

The invention relates to a method for the manufacture of a nonlinear control element for a flat electrooptical display screen, in particular for a liquid crystal display screen.

The general field of the invention is that of large-area thin-film electronics. The application addressed by the present invention is the integrated control of each elementary point of a liquid crystal screen.

As is known, these screens generally possess a large number of square or rectangular elementary points or picture elements. These picture elements can be individually addressed. The definition of the screen is governed by the number of points capable of receiving a signal. Each point is controlled by application of an electrical field. For displaying visual information, matrix type displays have been proposed. In this case each picture element is defined by the intersection of two mutually perpendicular systems of conductors called lines and columns.

There is no need for the addressing of a picture element by means of control voltages applied to the corresponding line and column to be sustained if a time-division multiplexing technique is adopted enabling the state of the screen to be recurrently renewed. This technique is based on a persistence effect which may be physiological or available within the screen element. In the case of liquid crystal display devices, a picture element can be likened to a capacitor whose time constant is sufficient to sustain the charge between two successive transitory addressings.

The design of a matrix type control by line and column conductors to obtain a screen of high complexity (large number of lines) involves the provision in series with the picture element of a nonlinear resistance which is practically insulating below a voltage threshold and which becomes more and more conductive beyond that threshold.

Such a nonlinear element may be made of varistor material as described in French Patent Application No. 8116217 filed on 25th August 1981 in the Applicant's name, and published under No. 2512240.

At present, the demands of the industry in relation to display screens are concentrated on improved picture definition. In the case of matrix type screens, this means designing devices with a large number of address lines or columns. Their number may be as high as 512 or even 1024. There is a corresponding increase in the switching elements, and hence in the number of varistors. For series manufacture, it is necessary in particular to obtain good reproducibility and high stability for these components. It is also necessary - likewise with good reproducibility - to adapt the electrical capacity of the component to that of the associated cell. Materials currently used, such as conglomerates of zinc oxide powder, containing particles of bismuth oxide and manganese oxide or other similar material, do not entirely satisfy these requirements. The reproducibility and stability of the varistors depend on, among other things, the size of grain and the techniques used in production for passivating the grain boundaries. The stray capacity of the varistor, which is also associated with the grain boundaries, is difficult to control.

Other switching elements may be used. In any event, liquid crystal display screens generally have defects of consistency of contrast as between picture elements, due to dispersion in the characteristics of the switching elements which may be considerable, and which is difficult to eliminate over large areas. These defects may also, to a lesser extent, originate from the thickness of the liquid crystal film, and from its bonding layer.

With a view to remedying these drawbacks, there are known devices in which the nonlinear elements are transistors with thin films principally based on amorphous silicon or polycrystalline silicon. However, this type of technology presents some problems which have to be solved in order to obtain addressing of high quality:

- 1) better control of the characteristics which depend on the properties of two films (silicon and insulating material) and their interface;
- 2) a technology of self-alignment is necessary for improved reproducibility over a large area.

In other solutions the nonlinear elements are dipolar elements such as the structure based on two diodes in series and in opposition.

These diodes are semiconductive diodes all possessing the same operating point in the voltage-current characteristic. French Patent Application No. 8314542 filed on 13th September 1983 by the Applicant and published under No. 2551902 describes such devices, in particular in the form of Schottky diodes.

However, the implementation of this solution generally necessitates at least four masking levels.

The present invention relates to a method for the manufacture of a non-linear control element allowing the number of maskings to be reduced to two, and not requiring high precision in the production of the masks. In addition, the control elements obtained take up very little surface area and are therefore less noticeable than those known in the art.

