PATENT SPECIFICATION

(11) 1 568 822

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(21) Application No. 15327/79 (22) Filed 23 Sept. 1976
(62) Divided out of No. 1568821
(31) Convention Application No. 50/115193
(32) Filed 23 Sept. 1975
(31) Convention Application No. 50/115192
(32) Filed 23 Sept. 1975
(31) Convention Application No. 50/115190
(32) Filed 23 Sept. 1975
(31) Convention Application No. 50/115191
(32) Filed 23 Sept. 1975 in
(33) Japan (JP)
(44) Complete Specification published 4 June 1980
(51) INT CL³ G02F 1/133
(52) Index at acceptance
G2F 23E 24T 25F 25P2 CD

(19)

(54) METHOD OF MAKING LIQUID CRYSTAL DISPLAY CELLS

(71) We, SHARP KABUSHIKI KAISHA, a Japanese corporation, of 22-22 Nagaike-cho, Abenoku, Osaka 545, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to methods of making liquid crystal display cells. The invention also extends to cells made by such methods, and to electronic calculators including such cells.

In certain types of liquid crystal display cells it is necessary to align the molecules of the liquid crystal composition, and this is achieved by providing fine grooves on opposed surfaces between which the composition is sandwiched. It is desirable to simplify the method by which these grooves are obtained.

In accordance with the invention, there is provided a method of making liquid crystal display cells, each comprising a pair of glass layers and an intermediate layer of liquid crystal composition in contact with adjacent surfaces of the glass layers having fine grooves formed thereon, in which the fine grooves on a plurality of said glass layers are formed on a single sheet which is divided to form said plurality of glass layers.

Arrangements embodying the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a plan view of an electronic calculator having a liquid crystal display cell formed by a method of the present invention;

Figure 2 is a cross-sectional view taken along the line A—A′ of Figure 1;

Figure 3 is an exploded perspective view showing the internal construction of the calculator of Figure 1;

Figure 4 is an explanatory diagram showing the twisted nematic phase of the liquid crystal display employed in the calculator of Figure 1;

Figures 5(A), 5(B), 5(C) and 5(D) are diagrams showing steps during liquid crystal rubbing procedure;

Figures 6(A), 6(B) and 6(C) are explanatory diagrams showing rubbing directions during different rubbing procedures;

Figures 6(D) and 6(E) are detailed explanatory diagrams of Figure 6(B);

Figures 7(A), 7(B), 7(C) and 7(D) are perspective views of the liquid crystal display during fabrication steps;

Figures 8(A) and 8(B) are plan and cross-sectional side views of the liquid crystal display after being fabricated;

Figures 9(A) and 9(B) are explanatory diagrams showing the relative positions of polarizing filters employed with the liquid crystal display wherein Figure 9(A) shows the prior art arrangement and Figure 9(B) shows the filter arrangement in the present embodiment;

Figures 10(A) and 10(B) are cross-sectional views showing examples of installation of the polarizing filters;

Figure 11 is an exploded perspective view of the liquid crystal display cell formed by the method of the present invention;

Figure 12 is an explanatory diagram of an example of the installation of the data processor LSI chip employed in the calculator of Figure 1;

Figure 13 is an exploded perspective view of integral key actuators and a flexible printed circuit film;

Figures 14(A), 14(B) and 14(C) are cross-sectional views showing fabrication steps for the flexible printed circuit film;

Figures 15(A), 15(B) and 15(C) are expanded views showing various shapes of the flexible printed circuit film;

Figures 16(A), 16(B) and 16(C) are schematic diagrams showing some implementations of reflectors on the printed circuit flexible film;

Figure 17 is an enlarged cross-sectional view of part of the keyboard employed in the calculator of Figure 1;

Figures 18(A) and 18(B) are explanatory diagrams of the spring plate provided with the keyboard;

Figures 19(A) and 19(B) are explanatory diagrams showing fabrication steps for sealing the keyboard portion;

Figures 20(A), 20(B) and 20(C) are examples of sealing means for the keyboard portion wherein Figures 20(A) and 20(B) are plan views of the flexible film and Figure 20(C) is a cross-sectional view of the sealed type keyboard portion;

Figures 21(A) and 21(B) are explanatory diagrams of the folded printed circuit flexible film; and

Figures 22(A) and 22(B) are explanatory diagrams of modifications in the power supply unit employed in the calculator of Figure 1.

Referring now to Figure 1, there is illustrated a plan view of an electronic hand held calculator which essentially comprises integral key actuators of a keyboard unit 1, a display 2 disposed adjacent and in the longitudinal direction of the keyboard unit 1, a data processor circuit unit 3 provided adjacent one end of the display 2 and in the direction of length of the display 2 and a power supply unit 4 provided adjacent both the keyboard unit 1 and the data processor unit 3.

Figure 2 is a cross-sectional view taken along the line A—A′ of Figure 1 wherein the key actuators of the keyboard unit 1 and the display 2 are located on a printed circuit flexible film 5 carrying electrical connector leaves and then housed within an upper cabinet 6 and a lower cabinet 7. Figure 3 is an exploded perspective view of the internal arrangement of these constitutional components which will be respectively discussed in the following detailed description.

Display

The display is implemented with a liquid crystal cell and more particularly a field effect mode liquid crystal cell. This liquid crystal cell 21 comprises a pair of glass layers or sheets 22, 23 holding the field effect mode liquid crystal one of which (22, for example) is provided with an extension in the direction of length of the liquid crystal display, that is, the extension is located with respect to the display cell, in a direction which is orthogonal relative to that of the keyboard unit 1 as shown in Figure 3. A liquid crystal cell 21 of this type is preferable from the viewpoint of simplified construction. In other words, a liquid crystal cell 21 with such an arrangement fulfills the conditions that it be suited for automated manufacture in the case of mass-production purposes and multiple processing even in the case of manual assembly.

The liquid crystal cell 21 illustrated in Figure 4 is formed into a twisted nematic phase cell by being passed through horizontal orientation processing (rubbing) which is carried out on the opposed surfaces 22A, 23A of the glass sheets for the purposes of obtaining a twisted alignment of the liquid crystal molecules. This is a procedure for providing the liquid crystal molecules LC with orientation and therefore improving the viewing angle characteristics of the liquid crystal cell 21. The rubbing directions for the glass sheet surfaces 22A, 23A are right-angled as denoted by the arrows A, B and as a consequence the liquid crystal molecules LC between the rubbed glass sheets 22, 23 have a step-by-step twisted relationship therebetween. As suggested in Figures 5(A) and 5(B), the horizontal orientation processing (rubbing) can be accomplished by sliding a cloth C on the opposed surfaces 22A, 23A of the glass sheets with rotation of the cloth C. Alternatively, a film of SiO_2 or the like with oriented fine grooves can be formed on the surfaces 22A, 23A of the glass sheets by an oblique vacuum deposition technique to thereby assure the desired molecular alignment. Figure 5(C) and Figure 5(D) depict the aspects of the processed glass surfaces 22A, 23A in the plan view and the cross-sectional view, respectively. More particularly, grooves 22B (23B) are provided with the desired orientation and a saw-tooth shape in the rubbing direction. Thus, the liquid crystal molecules LC are aligned in agreement with the saw-tooth surface of the grooves.

Since the liquid crystal molecules will be oriented along the saw-tooth surfaces of the opposed glass sheets when applying an electric field, the orientation behaviour becomes stable to thereby assure improved viewing angle characteristics.

