

The invention relates to a method for the production of nonlinear control elements for a flat display screen, in particular for a liquid crystal display screen, and a flat screen produced by this method.

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.

In the present invention, a nonlinear resistance, which is practically insulating below a voltage threshold, and which becomes more and more conductive beyond that threshold, is placed in series with the picture element.

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 improving 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. Nevertheless, 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 allowing the number of maskings to be reduced to two, and not requiring high precision in [the production of] the masks.

The invention, then, relates to a method for the production of nonlinear control elements for an electrooptical display screen comprising an electrooptical material placed between a first and second plate, comprising the following successive phases performed on the second plate (1):

- a) a first phase of deposition of a layer of an amorphous n^+ doped semiconducting material;
- b) a second phase of deposition of a layer of an amorphous non-doped semiconducting material;
- c) a third phase of deposition of a layer of a metallic material, characterized in that it comprises, after these phases, the following further successive phases:
- d) a fourth phase of masking the control elements to be produced;
- e) a fifth phase of etching the three preceding unmasked layers so as to produce mesa structures;
- f) a sixth phase of deposition of a layer of an insulating material;
- g) a seventh phase of etching the parts of the layer of insulating material located on the surface of the layer of metallic material;
- h) an eighth phase of deposition of a layer of a conductive material;

i) a ninth phase of etching on the one hand the layer of conductive material so as to define display screen electrodes and control conductors such that the electrodes are coupled with the control conductors by the control elements thus produced, and on the other hand the layer of metallic material so as to constitute two metallic control element grids on each control element.

The invention also relates to a flat electrooptical display screen comprising first and second parallel plates enclosing an electrooptical material, each plate being provided on its face in contact with the electrooptical material with electrodes and control conductors, the electrodes and control conductors of the second plate being coupled with one another by nonlinear control elements produced in accordance with the method, and each comprising two diodes in series and in opposition, itself comprising a layer of amorphous n^+ doped semiconductor, a layer of amorphous non-doped semiconductor and a metallic layer, characterized in that each control element makes it possible to couple one control conductor with first and second electrodes by two superimposed layers of amorphous n^+ doped semiconductor and amorphous non-doped semiconductor, on which a first metallic element connected with the control conductor, a second metallic element connected with the first electrode E1 and a third metallic element connected with the second electrode E2 are deposited.

The various purposes and features of the invention will be detailed in the description which follows, which is given by way of example, with reference to the accompanying drawings, in which:

Figures 1 to 9 show one embodiment of the method according to the invention;

Figure 10 is a perspective view of a control element produced by the method according to the invention;

Figure 11 shows a general view of a control matrix produced in accordance with the invention;

Figure 12 shows a sectional view of the control matrix in Figure 11.

An embodiment of the method according to the invention will now be de-

scribed by way of example, with reference to Figures 1 to 9.

In a first phase of the method, a layer 2 of amorphous n^+ doped silicon is deposited on a flat substrate 1 made of a material which is insulating and transparent, such as a glass plate. This can be deposited either by plasma-assisted deposition (glow-discharge in Anglo-American terminology) at a temperature of about 250 degrees Celsius; or 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 30 and 100 nm. This yields a structure as shown in Figure 1.

In a second phase, a layer of amorphous non-doped silicon 3 is deposited. The method of deposition used may be one of the three methods referred to above. 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.

The thickness of the layer of amorphous non-doped silicon 3 should be between 200 and 600 nm. The part obtained appears as shown in Figure 2.

In a third phase, deposition of a layer of metal 4 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.

In a fourth phase, a mesa structure is made by photolithography in the three layers 2, 3 and 4 deposited as described above. This is done, as shown in Figure 4, by masking the region corresponding to the mesa structure desired, by means of a mask M1. The layers 2, 3 and 4 are then etched by dry (plasma) or chemical etching in the non-masked region. This yields a structure as depicted in Figure 5.

In a fifth phase, deposition of a layer of a negative photosensitive resin 5 is effected, such as a layer of photosensitive polyimide possessing the property of dissolving, on the non-insulated regions, in development after insolation.

In a sixth phase, the layer of resin 5 is insolated through the substrate 1 by means of a light source (not shown), as indicated by the arrows in Figure 6. The metal of the layer 4 acts as a screen for the resin on the metallic layer 4 and acts as a photoetching mask. This resin is therefore not insolated, and is dissolved after developing. This yields a part as shown in Figure 7.

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

In an eighth phase (Figure 8), a layer 7 of a conductive material is deposited; this may be a transparent material where the control element is used in a display screen functioning by transmission. Thus, a layer of mixed tin and indium oxide (ITO) or an equivalent material (In_2O_3 , SnO_2) may be deposited. Such a layer should have a thickness of 10 to 200 nm.

In a ninth phase, as depicted in Figure 9, surfaces of the layer 7 of conductive material are masked with masks M2 and M3, and the layer 7 is etched.

