



\*166166\*

## Reducing water permeation into electronic devices

### Field of the invention

The present invention relates to electronic devices of the kind having an array of electronic components (e.g. diode display elements) covered on at least one side by a polymer substrate, and to methods of producing such devices. In particular in relates to techniques for reducing the permeation of moisture into such devices.

### Background of Invention

Thin film transistors have been widely used in recent years to reduce physical dimensions of electronic devices, and to minimize the fabrication and assembly costs of the components. Such thin integrated structures suggest that a breakthrough may be possible in electronic technology by the construction of electronic components on plastic material to obtain lightweight and flexible features for the next generation of handheld electronics. The realization of thin film transistors aims at producing a significant impact on the display industry when plastic substrates are used in place of glass to create thousands or millions of illuminated pixels, for example in Organic Light Emitting Diode (OLED) displays.

However, the development of thin film display technology is impeded by the degradation of the electronic components due to attacks of moisture permeating through the plastic substrate. Flexible plastics, commonly known as polymer substrates, unlike glass, contain pinholes and micro-pores because of their soft material structures. Often, water vapour from the atmosphere surrounding the displays are liable to be transmitted through these openings, and damage the electrical circuitry layers. In most sensitive electronic components, moisture permeation affects the material properties of the components, leading to undesirable reduced lifetimes of the display



\*G00002\*

elements when oxidation or other forms of deterioration occurs on those thin structured layers.

Much research has been carried out to try to develop a good barrier protective coating for polymer substrates to eliminate undesirable effects of water permeation. In most cases, one or more inorganic layers such as Aluminium Oxide, Silicon Oxide, etc, are coated on one surface of a polymer substrate to prevent penetration of water molecules from the surrounding atmosphere. This is illustrated in Fig. 1, which shows a known display device, in which a polymer substrate 101 is spaced by an inorganic barrier film 102 from the front surface of an OLED display 103 made up of an array of OLED display elements. The other faces of the OLED display 103 are protected by a metallic cover 104. The arrow 105 indicates the permeation of water vapour through the substrate 101 driven by an effective pressure different across the substrate 101. In many display devices the substrate 101 is chosen to be thin, so as to achieve high mechanical flexibility of the substrate 101, but this makes the rate of moisture permeation even higher. The inorganic barrier film 102 aims to prevent this moisture from reaching the OLED display 103. Unfortunately, the inorganic barrier film 102 often contains cracks or other forms of deposition defects due to imperfect production processes. Therefore, water permeation may still occur through the barrier coating 102. This can cause the OLED display 103 to break down due to the corrosive chemical reactions of the water molecules.

In order to enhance the effectiveness of the barrier coating, it has been proposed to add an additional barrier layer to remove permeant from the polymer substrate 101. For example, it has been proposed to coat the outer face of the polymer substrate with a special hydrophobic coating, to prevent absorption of molecules on the surface of the polymer substrate 101. However, the adhesive strength of the added coating may not be adequate,

so that the permeation resistance of the system may deteriorate over time. Thus, much attention is presently being given to developing an active barrier layer which avoids moisture absorption on the polymer substrate 101.

## 5 Summary of the Invention

The present invention aims to provide new and useful microelectronic devices, and in particular ones having a higher resistance to damage by water permeation.

The invention further aims to provide methods of constructing such devices.

- 10 In general terms the invention proposes that in a electronic device having an array of electronic elements constructed on a polymer substrate, the polymer substrate should be provided with a resistive element between the polymer substrate and the array of electronic elements. The resistive element is supplied with electrical power by electrical power supply means for resistive  
15 heating of the resistive element.

The heat generated by the resistive layer reduces the risk of water molecules penetrating the polymer substrate, and/or reduces the risk of it reaching the array of electronic elements.

- 20 In a preferred form, the device is a display device and the electronic elements are display elements such as diodes, so that the array of display elements together constitute a display area of the display device.

- There may be a further polymer substrate between the resistive layer and the array of display elements to further prevent water permeation, and to protect the display elements from the heat generated in the resistive layer. In some  
25 embodiments the first and second polymer substrates may be formed as a single composite body (e.g. by forming the polymer substrates separately, and adhering them together using an adhesive layer), so that the resistive

element is between the substrates of the composite body, which is adjacent to the display elements.

The resistive element may be in the form of a conductive layer. It may extend continuously, or may include openings. For example, the conductive layer  
5 may be arranged in a mesh formation. In some embodiments there may be a plurality of resistive elements, typically sharing a common electrical supply. The resistive element(s) may be formed as a layer by a deposition technique, optionally followed by a patterning operation.

The display device may include channels, such as grooves or trenches  
10 formed in one or other of the polymer substrates (preferably the one which does not carry the conductive layer), allowing the passage of air heated by the resistive elements out of the display device.

The display elements may include any form of electronically controlled display elements, such as an organic light emitting diodes (OLED) or a liquid crystal  
15 display (LCD) elements.