To simplify the formation of the grooves, each sheet 22, 23 of a plurality of cells 21 is formed by dividing up a composite sheet after the latter has had the fine grooves 22B, 23B formed thereon; a structure comprising a pair of such composite sheets and an intermediate layer of liquid crystal composition can be formed so that dividing the sheets forms a plurality of cells.

Figures 6(A), 6(B) and 6(C) are plan views showing a variety of combinations of composite glass sheets 22C, 23C and the rubbing directions in the fabrication of the liquid crystal cells. In Figure 6(A), the direction of length of the glass sheets 22C, 23C is in agreement with that of the liquid crystal cells 21. One of the glass sheets 22C is provided with an extended portion, to provide each cell with an extension 22D for display connections located in a direction at right angles to the longitudinal direction of the glass sheets. The respective cells 21 are separated by the lines *a*.

Figure 6(B) depicts another example wherein the liquid crystal cells 21 are formed in a parallel relationship from glass sheets 22C, 23C of relatively broader width in such a way that the longitudinal direction of the liquid crystal cells is in agreement with that of the glass sheets 22C, 23C as in the above example. Similarly, the regions 22D for display connections are disposed orthogonally with respect to this direction. The cells are separated by the lines *a* and *b*.

The third and last example in Figure 6 (C) resembles the second example of Figure 6(B) except that at least one of the glass sheets 23C is divided into two segments 23C′, and 23C″. The reference 21A represents a liquid crystal insertion aperture.

In these drawings, the arrow defined by the solid line shows the rubbing direction of the one glass sheet 22C whereas the arrow defined by the broken line shows the rubbing direction of the other glass sheet 23C. As noted earlier, the rubbing directions are right-angled to each other.

Nevertheless, there are still various problems in the above discussed examples of Figures 6(A), 6(B) and 6(C).

When manufacturing the liquid crystal cells 21 of Figure 6(A), substantially lengthy glass sheets 22C, 23C are required. This will create difficulties in manufacturing the liquid crystal cells in view of limitations on size of production facilities, for example, printers and also provide distortion problems due to "arched" glass sheets.

In the case of the liquid crystal cells 21 illustrated in Figure 6(B) there is a requirement that each of the glass sheets 22C, 23C be rubbed in different directions. Figure 6(D) is a perspective view of Figure 6(B) and Figure 6(E) illustrates the rubbing directions of the glass sheets 22C, 23C. To this end, while one of the glass sheets, for example, 22C is being rubbed in a specific direction, a protecting mask should be positioned against the adjacent surface to be rubbed in the opposite direction. Failure to do so will result in that the rubbing is effected in opposed directions on the same glass surface.

In the case of Figure 6(B), the rubbing procedure will be troublesome and cutting of the glass sheets must be effected in different directions.

In the case of the liquid crystal cells 21 of Figure 6(C), while the rubbing directions of the glass sheets 22C, 23C are in agreement with each other to thereby overcome difficulties in the rubbing procedure to a certain extent, the liquid crystal composition filling procedure will be troublesome because of interspersion of the liquid crystal filling apertures. That is, when the liquid crystal composition is to be inserted into the respective liquid crystal cells, the composition should be injected by means of an injector or the whole of the glass sheets 22C, 23C′, 23C″ should be dipped in a liquid crystal reservoir such that the respective cells would be filled with the liquid crystal composition via the apertures 21A through the utilization of the capillary effect. In the former method injection of the liquid crystal composition is repeatedly required. In the latter method unwanted liquid crystal composition on the entire surfaces of the glass sheets should be cleaned away after filling up with the liquid crystal composition. These methods, therefore, are not deemed favorable in view of the foregoing.

One approach shown in Figures 7(A) through 7(D) avoids the above discussed disadvantages. The longitudinal directions of the respective liquid crystal cells 21 are positioned at right angles to the direction of the lengths of the glass sheets 22C, 23C. See Figures 7(A) and 7(B). A plurality of liquid crystal cells 21 disposed along the direction of length of the glass sheets 22C, 23C is furnished by division along the lines *a*. One of the glass sheet pair 22C provides the extensions 22D for display connection. See Figure 7(C). The insertion apertures 21A are formed at positions opposed to the display connection regions 22D.

The liquid crystal cell fabrication method suggested with respect to Figures 7(A) through 7(D) has a combination of advantageous features as set forth below.

(1) Since the direction of width of the respective liquid crystal cells is aligned with the longitudinal direction of the composite glass sheets, a multiplicity of the liquid crystal cells can be furnished along the longitudinal direction of the glass sheets and the "arched" glass problem can be solved.

(2) As illustrated in Figure 7(D), the rubbing procedure for the two glass sheets

22C, 23C is effected in the same direction to thereby overcome the difficulties encountered with respect to Figure 6(B).

(3) Only the two glass sheets 22C, 23C are employed such that the glass laminating procedure is facilitated and also, the glass cutting procedure is simplified as cutting is along only one line *a* for each cell and in only one direction.

(4) Since the liquid crystal composition insertion apertures 21A are all located at one side of the structure formed by the glass sheets 22C, 23C, all that is necessary to complete the filling up of the liquid crystal composition is to dip that side of the structure into the liquid crystal reservoir. This overcomes the problem experienced in the case of Figure 6(C).

(5) The advantages set forth in the above paragraphs (1) through (4) make the liquid crystal cells suitable for mass-production purposes. In addition, it permits a multiplicity of the liquid crystal cells to be furnished at the same time.

As will be obvious from the plan view of Figure 8(A), the liquid crystal cell 21 as set forth above has eight digit display positions disposed along its length and an extension 24 for display connection (corresponds to 22D in Figure 7). Electrical connections for the liquid crystal cell 21 can therefore be provided on the extension 24. Figure 8(B) illustrates a cross-sectional side view wherein a pair of polarizing filters 25, 26 is provided, one above and one below the liquid crystal cell 21, and a reflector plate 27 is disposed below the lower polarizing filter 26.

The polarizing filters 25, 26 are essential to the field effect mode of liquid crystal and can be disposed in intimate contact with the surfaces of the liquid crystal cell 21 in accordance with known manners, such as pressure adhering.

However, in the event that the contact status between the polarizing filters 25, 26 and the liquid crystal cell 21 is partially different and either of the filters 25, 26 is curved, that curved portion will come into contact with the plane surface of the liquid crystal cell 21 to thereby develop a homocentric circle and thus Newtons rings by means of interference of light.

Figure 9(A) shows an example which will create the possibility of the Newton rings occurring. When the polarizing filters 25, 26 are both curved relative to the plane surfaces of the glass sheets 22, 23 of the liquid crystal cell 21, each filter may come into contact with one of the surfaces. Also, there is a difference in light path length between light L_1 reflected from the lower surface of the polarizing filter 25 and light L_2 reflected from the upper surface of the glass sheet 22. If such difference in light path length closely approximates the wavelength of light, then the Newtons rings will appear. The same is applicable to the relationship between reflected light L_3 and reflected light L_4.

The arrangement shown in Figure 9(B) is intended to prevent the above stated phenomenon from being developed. The pair of polarizing filters 25, 26 is spaced from the glass sheets 22, 23 by a distance considerably greater than the wavelength of light. With such an arrangement, the difference in light path length between the reflected light L_1 from the polarizing filter 25 and the reflected light L_2 from the glass sheet 22 becomes greater than the wavelength of light to thereby preclude the formation of the Newtons rings. Likewise, the Newtons rings will not appear because of the reflected light L_3 and L_4.

