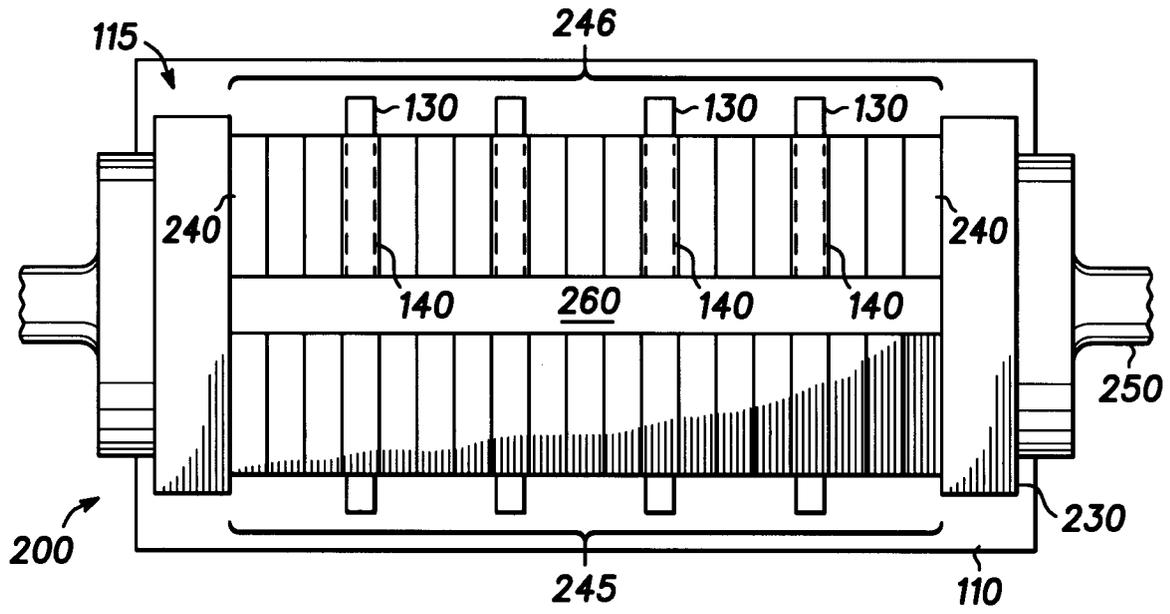
FIG. 4



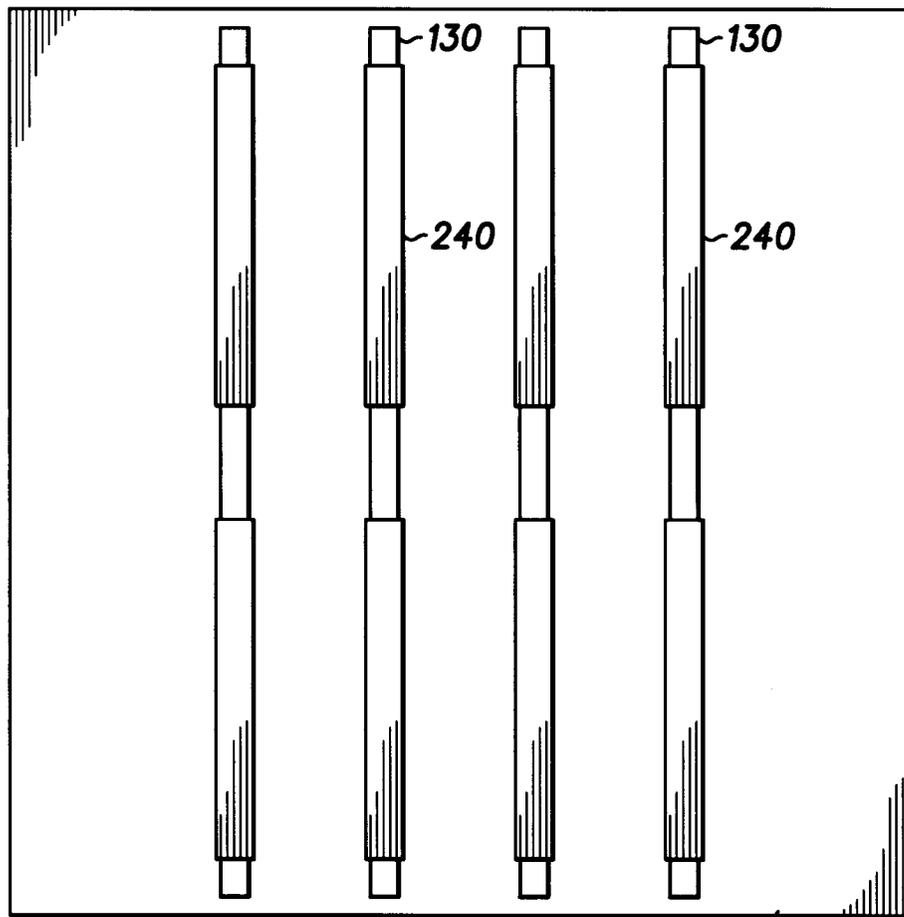
300 FIG. 5