Specifically, in a first aspect the invention provides an electronic device comprising:

an array of electronic elements;

a first transparent polymer substrate covering the array of electronic  
20 elements; and

at least one electrically resistive heater element between the first polymer substrate and the array of electronic elements, for generating sufficient heat to repel water molecules permeating through the first transparent polymer substrate.

In a second aspect the invention provides a method of constructing an electronic device, the method comprising forming a two-dimensional array of electronic elements, and attaching a first polymer substrate parallel to the array of electronic elements with at least one electrically resistive heater element between the polymer substrate and the array of electronic elements,  
5 the resistive heater element being for generating sufficient heat to repel water molecules permeating through the first transparent polymer substrate.

In a third aspect, the invention provides a method of operating an electronic device comprising:

10 an array of electronic elements;

a first transparent polymer substrate covering the array of electronic elements; and

at least one electrically resistive heater element between the first polymer substrate and the array of electronic elements, the method including  
15 applying a voltage to the resistive heater layer to heat it sufficiently to repel water molecules permeating through the first transparent polymer substrate.

#### Brief Description of The Figures

Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following figures in which:

20 Fig. 1 is a cross-sectional view of part of a known display device;

Fig. 2 is a cross-sectional view of part of an embodiment of the invention;

Fig. 3 is an exploded view of the embodiment of Fig. 2; and

Fig. 4 is a schematic view illustrating the operation of the embodiment.

Detailed Description of the embodiments

Referring to Fig. 2, an embodiment of the invention is shown in cross-section. Elements of the embodiment which correspond to those of the known structure of Fig. 1 are labelled by identical reference numerals.

The embodiment includes an OLED display 103 (which in alternative embodiments may be an LCD display element) made up of a two-dimensional array of OLED display elements which are individually controlled electronically. The rear and sides of the display 102 are covered and protected by a metallic cover 104. In fact, starting from the barrier film 102, and moving to the right in the figure, the entire structure may be exactly as in the known structure of Fig.1, and be formed in the same way. The display element is protected from the front by a composite body 207 and an inorganic barrier film 102. Thus, the composite body 207 plays the role of the polymer substrate 201 in the prior art display device shown in Fig. 1. In fact, starting from the barrier film 102 and moving to the right in Fig. 2, the entire structure

may be exactly as in the known structure of Fig. 1, and formed in the same way.

The composite body 207 is composed of a first polymer substrate 201 which  
5 is adhered by an adhesive 204 to a conductive mesh layer 202, which is in turn formed on the surface of a second polymer substrate 203.

The first polymer substrate 201 is transparent, flexible and includes multiple slots as described below. It may be formed from a material such as PC  
10 (polycarbonate), PEN (a Polyethylene naphthalate resin), Polyimide, etc. The second polymer substrate 203 may be formed from the same materials, but has planar surfaces, i.e. without slots. The polymer substrates 201, 203 should have good mechanical flexibility, good surface finish, and be thermally stable. The barrier film 102 may be formed of a material such as  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  
15 so that the film 102 can provide a high degree of shielding from permeation.

Referring now to Fig. 3, the structure of Fig. 2 is shown in an exploded form and without the metallic cover layer 104.

20 The steps of a method for constructing such a structure will now be described. Initially, the first polymer substrate 201 may be formed. The first polymer substrate 201 has an overall thickness of preferably less than 100 micrometers, such as about 75 micrometers. It is etched by an etching technique such as oxygen plasma etching in vacuum conditions using a mask  
25 to create uniformly straight grooves or trenches 310 having a depth of preferably between 5 and 20 micrometers, such as 10 micrometers. These grooves or trenches 310 (from now on referred to as "slots") are a few millimetres apart. The surface quality of the slots 310 is not critical, so conventional semiconductor processes are applicable to form them.

Next a second polymer substrate 203, which has the same dimensional ranges as the first polymer substrate 210, is coated by a deposition process with a layer 202 of a transparent conductive material, such as ITO. The layer 202 may for example have a uniform thickness in the range 20 to 70  
5 micrometers, such as about 50 micrometers thick.

Preferably, the conductive layer 202 is then etched using a photo-masking technique to pattern it as a fine mesh on the surface of the second polymer substrate 203. This patterning is not necessary to the invention, but is  
10 presently preferred since it raises the resistance of the layer 202, so that more heat will be generated later when a voltage is applied between the edges of the layer 202.

The first polymer substrate 201 is then placed with its slotted surface facing  
15 the conductive mesh 202, and the two are bonded firmly together using a thin layer of an organic adhesive 204, such as epoxy material. Depending upon the choice of adhesive, curing steps may be necessary to ensure that the adhesive is thermally and chemically stable as well as tough, these properties being necessary during the subsequent heating process.

20 The composite substrate 207 thus produced, having the polymer substrates 201, 203 on its two sides, meets the optical transmittance requirements of the front cover of a display. For this reason, each of the substrates 201, 203 is preferably individually thinner than the polymer substrate 101 of the structure  
25 shown in Fig. 1.

The composite substrate 207 is then used to form the structure shown in Fig. 2, which is done by conventional techniques, with the composite structure 207 taking the place of the known substrate 101.