Figure 10 suggests some installation assemblies for the polarizing filters 25, 26. In Figure 10(A), the polarizing filters 25, 26 are respectively installed by for example adhering with the intervention of spacers 28, 29 between the glass sheets 22, 23 of the liquid crystal cell 21 and the polarizing filters 25, 26. Figure 10(B) shows another example wherein the spacers 28, 29 are integrally united with the upper and lower cabinets 6, 7. The spacers 28, 29 function to keep the distance between the glass sheets 22, 23 and the polarizing filters 25, 26 sufficiently greater than the wavelength of light.

In Figures 9 and 10, 27 designates the reflector plate and LC designates the liquid crystal.

Data processing unit

The data processing unit is implemented with an MOS/LSI semiconductor chip, as well known in the art of calculators. The data processing unit chip may be installed by effective utilization of the extension 24 of the liquid crystal cell 21.

Figure 11 is an exploded perspective view illustrating the liquid crystal cell 21 and an installation assembly for the LSI chip 31. The extension 24 of the one glass sheet 22 of the liquid crystal cell 21 is previously provided at its rear surface with a desired printed circuit array to establish terminals 33 available for the installation of the LSI chip. Solder welding is effected on these terminals 33. The LSI chip 31 is mounted in such a way that its terminals confront the corresponding terminals 33. The terminals of the LSI chip 31 are tightly connected with the counterparts 33 of the glass sheet 22 in accordance with solder welding technique. Accordingly, the LSI chip 31 is mounted on the glass sheet 22 and the extension 24 of the glass sheet 22 serves as a physical support and simultaneously electrical connections are provided between the LSI chip 31 and the liquid crystal display cell 21. It will be noted that the connection terminals 34 are formed at the end portion of the extension 24.

The LSI chip 31 is covered with a cap 32 for protecting purposes. The protecting cap 32 is preferably made of glass. The employment of the glass cap 32 is to simplify attaching procedure and ensure tight attachment. In other words, distortions and hence cracks of the glass sheets will not be caused during adhering procedure because the cap 32 (glass) has substantially the same coefficient of expansion as the extension 24 of glass material. Moreover, since the glass cap 32 is transparent, photobonding methods may be used wherein photosetting adhesive is employed and light exposure is applied thereto. Especially, attachment of the glass cap 32 through the photobonding methods needs no step of installing the glass cap 32 immediately after coating of the adhesive since the progress of vulcanization of the adhesive is controllable under light exposure. This implies that the adhesive coating step need not be immediately followed by the cap attaching step, which results in simplification in the LSI chip installation procedure.

Figure 12 illustrates an example of installation of the glass cap 32 which uses the photobonding technique. The periphery of the LSI chip 31 on the glass sheet 24 (extension) is coated with the photosetting adhesive 35 and then the LSI chip 31 is covered with the dish-like glass cap 32 in such a way that the periphery of the cap 32 is located on the adhesive 35. Subsequent to this, light (or ultraviolet rays) is applied to vulcanize the adhesive 35.

In Figure 11, 36, 37 are leaf spring contact members secured on the extension 24 which will be discussed in detail below.

Printed circuit flexible film

The board 5 is a printed circuit flexible film made, for example of polyester, which carries electrical leaf conductors, some serving as key contacts in the keyboard unit and the remainder serving as interconnections between the respective constitutional components.

Figure 13 is a perspective view wherein the key actuators and the board 5 shown in Figures 2 and 3 are exploded. The flexible film 5 has on one of its major surfaces a first set of key contacts 51 and a second set of key contacts 52 together with conductors 54 leading to the key contacts 51, 52 and a terminal region 55 where the leaf conductors 54 are concentrated. The first and second sets of the key contacts are held in opposed relationship. That is to say, the flexible film 5 is folded about a region 56 such that the first set of key contacts 51 confronts the second set 52. When the flexible film 5 is folded, a spacer 57 made of elastic insulator material is intervened therebetween. Through-holes 57A formed in the spacer 57 are between the key contacts 51, 52. Therefore, when a specific contact area of the flexible film 5 is manually depressed, the corresponding pair of contacts is closed. If the depression is released, the contacts open.

More particularly, when a specific key contact is depressed, the upper contact will come into contact with the lower contact after passing through the through-hole 57A to establish a closed circuit due to the flexibility of the film 5. If the depression is released, the upper contact will be separated from the lower contact by virtue of the stability of the flexible film 5 and the intervention of the spacer 57.

The terminal region 55 where the leaf connectors 54 are gathered together is located at an extension 53 of the flexible film 5. This extension of the flexible film 5 corresponds to the extension 24 of the liquid crystal cell 21. Accordingly, electrical connections between the printed circuit flexible film 5 and the liquid crystal cell 21 are provided via these extensions 53, 24.

As shown in Figure 3, to achieve electrical connections between the printed circuit flexible film 5 and the liquid crystal cell 21, the tip portion of the extension 53 of the flexible film 5, that is, the terminal region 55 is curved to come into contact with the terminals 34 formed at the extension 24 of the liquid crystal cell 21 through the utilization of the flexibility of the printed circuit film 5.

The electrical connections between the terminals 55, 34 of the extensions 53, 24 are maintained in the following manner. A pressure member 71 is provided which is integrally united with the lower cabinet 7 and received below the curved terminal region 55 when the upper cabinet 6 is fitted into the lower cabinet 7. An elastic member 72 such as rubber also is provided above the pressure member 71. Both the terminals 53, 34 are held in intimate contact with each other by upwardly directed pressure exerted by the member 71. In this way, the terminals 55, 34 are sandwiched in electrically connected relationship between the upper cabinet 6 and the pressure member 71. The details of the integral key actuators will be discussed later.

The following sets forth the fabrication of the printed circuit flexible film 5 referred to above. Figure 14 shows a sequence of the fabrication steps.

(1) A leaf of aluminum Al is disposed on the entire area of an electrical insulator film F such as polyester by well known methods,

for example adhering or evaporation. cf. Figure 14(A).

(2) For the key contacts 51, 52, the connectors 54 and the terminals 55 leaf conductors are formed in a desired pattern by printing of carbon paste CP. cf. Figure 14(B).

(3) The insulator film F is dipped into etching liquid such as sodium hydroxide for etching purposes. cf. Figure 14(C).

During the etching step the aluminum leaf Al is etched while the remaining portions printed or coated with the carbon paste CP are left on the film. Therefore, the resulting flexible film 5 contains three layers of the insulator film F, the aluminum leaf Al and the carbon paste CP.

The aluminum leaf conductors are advantageous as they are stronger and more inexpensive than other metal materials such as copper, taking into account the facts that the flexible film 5 is folded and the fine conductors 54 also are folded.

Also, the coating of carbon paste CP consists of a mixture of carbon and resin such as epoxy resin to thereby exhibit strong adhesion. For this reason, when the film 5 is folded, the aluminum leaf conductors Al are reinforced by the carbon paste coating CP to prohibit breaking of the leaf conductors. The carbon paste CP prevents oxidation of aluminum and permits cost reduction as compared with gold plating or silver plating. Although the conductivity of the carbon paste is poor as compared with gold or silver, this never provides an obstacle to operation because a base of aluminum is employed. When using a MOS-FET circuit, voltage drop can be ignored to a certain extent. The flexible film furnished as described above is most suitable even when it is folded in two as indicated by Figure 13.