The invention, then, relates to a method for the manufacture of a non-linear control element for a display screen placed on a plane face of a substrate comprising the following successive phases:

- a) a first phase of deposition of a first layer of a metallic material;
- b) a second phase of deposition of a first layer of an amorphous non-doped semiconducting material;
- c) a third phase of deposition of a layer of an amorphous doped semiconducting material;
- d) a fourth phase of deposition of a second layer of an amorphous non-doped semiconducting material;
- e) a fifth phase of deposition of a second layer of a metallic material;
- f) a sixth phase of cutting, in all the said layers deposited in the course of the preceding phases, a control column;
- g) a seventh phase of passivation of the flanks of the column produced in the course of the preceding phase;
- h) an eighth phase of deposition, on the assembly made up of the substrate

and the column, of a layer of a conductive material;

i) a ninth phase of cutting at least one control electrode connected with the second layer of metallic material, in the layer of conductive material.

The various purposes and features of the invention will be clear from the description which follows, which is made with reference to the accompanying drawings, in which:

Figure 1 shows one embodiment of a nonlinear control element;

Figures 2 to 7 show one example of a method for the manufacture of a nonlinear control element according to the invention.

Figures 8 to 10 show a variant of an example of a method for the manufacture of a nonlinear control element according to the invention;

Figures 11 to 14 show another variant of the method of manufacture according to the invention;

Figures 15 and 16 show examples of forms of control electrode coupled to column conductors by nonlinear control elements according to the invention.

First of all, an embodiment of a nonlinear control element will be described, with reference to Figure 1.

Such a control element has a layer of a conductive material 8 deposited on a plane face of a plate of substrate 1.

A mesa-structured element is deposited on this layer 8 and is successively made up of five different layers:

- a first layer of a metallic material 2, such as molybdenum (Mo);
- a first layer of an amorphous non-doped semiconducting material 3, such as amorphous non-doped silicon, labelled aSi(i) in Figure 1;
- a layer of an amorphous doped semiconducting material 4, such as n^+ doped silicon;
- a second layer of an amorphous non-doped semiconducting material 5 of the same type as the first layer 3;
- a second layer of a metallic material 6, such as molybdenum as used for the first layer 2.

This nonlinear control element may be used for controlling a liquid crystal display cell. A second plate of substrate 10 is then linked with the substrate 1. A liquid crystal 12 is placed between the two plates of substrate 1 and 10. The layer of conductive material 8 constitutes a control electrode 14 and has a suitable shape. The plate of substrate 10 also carries a control electrode 9 of the same shape and size as the control electrode 14, and placed opposite the latter.

Control of [the] liquid crystal cell is by application of a voltage between the electrode 9 and the second metallic layer 6 by means of [circuits] not shown [in the drawing]. Hence the electrical circuit comprises: the electrode 9, the layer of liquid crystal 12, the electrode 14, the first metallic layer 2, the layers of semiconducting material 3, 4 and 5, and the second metallic layer 6. The layers of amorphous non-doped semiconducting material 3 and 5 and the layer of amorphous doped semiconducting material 4 contained between the two layers of metallic material 2 and 6 constitute two Schottky diodes mounted in series and in opposition. These two diodes only pass current at or above a voltage threshold. That threshold determines the switching threshold of the liquid crystal cell.

As is known in the art, if the two plates 1 and 10 are of transparent material such as glass, and the electrodes 9 and 14 are likewise of transparent material such as indium and tin oxide, the cell operates by optical transmission.

According to another embodiment, the first metallic layer 2 may cover the control electrode 14, and be reflective. The plate 1 does not then need to be transparent, and the cell functions by optical reflection.

An example of a method for carrying out the invention will now be described with reference to Figures 2 to 7.

A layer of metal 2 such as platinum, molybdenum or palladium is deposited by cathode evaporation in a vacuum on to a plate of substrate 1 such as a glass plate. The thickness of this metallic layer 2 should be a few

hundreds of ångström. This yields a structure as shown in Figure 2.

In a second phase, a first layer of amorphous non-doped silicon 3 is deposited.