The operation of the embodiment is explained with reference to Fig. 4, which shows the structure of Fig. 2 in an enlarged view in a plane including one of the slots 310. A low electrical current is supplied through two uncovered terminals 403, 405 of the conductive mesh 202. A dry cell 401 supplying of the order of 5 volts may be used in this application depending on the area of the substrates 201, 203. The electrical current causes heating in the conductive mesh 202, which heats the mesh.

As in conventional devices, water molecules 407 are able to permeate the polymer substrate 201, due to its polymer structure including randomly distributed pores and pinholes 409. The water molecules tend to fill the pores and pinholes 409 due to atmospheric pressure. However, as soon as such molecules come into contact with the conductive mesh 202, the heat of the mesh 202 and the electrical current cause them to be evaporated.

Moreover, the heat generated in the conductive mesh 202 causes a build up of pressure over all the surfaces of the mesh layer 202, and thus helps to stop the migration of water molecules from the front surface of the polymer substrate 201.

Additionally, the built up pressure from the heating propels the vapour of the evaporated water molecules out to the ambient atmosphere constantly, though the open ends of the slots 310. This discharging of vapour is always in the direction out of the display due to the pressure generated by the heated conductive layer 202, so ambient moisture is unlikely to enter the substrate 201 through these open ends. Even after the heated conductive layer 202 has reached its constant temperature, the flow of air may continue due to any water molecules entering the device through the substrate 201 and being evaporated within the device. The temperature of the conductive mesh 202 is controlled to be such that it is effective in dispelling moisture without causing

undesirable consequences to the substrates 201, 203. At the moment a temperature of about 80°C is preferred.

5 In the case that the conductive layer 202 is turned off, the temperature and hence pressure of the air in the device will fall, possibly creating a flow of air into the device. However, elements may be provided to prevent entry of water into the device carried on this air flow. These elements may take the form of filter elements arranged in the air flow path.

10 Although only a single embodiment of the invention has been described, the invention is not limited in this respect and many variations are possible within the scope of the invention as will be clear to a skilled reader. For example, in some arrangements it may be advantageous for the mesh to be supplied with electricity intermittently, e.g. on a pulsed basis, to allow it to undergo a cycle  
15 of cooling down and warming up. During each warming phase, the air within the device is heated thus generating a flow of air out of the device which carries out undesired moisture.

20 The construction described above is applicable to a wide range of mobile consumer electronics with low power consumption and lightweight flexible structures. It is also robust to temperature differences, and provides high reliability and durability to control the rate of water permeation.

Claims

1. An electronic device comprising:  
  
an array of electronic elements;  
  
a first transparent polymer substrate covering the array of electronic  
5 elements; and  
  
at least one electrically resistive heater element between the first  
polymer substrate and the array of electronic elements, for generating  
sufficient heat to repel water molecules permeating through the first  
transparent polymer substrate.
- 10 2. A device according to claim 1 further comprising a second polymer  
substrate between the resistive heater element and the electronic elements.
3. A device according to claim 1 or claim 2 in which the resistive heater  
element is a conductive layer.
4. A device according to claim 3 in which the conductive layer includes a  
15 plurality of openings.
5. A device according to any preceding claim which includes air channels  
extending in the plane of the display for allowing air heated by the resistive  
element to pass to the sides of the device.
6. A device according to any preceding claim further comprising an  
20 inorganic barrier layer between the first polymer substrate and the array of  
electronic elements.
7. A device according to any preceding claim in which the electronic  
elements are display elements.
8. A device according to claim 7 in which the display elements are diodes.

9. A method of constructing an electronic device, the method comprising forming a two-dimensional array of electronic elements, and attaching a first polymer substrate parallel to the array of electronic elements with at least one electrically resistive heater element between the polymer substrate and the array of electronic elements, the resistive heater element being for generating sufficient heat to repel water molecules permeating through the first transparent polymer substrate.
10. A method according to claim 9 in which a second polymer substrate is positioned between the resistive element and the electronic elements.
11. A method according to claim 9 or claim 10 in which the resistive element is a conductive layer.
12. A method according to claim 11 in which the conductive layer is formed by deposition.
13. A method according to claim 12 in which following the deposition the conductive layer is patterned to form openings.
14. A method according to any of claims 9 to 13 further including providing channels in the device for allowing air heated by the resistive element to pass to the sides of the device.
15. A method according to any of claims 9 to 14 further comprising providing an inorganic barrier layer between the first polymer substrate and the array of electronic elements.
16. A method according to any of claims 9 to 15 in which the electronic elements are display elements.
17. A method according to claim 16 in which the display elements are diodes.

11a

18. A method of operating an electronic device comprising:

an array of electronic elements;

5 a first transparent polymer substrate covering the array of electronic elements; and

at least one electrically resistive heater element between the first polymer substrate and the array of electronic elements, the method including applying a voltage to the resistive heater layer to heat it sufficiently to repel water molecules permeating through the first transparent polymer substrate.