Figures 15(A), 15(B) and 15(C) show a variety of shapes of the flexible film 5. Figure 15(A) is a plan view of the flexible film as shown in Figure 13. Figure 15(B) is a plan view of an elongate version of the flexible film wherein the key contacts 51, 52 are formed in the direction of length of the film with intervention of the folding region 56. Figure 15(C) is a plan view of the flexible film of which the construction resembles that of Figure 15(A) except a cutout is not provided adjacent the extension 53 and the key contacts 51.

Figure 16 shows modified examples of the flexible film 5 illustrated in Figure 13. In Figure 16(A) the aluminum leaf conductor Al is left at the portion of the flexible film 5 where the liquid crystal cell 21 is received, during the fabrication steps shown in Figure 14. That portion A1 can be employed as the reflector for the liquid crystal cell 21 due to the light reflecting properties thereof. This avoids the necessity for the provision of the reflector 27 as shown in Figures 2, 3 or Figure 10.

As an alternative, as shown in Figure 16(B), the flexible film 5 may be made of an insulator material of high transmission and provided with an extension above the second key contact region 52. The aluminum leaf Al and the carbon paste CP on that extension remain in the same manner as the contact regions 51, 52, the connectors 54, etc. to form the reflecting surface 58. When the flexible film 5 is folded about the portion 56, the aluminum leaf region Al will be exposed via the transparent insulator film. Therefore, this serves as the reflector plate for the liquid crystal cell 21.

The modified example shown in Figure 16(B) can be completed by the same fabrication steps as discussed with respect to Figure 14 and accordingly the reflecting surface of the aluminum leaf Al can be coated with the carbon paste CP. The reflecting surface 58 shown in Figure 16(C) constitutes a portion of a connector 54.

Integral key actuators

As shown in Figures 2 and 3, the key actuators of the keyboard unit 1 are mounted on the board 5; Figure 13 shows the construction of the unit. In Figure 13, the keyboard unit 1 comprises: a key actuator frame 12 carrying a plurality of movable key actuators 11 each of which corresponds to a pair of key contacts 51, 52 formed on the folded flexible film 5; a leaf spring 13 provided below the key actuator frame 12 for depressing the flexible film 5 when a specific key actuator 11 is pressed; and a holding frame 14 which holds the leaf spring 13.

As obvious from the cross-sectional view of one key switch assembly shown in Figure 17, all the respective key actuators 11 are connected to the key actuator frame 12 via hinges 15. The key actuators 11, the hinges 15 and the key actuator frame 12 are combined into a unit component. Each of the key actuators 11 protrudes in the upward direction through the corresponding through-hole formed in the upper cabinet 6. When the protruding key actuators are depressed, they will be movable about the hinges 15.

As shown in the enlarged view of Figure 18(A), the leaf spring 13 includes side wall regions 13A, rectangular regions 13B connected to the side wall regions and protrusion regions 13C which extend from the rectangular regions 13B in the same direction as the side wall regions 13A. These regions 13A, 13B, 13C are integrally formed by well known techniques such as press working and etching.

The respective rectangular regions 13B correspond to associated key actuators 11 and are such that the tip portions of the rectangular regions 13B are movable in the downward direction when their associated key actuators 11 are depressed. As shown in Figure 18(B), the protrusion regions 13C are turned downwardly at the junctions with the rectangular regions 13B and further provided with "U" shaped tip portions. In this instance, the "U" shaped tip portions of the protrusion regions 13C are oriented inwardly toward the rectangular regions 13B.

Reverting to Figure 13, the holding frame 14 has longitudinal and lateral beams 14A on which the junctions of the side wall regions 13A and the rectangular regions 13B in the leaf spring 13 are mounted. Within partitions defined by the longitudinal and lateral beams 14A there are provided hollow regions 14B. In addition, through-holes 14C are formed in positions to correspond to the respective protrusion regions 13C to thereby allow passage of only the corresponding protrusion regions.

Accordingly, in Figure 13, when the intersections of the side regions 13A and the rectangular regions 13B of the leaf spring 13 are mounted on the holding frame 14, the respective rectangular regions 13B of the leaf spring 13 are received within the hollow regions 14B of the holding frame 14 and the protrusion regions 13C are passed through the holes 14C at this time. The result is illustrated in Figure 17.

In Figure 17, the integrated key actuator 11 is disposed over the printed circuit flexible film 5 above an opposed pair of key contacts 51A, 52A. When the key actuator 11 is in the normal state, the protrusion region 13C of the leaf spring 13 is somewhat shifted from the position of the opposed key contacts 51A, 52A. Under the circumstances, the leaf spring 13 forces the key actuators in the upward direction.

When the key actuator 11 is manually depressed, the key actuator 11 turns downward about the hinge 15 causing downward rotation of the protrusion region 13C. At this time the protrusion region 13C moves toward the opposed contacts 51A, 52A on the flexible film 5 since the "U" shaped tip portion of the protrusion region 13C of the leaf spring 13 is positioned inwardly with respect to the junction with the rectangular region 13B.

The key actuator 11 is depressed downward until the rectangular region 13B of the leaf spring 13 is positioned at the bottom of the hollow region 14B of the holding frame 14. As a result, the protrusion region 13C of the leaf spring 13 is positioned above the opposed key contacts 51A, 52A to thereby place the latter into the closed state and in other words the ON state. If the depression of the key actuator 11 is released, then the key actuator 11 will be restored its original position shown in Figure 17 by means of the spring force of the leaf spring 13.

The assembly of the keyboard unit 1 is facilitated and simplified due to the combination of the key actuator frame 12, the leaf spring 13 and the holding frame 14, thereby accomplishing the fabrication of low profile keyboard units. As well, since the key actuators 11, the hinges 15 and the key actuator frame 12 are integrally formed, spacing within the keyboard unit 1 will be minimized.

The holding frame 14 serves as a stop for preventing excessive depression of the key actuators 11 and also functions for preventing the folded flexible film 5 from expanding outwardly due to its stability. Although within the construction of the keyboard unit 1 of this embodiment, the key actuator frame 12 is separate from the upper cabinet 6, the cabinet 6 may be adapted to serve also as the key actuator frame 12.

Sealed key switch

The opposed key contacts 51, 52 of the flexible film 5 shown in Figures 13 and 17 may be of the sealed type as another modified example.

While the flexible film 5 of Figure 13 is folded in two such that the key contacts 51, 52 are positioned in opposed relationship with intervention of the spacer 57, dust or moisture may invade the extremely small spacing between the opposed key contacts. This may cause inadvertent interconnection of the key contacts. To conquer these difficulties, keyboard unit can be of the sealed type. As suggested in Figure 19(A), the flexible film 5 is folded about the region 56 and the peripheral portions thereof are bonded together through the use of an adhesive 59, except for the folded region 56. In this case, the adhesive 59 has only to be applied to three peripheral edge portions, thereby facilitating the bonding procedure in the case of the sealed type keyboard unit.

Since the two opposed major regions of the flexible film 5 are spaced by a small amount, the distance between the key contacts 51, 52 will vary due to expansion or contraction of air within the sealed spacing to adversely influence the switching functions. In other words, it is needed to permit air to escape from the sealed keyboard unit when the key actuators are manually operated. Consequently, air escape apertures should be formed.