This is preferably deposited by plasma-assisted deposition (glow-discharge in Anglo-American terminology) at a temperature of about 250 degrees Celsius. It is also possible to proceed by vapour phase epitaxy (CVD or chemical vapour deposition) at about 600 degrees Celsius, or, again, by vapour phase epitaxy at reduced pressure (LPCVD or low pressure chemical vapour deposition) at about 550 degrees Celsius. The thickness of the layer 2 which is formed should be between 200 and 600 nm. In the case of deposition by epitaxy (CVD or LPCVD), it is advisable to provide for post-hydrogenation to passivate hanging-bond defects, that is to say, to fill in broken bonds.

In a third phase, a layer of amorphous n^+ doped silicon 4 is deposited. The method of deposition used may be one of the three methods referred to above.

The thickness of the layer of amorphous n^+ doped silicon 4 should be between 30 and 100 nm.

In a fourth phase, a second layer of amorphous non-doped silicon 5 is deposited. The method of deposition used can again be one of the three methods described above and the thickness of the layer obtained is equal to that of the first layer of amorphous non-doped silicon 3.

The structure obtained after this fourth phase is as shown in Figure 3.

In a fifth phase, deposition of a layer of metal 6 such as platinum, molybdenum or palladium is effected by cathodic evaporation in a vacuum. The thickness of this metallic layer should be a few hundreds of ångström. This yields a structure as shown in Figure 4.

In a sixth phase, a mesa structure is made by photolithography in the five layers 2, 3, 4, 5 and 6 deposited as described above. This is done

by masking the region corresponding to the mesa structure desired with a protective resin mask. Layers 2 to 6 are then etched by dry (plasma) or chemical etching in the non-masked region, after which the protective resin is removed. This yields a structure as depicted in Figure 5, having the form of a column 13.

In a seventh phase, the flanks of the column 13 are passivated. This passivation can be done by various methods. It can be effected by an inorganic insulating deposit 7, such as SiO_2 , followed by an anisotropic etch of the RIE type (reactive ion etching in Anglo-American terminology) which leaves the insulating material on the flanks of the column 13 only.

If the substrate 1 is transparent, this passivation can also be effected by deposition of a photosensitive polyimide resin (negative type) followed by insolation through the substrate by means of a light source placed on the opposite side to the column 13 with respect to the substrate 1. The metallic layers 2 and 6 screen the light for the resin on the metallic layer 6 at the upper face of the column 13. Hence these metallic layers act as a photoetching mask. The non-insolated resin is dissolved after developing. The whole of the part shown in Figure 5 is then covered with an insulating layer, except for the upper face of the column 13.

This result can also be obtained by depositing by gas discharge (glow discharge in Anglo-American terminology) at low temperature (about 150°C) a layer of insulating material such as SiO_2 or Si_3N_4 , before removing the protective resin provided in the sixth phase described above, which is in place on the upper face of the column 13; [this] resin layer is then removed, thus eliminating the layer of insulating material present on the upper face of the column 13.

In an eighth phase, the layer of insulating material is cured in order to solidify it. The curing temperature depends on the exact nature of the insulating material, as is known in the art.

In a ninth phase, a layer 8 of a conductive material is deposited; this may be a transparent material where the control element is used in a dis-

play screen functioning by transmission. Thus, a layer of mixed tin and indium oxide (ITO) or an equivalent material (In_2O_3) may be deposited. Such a layer should have a thickness of 50 to 100 nm.

In a tenth phase, an area of the surface of the layer 8 of conductive material is masked and etching is performed on the layer 8.

This masking constitutes the second masking operation of the method. It does not require any particular degree of precision in the positioning.

The shape of this mask is such as to form an electrode 14 as shown in Figure 7 on the surface of the substrate 1. In Figure 7, it can be seen that the column 13 is coupled with the electrode 14 by an element as formed above and successively comprising a metallic layer 2, a layer of amorphous non-doped silicon 3, a layer of amorphous n^+ doped silicon 4, a layer of amorphous non-doped silicon 5, and a metallic layer 6. A control element thus defined constitutes two Schottky diodes mounted in series and in opposition.