The masks M2 and M3 are positioned so as to allow the etch to cut the layer 7 into two parts. It also enables the metallic layer 4 to be etched likewise to yield two distinct metallic regions 41 and 42 separated by a free space 40.

The masks M1 and M2 are shaped so that electrodes E and control conductors C are formed on the surface of the substrate 1, as shown in Figure 10. In this figure, it can be seen that a control conductor C is coupled with an electrode E by an element produced as above and successively comprising a metallic layer 41, a layer of amorphous non-doped silicon 3, a layer of amorphous n^+ doped silicon 2, another layer of amorphous non-doped silicon 3, and a metallic layer 42. 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 an assembly of electrodes E, control conductors C and control elements

coupling each electrode E with a control conductor C to be produced collectively on a plate of substrate.

In Figure 11, a control conductor C enables two electrodes E1 and E2 to be controlled by a control element whose structure has been split in relation to the structure in Figure 10. The electrode E1 is coupled with the conductor C by two diodes mounted in series and in opposition between the metallic layers 41 and 42. The electrode E2 is coupled with the conductor C by a structure symmetrical to the preceding one.

Figure 12 represents a liquid crystal cell having two parallel plates L1 and L2 enclosing a liquid crystal LC. The plate L1 carries electrodes E3. The plate L2 carries a conductor C coupled with two electrodes E1 and E2 by an element constituted by two diodes mounted in series and in opposition between the metallic layers 41 and 44.

According to a variant of the method according to the invention, the third and fourth phases whereby mesa structures are formed in the layers 2, 3 and 4 may be performed differently. They may be replaced by the following successive operations: resin [coating], masking, metallic deposition, and removal of the metal by removal of the resin. This procedure allows the use of metals whose direct etching is difficult, with the metal, after etching, acting as etching mask for the mesa structure of silicon layers.

According to another variant of the method according to the invention in the fifth phase, an inorganic insulating material such as SiO_2 or Si_3N_4 is deposited. In this case, in the sixth phase, an anisotropic plasma etch of the RIE type is performed (RIE: reactive ion etching in Anglo-American terminology), which leaves the insulating material on the flanks of the mesa structure only.

It will be seen that the method according to the invention involves only two masking operations, each requiring only low precision. This method is therefore suitable for the production of redundant structures and in particular for a structure of the type described in relation to Figures 11 and 12.

CLAIMS

1. Method for the production of nonlinear control elements for an electrooptical display screen comprising an electrooptical material placed between a first and a second plate, comprising the following successive phases performed on the second plate (1):

a) a first phase of deposition of a layer of an amorphous n^+ doped semi-conducting material (2);

b) a second phase of deposition of a layer of an amorphous non-doped semi-conducting material (3);

c) a third phase of deposition of a layer of a metallic material (4);
characterized in that it comprises, after these phases, the following further successive phases:

d) a fourth phase of masking the control elements to be produced;

e) a fifth phase of etching the three preceding non-masked layers so as to produce mesa structures;

f) a sixth phase of deposition of a layer of an insulating material (5);

g) a seventh phase of etching parts of the layer of insulating material located on the surface of the layer of metallic material (4);

h) an eighth phase of deposition of a layer (7) of a conductive material;

i) a ninth phase of etching on the one hand the layer of conductive material (7) so as to define display screen electrodes (E) and control conductors (C) such that the electrodes are coupled with the control conductors by the control elements thus produced, and on the other hand the layer of metallic material (4) so as to constitute two metallic control element grids on each control element.

2. Method of production according to Claim 1, in which at least the second plate (1) is transparent, characterized in that the layer of insulating material (5) is a negative resin and the seventh phase of processing this layer of insulating material principally consists in insulation* by a light beam directed through the said second plate (1) in such a manner that the insulating material located on the surface of the layer



of metallic material (4) is not insulated [sic] and only this material is removed by washing of the layer of insulating material.

3. Method according to Claim 1, characterized in that the material (5) deposited in the course of the sixth phase is an inorganic insulating material, and in the course of the seventh phase this material is removed, except on the flanks of the mesa structures, by an anisotropic plasma etch.

4. A flat electrooptical display screen comprising first and second parallel plates (L1, L2) enclosing an electrooptical material, each plate being provided on its face in contact with the electrooptical material with electrodes and control conductors, the electrodes (E1 and E2) and the control conductors (C) of the second plate being coupled with one another by nonlinear control elements produced in accordance with the method in Claims 1 to 3, and each comprising two diodes in series and in opposition itself comprising a layer of amorphous n^+ doped semiconductor (2), a layer of amorphous non-doped semiconductor (3) and a metallic layer (4), characterized in that each control element makes it possible to couple one control conductor (C) with first and second electrodes (E1, E2) by two superimposed layers of amorphous n^+ doped semiconductor (2) and amorphous non-doped semiconductor (3) on which a first metallic element (41) connected with the control conductor (C), a second metallic element (42) connected with the first electrode (E1), and a third metallic element (44) connected with the second electrode (E2) are deposited.



* C L M S *