Nevertheless if air escape apertures are formed for this reason, it is possible that air within the sealed spacing is discharged via the escape apertures due to sudden variation in pressure when the key actuators are depressed, whereas outside air cannot be introduced promptly via the air escape apertures when the key actuators are released. In other words, although the key contacts can be quickly closed upon depression of the key actuators, they cannot be opened immediately after the key actuators are free from depression.

Some ways to solve these problems are shown in Figure 20. In Figure 20(A) air escape apertures 5A are formed adjacent the key contacts 52 which are positioned above the other contacts 51 when the flexible film 5 is folded. In the example shown in Figure 20(B) the air escape apertures 5A are formed intermediate adjacent key contacts 52.

Figure 20(C) is a cross-sectional view of another example of the sealed key switch assembly wherein the air escape aperture 5A is formed adjacent the key contact 52A of the upper region of the folded flexible film 5. The other key contact 51A is positioned below on the lower region of the flexible film 5 with intervention of the spacer 57. The leaf spring 13 is positioned above the flexible film 5.

With such an arrangement, when the key actuator is depressed, the leaf spring 13 forces the upper portion of the flexible film 5 in the downward direction and at this time air escapes from many apertures 5A and, subsequent to this, air is introduced promptly via many apertures 5A after the release of the depression of the key actuator. Rapid switching can thus be achieved. Dust invasion will be avoided because the apertures are extremely small.

Figure 21(A) illustrates an insulator rod 75 positioned about the folding region 56 of the flexible film 5, which is accessible in the case of the sealed type keyboard unit, thereby preventing breaking of the leaf conductors about the folding region 56. By intervention of the insulator rod 75, the folding region 56 of the flexible film 5 is gently curved around the insulator rod 75.

Figure 21(B) illustrates a modification of Figure 21(A) wherein the insulator rod 75 is formed integrally on the lower cabinet 7 to thereby omit the necessity for a separate insulator rod 75. Needless to say, the insulator rod 75 may also be used with the folded flexible film 5 shown in Figure 13.

Power supply

As clear from Figure 3, the power supply unit 4 of Figure 1 can comprise one or more power supply batteries 41 secured within a compartment 4A at the side of the keyboard unit 1, the compartment 4A being defined by the liquid crystal cell 21 and the keyboard unit 1. The illustrative example comprises two serially connected batteries 41, guide plates 42, 43 holding the batteries and leaf springs 36, 37.

The leaf springs 36, 37 are made of electrically conductive, elastic material and, as obvious from Figure 11, are secured on the extension 24 of the liquid crystal cell 21 for the purposes of establishing electrical connections between the batteries 41 and the data processor MOS/LSI chip 31. The leaf spring members 36, 37 are each provided at one end with "U" shaped holding regions 36A, 37A and at the other end with contact regions 36B, 37B to contact the batteries 41.

The leaf spring members 36, 37 are secured side-by-side and disposed at right angles to the direction of the extension 24 of the liquid crystal cell 21. Under these circumstances the holding regions 36A, 37A are secured under pressure on the extension 24, while the contact regions 36B, 37B are oriented toward the batteries 41.

Terminal regions 38, 39 are provided on the extension 24 of the glass sheet 22 where the holding regions 36A, 37A are secured, the terminal regions 38, 39 being electrically connected to the LSI chip 31. Accordingly, electrical connections to the LSI chip 31 are accomplished concurrently with installation of the leaf spring members 36, 37 onto the extension 24.

Refering to Figure 3, the first guide plate 42 is shown as having groove regions 42A, 42B where the contact regions 36B, 37B of the leaf spring members 36, 37 are received. The guide member 42 is secured on the lower cabinet 7 in such a way as to connect the contact regions 36B, 37B received within the groove regions 42A, 42B to respective electrode terminals of the batteries 41.

The second guide plate 43 which holds the other ends of the batteries 41, is secured on the lower cabinet 7 to confront the first guide plate 42. This plate 43 includes a contact region 43A, a groove 43B receiving the contact region 43A and a cutout region 43C adjacent the end of the first one of the batteries 41.

The contact region 43A is made of a spirally-shaped wire of electrically conducting and elastic nature, the spiral portion thereof being received within the groove 43B and held in electrical engagement with the electrode terminal of the other battery 41.

The contact region 43A serves also as a major component of a power switch. The end of the spirally-shaped portion extends to a position adjacent the cutout region 43C. That extension 43A′ is normally positioned away from the cutout region 43C. The extension 43A′ is a movable contact region that will be connected directly to the electrode terminal of the first battery 41 through the cutout region 43C in response to depression or movement toward the battery 41.

A sliding knob 44 which operates the movable contact region 43A', is slidably secured outwardly of the guide plate 43. When the sliding knob 44 is shifted in the direction shown by the arrow A, the movable contact region 43A' will be forced toward the battery 41 to render the power switch ON. If the sliding knob 44 is shifted, back, the depression of the movable contact region 43A' will be released. This results in that the contact region 43A' is separated from the electrode terminal of the battery 41 due to its elastic nature, to thereby render the power switch OFF. The contact region 43A' may be formed of leaf spring materials instead of the wire material used in this embodiment.

These components of the power supply unit 4 can be closely disposed to thereby attain compactness and small size of the power supply unit 4. In addition, because the leaf spring contacts 36, 37 are secured directly on the extension 24 of the liquid crystal cell 21 for the purposes of providing connections between the batteries 41 and the LSI chip 31, connection path lengths can be remarkably reduced to minimize voltage drop on the leaf connectors therebetween. The possibility of incomplete contact will be minimized due to the thus reduced points of connection. Since the connections between the batteries 41 and the LSI chip 31 also are provided on the extension 24 of the liquid crystal cell, all the connections, including those to the remaining components, can be focused on the extension 24. This affords may merits to the fabrication of calculators. Because the contact regions 43A' secured on the guide plate 43 serves also as the power switch, the number of necessary components is reduced with accompanying simplification in the power supply assembly procedure.

Figure 22 shows a modification in the battery power supply unit 4. In Figure 22(A), a region 45 holding the batteries 41 is an integral part of the flexible film 5 and connection contact regions 46, 47 for the batteries 41 are formed concurrently with the formation of the leaf conductors on the flexible film 5.

As shown in Figure 22(B), both end portions of the holding region 45 are curved in such a way that the contact regions 46, 47 confront the electrode terminals of the batteries 41. The curvature of the regions being maintained with the aid of a support member (not shown) formed in the lower cabinet 7. The batteries 41 are housed within the holding region 45. In this case, the battery holding region 45 can be formed concurrently with the fabrication of the flexible film 5, to thereby minimize the necessary number of parts and attain reduction in manufacture cost.

The electronic calculator described above is also described, and certain aspects thereof claimed, in our co-pending patent application No. 39565/76 Serial. No. 1,568,821.

WHAT WE CLAIM IS:—

1. A method of making liquid crystal display cells, each comprising a pair of glass layers and an intermediate layer of liquid crystal composition in contact with adjacent surfaces of the glass layers having fine grooves formed thereon, in which the fine grooves on a plurality of said glass layers are formed on a single sheet which is divided to form said plurality of glass layers.

2. A method as claimed in Claim 1, including the step of forming a composite liquid crystal display cell structure comprising a pair of said sheets and an intermediate layer of liquid crystal composition, wherein the sheets are divided by separating said structure into individual liquid crystal display cells.

3. A method as claimed in Claim 2, wherein liquid crystal injection holes are formed along an edge of one of said sheets.

4. A method as claimed in Claim 2 or Claim 3, wherein the structure is elongate, and is divided so as to form elongate cells extending transverse to the length of the structure.