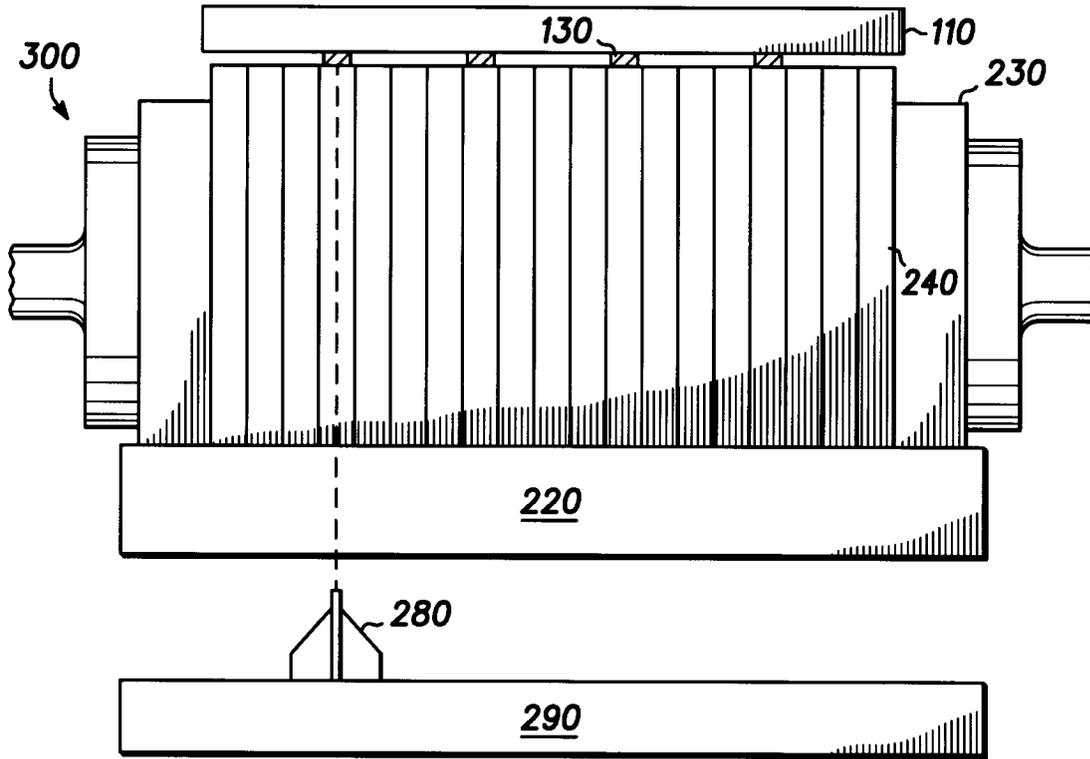
300 FIG. 6



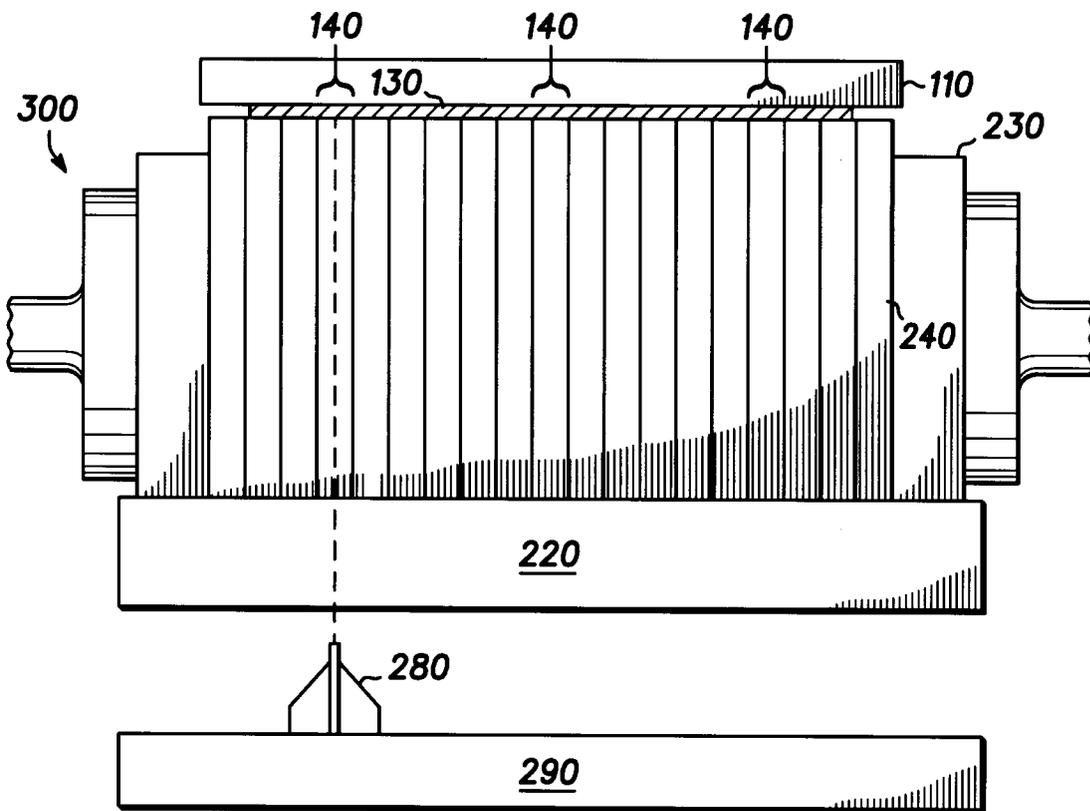
300 **FIG. 7**