The method of carrying out the invention described above enables a set of electrodes 14, columns 13 and control elements coupling each electrode to a column 13 to be formed collectively on a plate of substrate.

It should be noted that the resultant structure depicted in Figure 7 corresponds to the case in which the flanks of the column have been passivated by the first method described above in the course of the seventh phase. In the case where the flanks of the column are passivated by one of the other two methods, a layer of insulating material covers the substrate 1 and the flanks of the column 13. The electrode 14 is then made on this insulating layer.

Lastly, in an eleventh phase, the layer of conductive material 8 (ITO) is cured at low temperature (200°C to 300°C).

A variant of the method according to the invention will now be described with reference to Figures 8 to 10.

According to this method, a layer of conductive material 8 such as ITO, and then a layer of metallic material 2, are deposited on a plate of substrate 1 (Figure 8).

At least one electrode 14 is then cut into these two layers (Figure 9).

On to the assembly thus obtained, a layer of amorphous non-doped silicon 3, a layer of amorphous n^+ doped silicon 4, a layer of amorphous non-doped silicon 5 and a layer of metallic material 6 are deposited in succession. A column 13 straddling part of the electrode 14 is then cut into these four deposited layers. This yields a structure as shown in Figure 10. The structure is similar to that in Figure 1 in which the control element is constituted by Schottky diodes in series and in opposition, but with the difference that the electrode 14 carries a layer of metallic material 2. Even so, by using the same method, it is possible to obtain the same structure as that shown in Figure 1 by cutting the electrode 14 into the layer 8 before deposition of the metallic material 2. The structure obtained will then possess the special feature of being capable of functioning by transmission provided the substrate 1 is transparent.

This variant of the method according to the invention uses the same techniques of deposition, cutting and curing as in the first method described. It requires only two masking operations: that necessary for cutting the electrode 14 and that necessary for cutting the column 13. The thicknesses of the layers are the same as those provided above.

Another variant of the method of carrying out the invention will now be described with reference to Figures 11 to 14.

According to this method, in the course of five successive initial phases, the following are deposited on a substrate 1:

- a layer 8 of a conductive material (ITO);
- a layer of a metallic material 2;
- a layer of amorphous non-doped silicon 3;
- a layer of amorphous n^+ doped silicon 4;
- a layer of amorphous non-doped silicon 5.

This yields a part as shown in Figure 11.

In a sixth phase, the shape of an electrode is cut into the five layers deposited. This yields a structure as depicted in Figure 12.

In a seventh phase, the flanks of the electrode are passivated by means of a film 7. This yields a structure as depicted in Figure 13.

In an eighth phase, a layer of a metallic material 6 is deposited. The metallic material 6 and the four layers 2, 3, 4 and 5 are then cut, without attacking the layer of conductive material 8, [so as to leave] a column 13 straddling the electrode 14. This yields a structure as shown in Figure 14 in which the film 7 insulates the layer of metallic material 6 from the other layers deposited. The structure is similar to that shown in Figure 1.

The various phases of this method are performed by the same techniques as those described above. This variant of the method for carrying out [the invention] likewise uses only two masking operations, viz. that for obtaining the electrode 14 and that for obtaining the column 13.

The variants of the method according to the invention which have been described enable electrodes 13 and columns 14 [sic] to be produced collectively over a large area. As shown in Figure 15, they enable an electrode 14 to be duplicated by an electrode 14^x coupled with the same column 13.

As shown in Figure 16, these variants enable an electrode 14 to be coupled with a column 13 by several nonlinear control elements such as the four elements 15, 16, 17, 18. Defective or unused control elements such as 16, 17 and 18 can be eliminated by laser cutting in regions indicated by jagged lines in Figure 16, at the base linking the control elements to the electrode 14.