5. A method as claimed in any one of Claims 2 to 4, wherein one of said sheets is wider than the other said sheet, so that each individual cell is provided with an extension formed by part of the wider sheet.

6. A method of making a multi-digit liquid crystal display cell, substantially as hereinbefore described with reference to Figures 4 and 5(A) to (D), with Figure 6(A), Figures 6(B), (D) and (E), Figure 6(C), or Figures 7(A) to 7(D) of the accompanying drawings.

7. A liquid crystal display cell formed by a method as claimed in any preceding claim.

8. A liquid crystal display unit comprising a cell as claimed in Claim 7 and a pair of polarizing filters each spaced from a respective side of said cell.

9. A unit as claimed in Claim 8, wherein each filter is spaced from the cell by a distance longer than the wavelength of light.

10. An electronic calculator having a liquid crystal display cell as claimed in Claim 7.

11. An electronic calculator as claimed in Claim 10, having a keyboard including a flexible substrate carrying electrical leaf conductors in a predetermined pattern, and a plurality of keys, situated over said substrate, depression of which causes

electrical connections to be made with contacts formed by said conductors, wherein the display cell overlies said substrate and is provided with a plurality of terminals extending from an end thereof in the direction of a length of the cell and disposed in contact with terminals formed by said conductors on said flexible substrate.

12. A calculator as claimed in Claim 11, wherein the cell has been formed by a method as claimed in Claim 5, and wherein the display cell terminals are provided on said extension.

13. A calculator as claimed in Claim 11, having a data processing LSI chip positioned on said extension.

R. G. C. JENKINS & CO.,
Chartered Patent Agents,
Chancery House,
53/64 Chancery Lane,
London, WC2A 1QU.
Agents for the Applicants.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1980
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

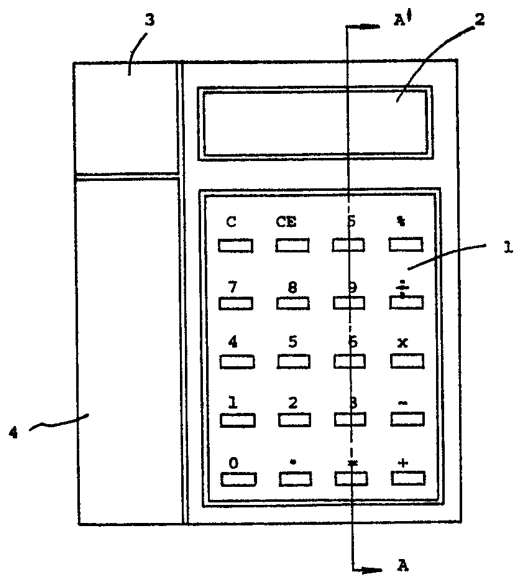


FIG 1

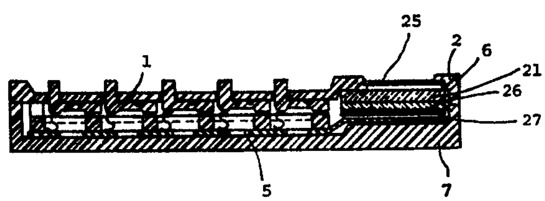
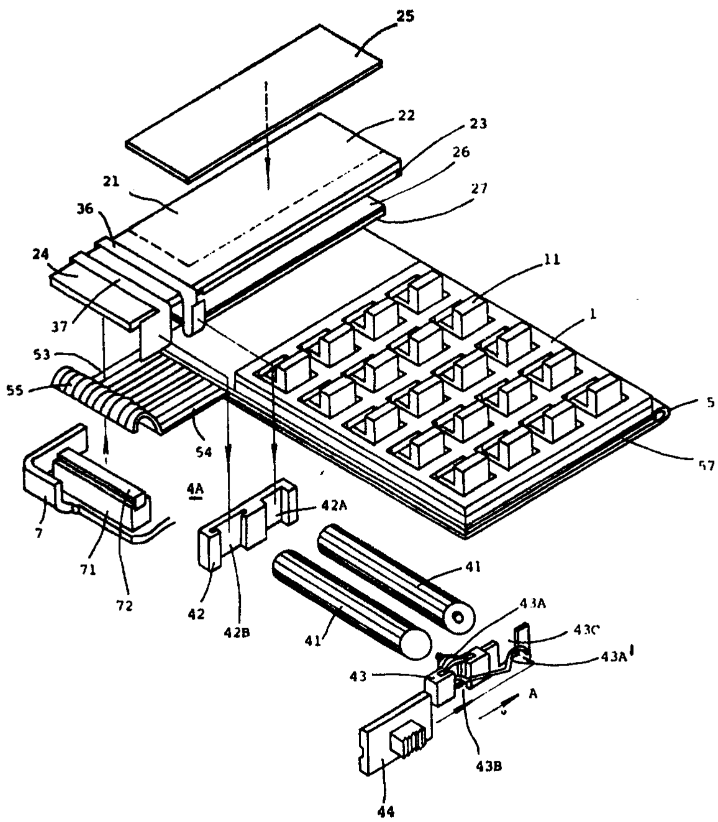


FIG 2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36
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24
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37
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5
54
57
4A
42A
7
71
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72
42
42B
43A
43C
41
43A'
43
A
43B
44

FIG 3

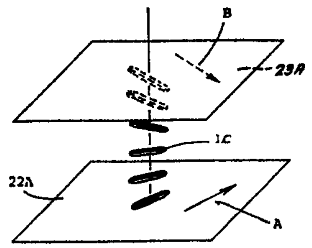


FIG 4

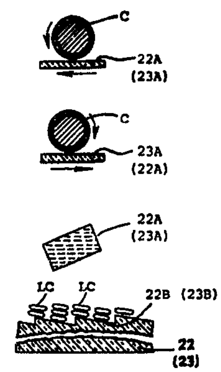


FIG 5(A)
FIG 5(B)
FIG 5(C)
FIG 5(D)

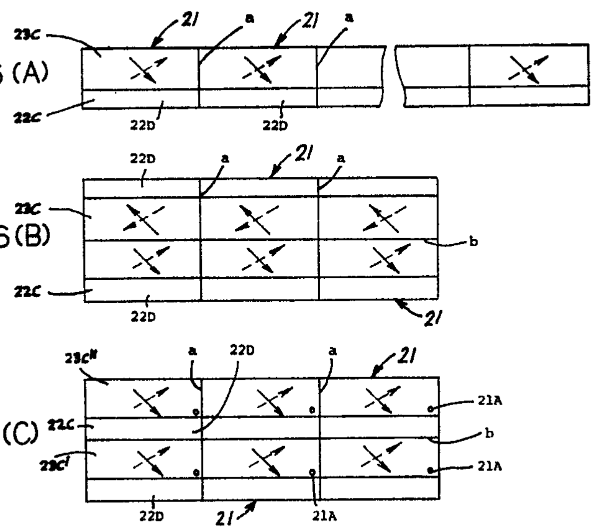


FIG 6(A)
FIG 6(B)
FIG 6(C)

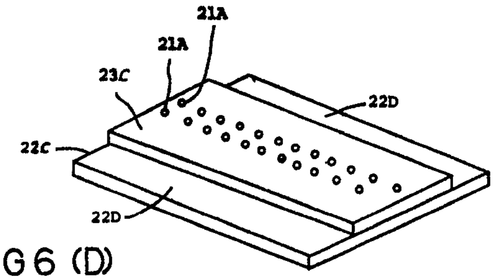


FIG 6 (D)