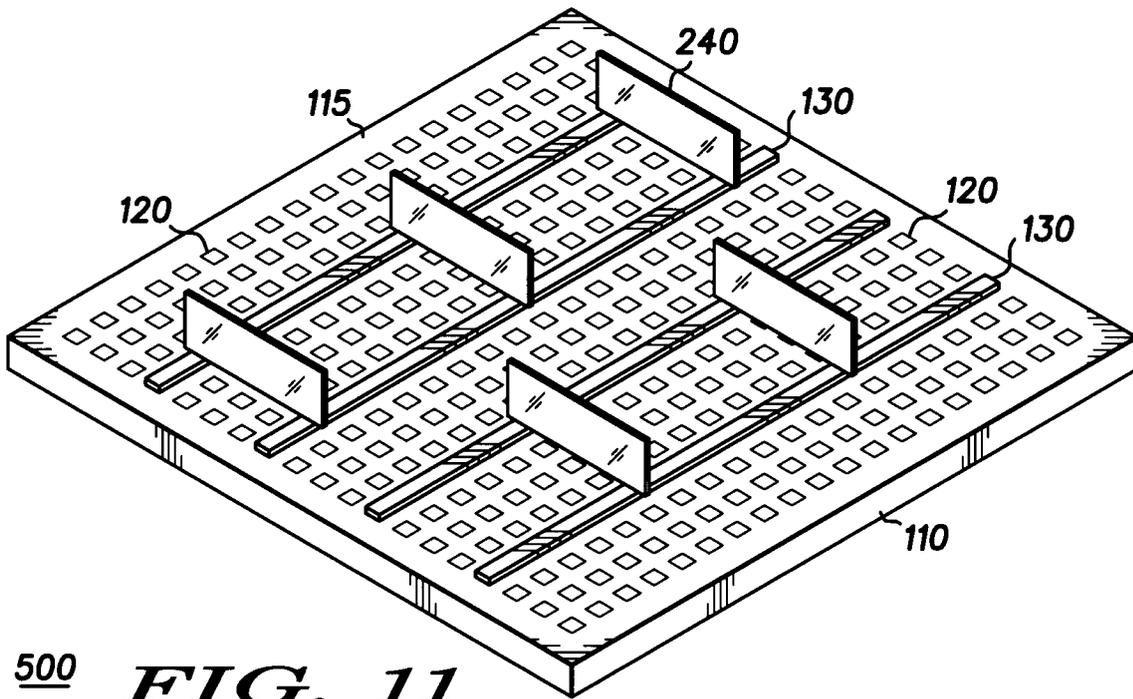
400 **FIG. 8**



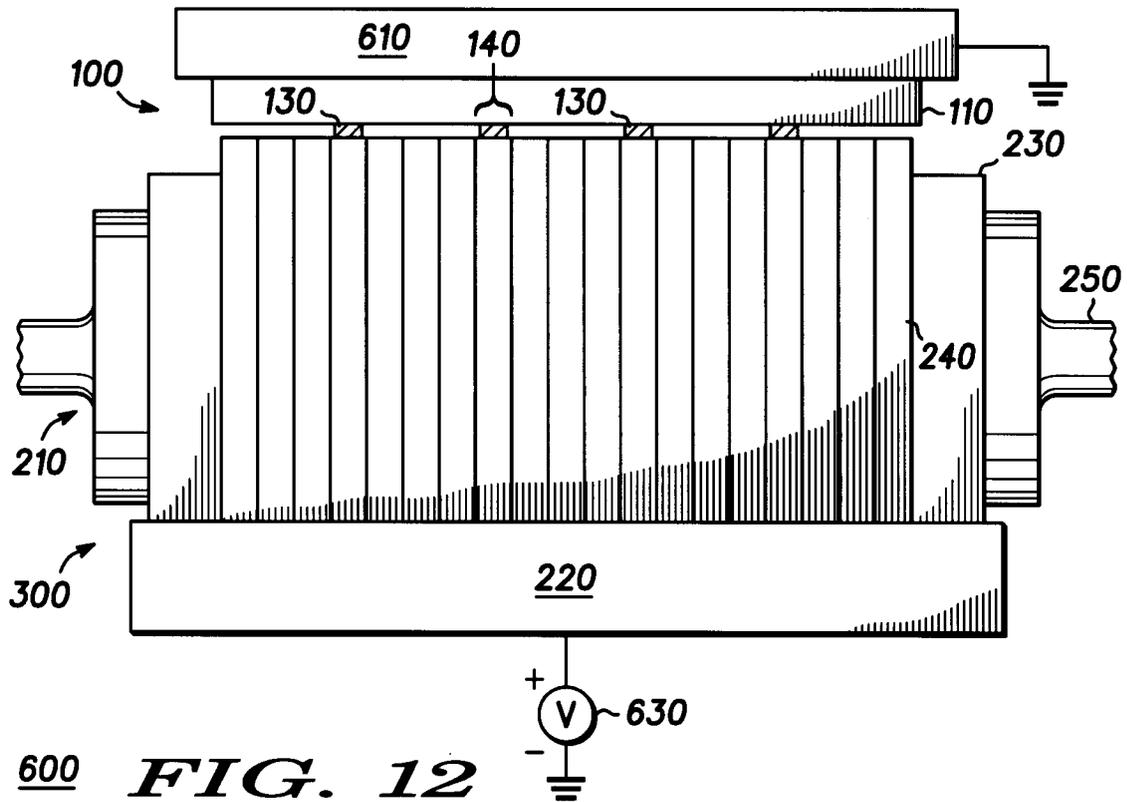
350 **FIG. 9**