The variants described above also allow production of control elements each comprising two PIN type diodes mounted in series and in opposition. In this case, instead of having three layers of silicon (two layers of

non-doped silicon surrounding one layer of doped silicon), five layers of silicon are provided:

- a layer of amorphous p^+ doped silicon;
- a layer of amorphous non-doped silicon;
- a layer of amorphous n^+ doped silicon;
- a layer of amorphous non-doped silicon;
- a layer of amorphous p^+ doped silicon.

then

The variants of the method according to the invention follow the same procedure, with the difference that the number of phases of deposition of silicon is five, rather than three.

CLAIMS

1. Method for the manufacture of a nonlinear control element for a display screen placed on a plane face of a substrate comprising the following successive phases:

- a) a first phase of deposition of a first layer of a metallic material (2);
- b) a second phase of deposition of a first layer of an amorphous non-doped semiconducting material (3);
- c) a third phase of deposition of a layer of an amorphous doped semiconducting material (4);
- d) a fourth phase of deposition of a second layer of an amorphous non-doped semiconducting material (5);
- e) a fifth phase of deposition of a second layer of a metallic material (6);
- f) a sixth phase of cutting, in all the said layers (2 to 6) deposited in the course of the preceding phases, a control column (13);
- g) a seventh phase of passivation of the flanks of the column (13) produced in the course of the preceding phase;
- h) an eighth phase of deposition, on the assembly made up of the substrate (1) and the column (13), of a layer of a conductive material (8);
- i) a ninth phase of cutting at least one control electrode (14) connected with the second layer of metallic material (6) in the layer of conductive material (8).

2. Method for the manufacture of a nonlinear control element for a display screen placed on a plane face of a substrate comprising the following successive phases:

- a) a first phase of deposition of a layer of conductive material (8);
- b) a second phase of deposition of a first layer of metallic material (2);
- c) a third phase of cutting, in the two preceding layers, at least one control electrode (14);
- d) a fourth phase of deposition of a [first] layer of an amorphous non-doped semiconducting material (3);



- e) a fifth phase of deposition of a layer of an amorphous doped semi-conducting material (4);
- f) a sixth phase of deposition of a second [layer] of an amorphous non-doped semiconducting material (5);
- g) a seventh phase of deposition of a second layer of a metallic material (6);
- h) an eighth phase of cutting, in the said layers (2 to 6) deposited in the course of phases c) to g) above, a control column (13) without attacking the control electrode and in such a manner that a portion of the said column (13) is in contact with the control electrode (14).

3. Method according to Claim 2, characterized in that the third phase of cutting is performed before the second phase of deposition of a first layer of metallic material (2).

4. Method for the manufacture of a nonlinear control element for a display screen placed on a plane face of a substrate comprising the following successive phases carried out on the substrate (1):

- a) a first phase of deposition of a layer of a conductive material (8);
- b) a second phase of deposition of a first layer of a metallic material (2);
- c) a third phase of deposition of a first layer of an amorphous non-doped semiconducting material (3);
- d) a fourth phase of deposition of a layer of an amorphous doped semi-conducting material (4);
- e) a fifth phase of deposition of a second layer of an amorphous non-doped semiconducting material (5);
- f) a sixth phase of cutting, in all the layers deposited as above, at least one control electrode (14);
- g) a seventh phase of passivation of the flanks of the control electrode (14);
- h) an eighth phase of deposition of a second layer of a metallic material (6);
- i) a ninth phase of cutting a control column (13) in the second layer of



metallic material and the materials of the control electrode (14) deposited in the course of at least phases b) to d) without attacking the layer of conductive material (8).

5. Method for the manufacture of a control element according to Claim 4, characterized in that the ninth phase of cutting a control column (13) does not attack the first layer of metallic material (2).

6. Method of manufacture according to any one of Claims 1, 2, 3, 4 or 5, characterized in that the phase of cutting a control column (13) is such that a column is coupled with several control electrodes (14).

7. Method of manufacture according to any one of Claims 1 to 6, characterized in that the phase of cutting a control column (13) is such that a control column is coupled at several points to each control electrode (14).