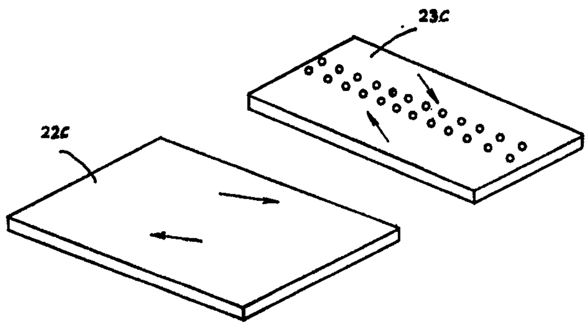


FIG 6 (E)

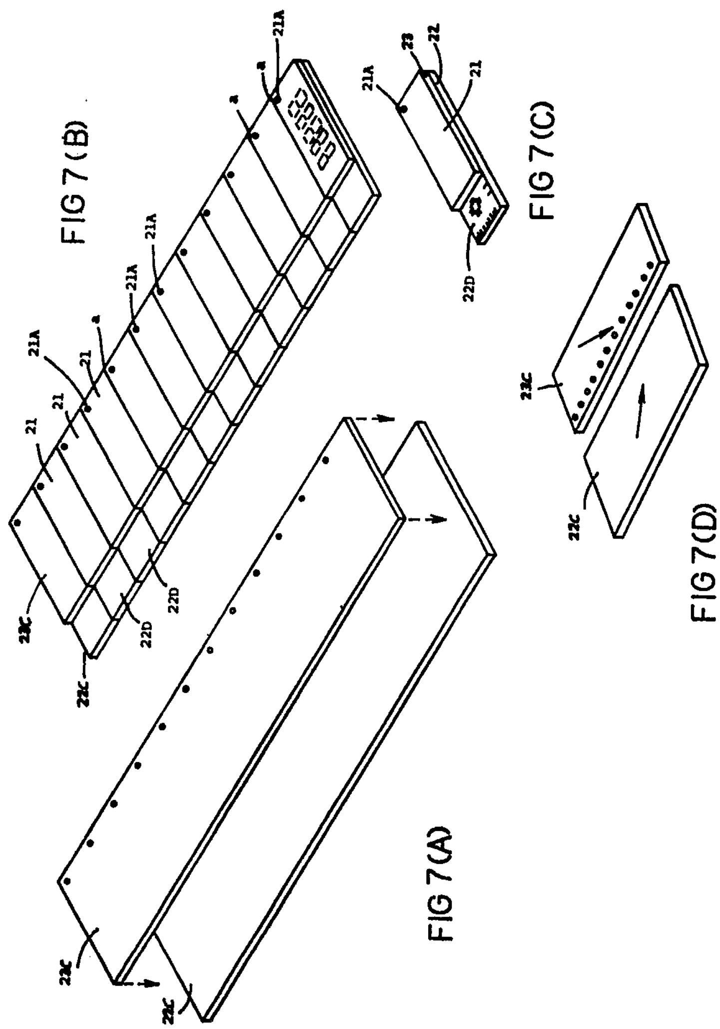


FIG 7(A)

FIG 7(B)

FIG 7(C)

FIG 7(D)

FIG 8 (A)

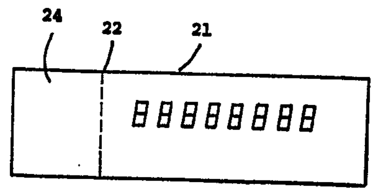
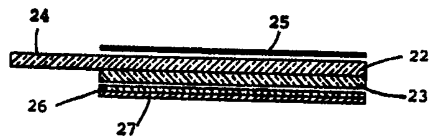


FIG 8 (B)



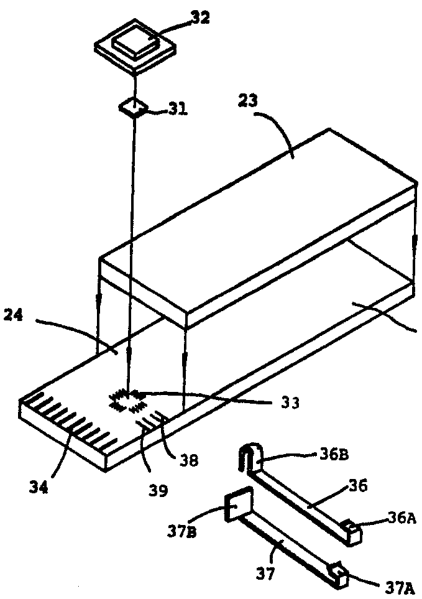


FIG 11

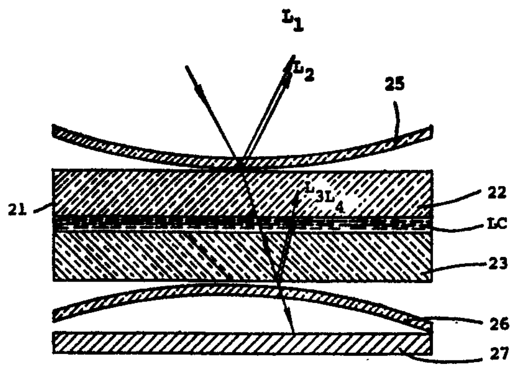


FIG 9 (A)

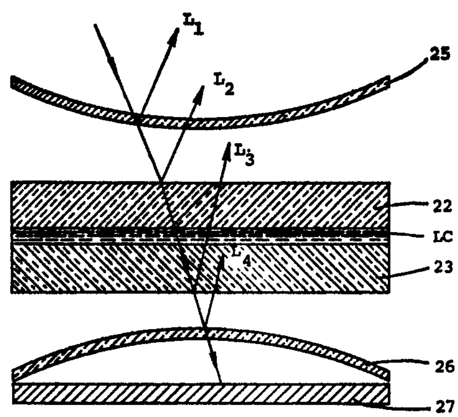


FIG 9 (B)

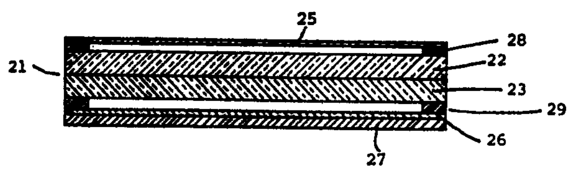


FIG 10(A)

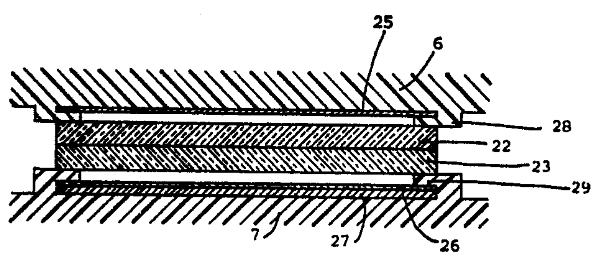


FIG 10 (B)