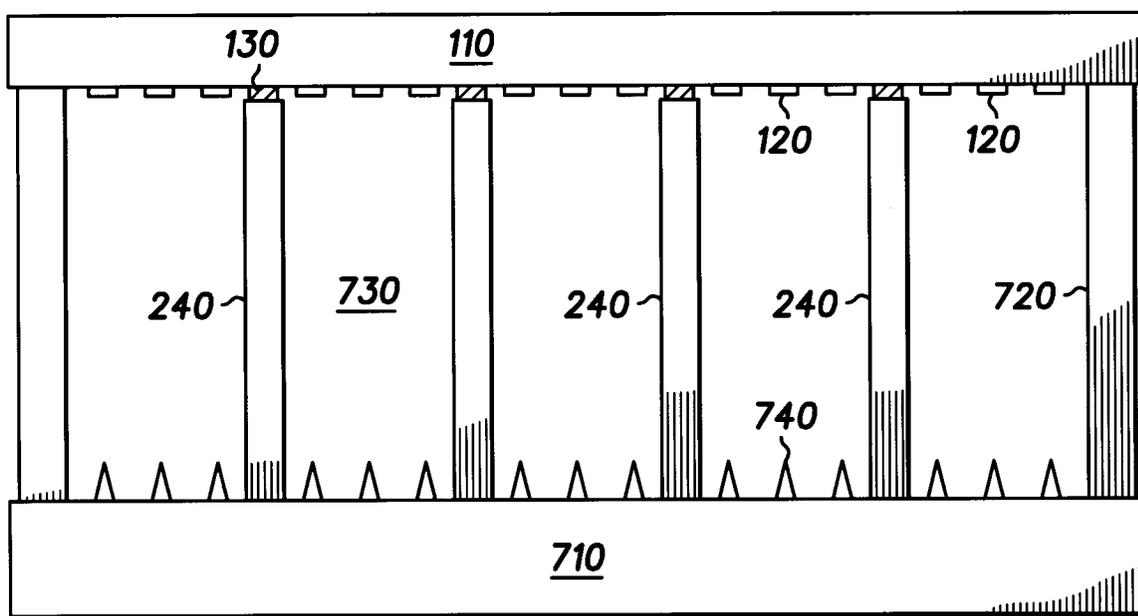
375 **FIG. 10**



500 **FIG. 11**



600 **FIG. 12**



700 **FIG. 13**