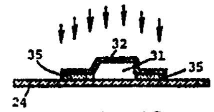

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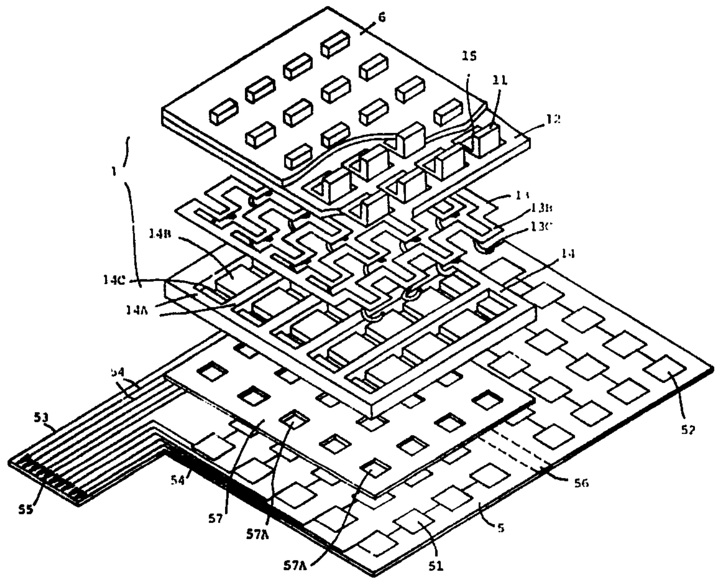
FIG 12


6
15
11
12
1
14B
14C
14A
13B
13C
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57A
57A
51
5
56
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FIG 13

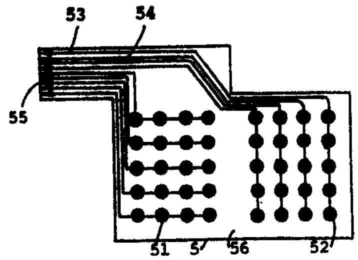

FIG 15 (A)

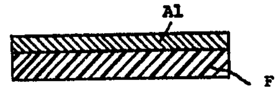

FIG 14 (A)

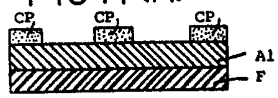

FIG 14 (B)

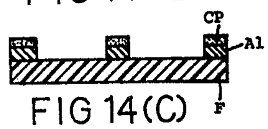

FIG 14 (C)

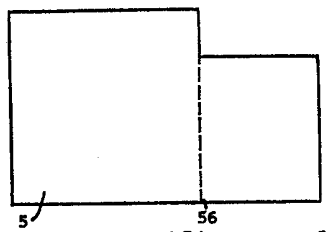

FIG 15 (C)

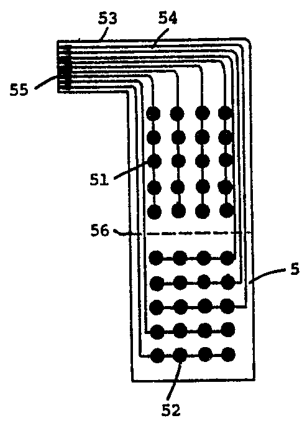

FIG 15 (B)

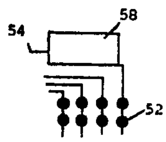

FIG 16 (C)

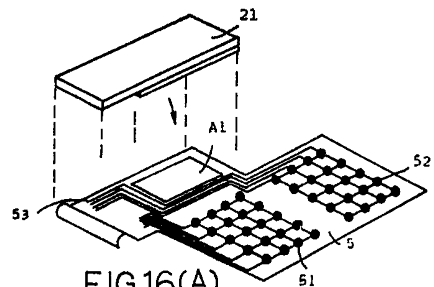

FIG 16(A)

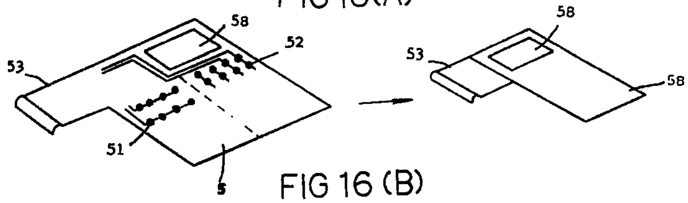

FIG 16 (B)

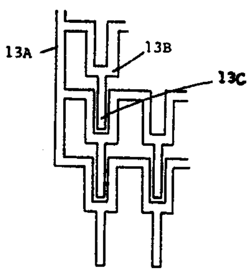

FIG 18 (A)

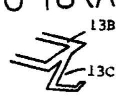

FIG 18(B)

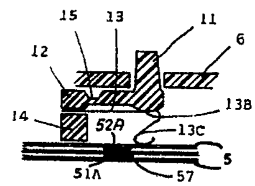

FIG 17

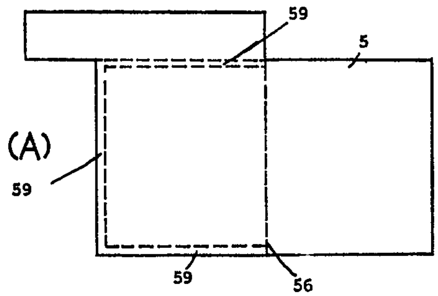

FIG 19(A)

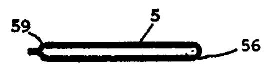

FIG 19(B)

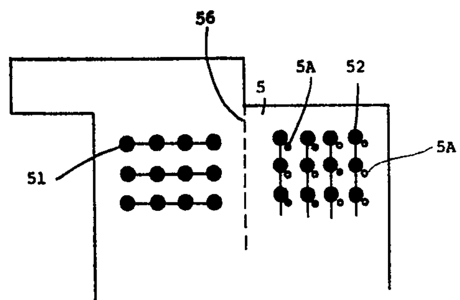

FIG 20(A)

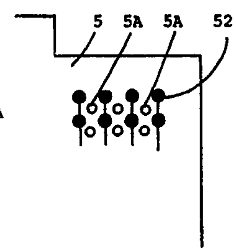

FIG 20(B)

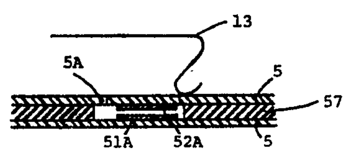

FIG 20(C)

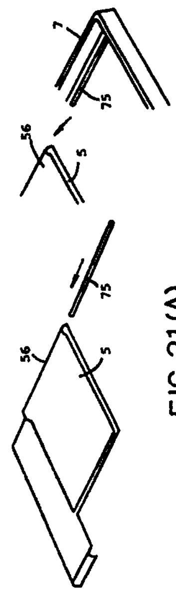

FIG 21 (A)

FIG 21 (B)

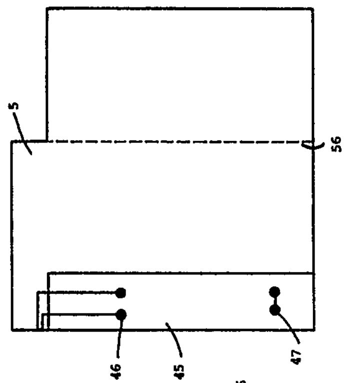

FIG 22 (A)

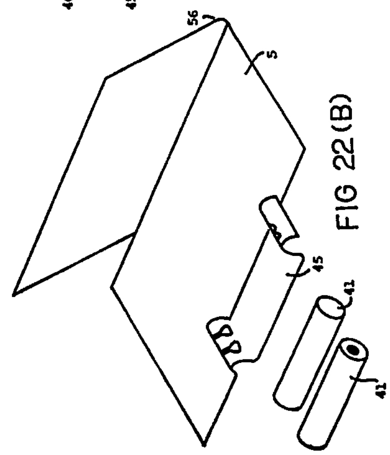

FIG 22 (B)