Novel Temperature Sensor Fabricated with Oxide and Metal

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Abstract

Resistance of metal depends on temperature. Therefore, the metal can be used as a temperature sensor with a reference resistor. The reference resistor is connected serially and the voltages of the sensor metal are measured after applying DC voltage. However, it is not easy to keep the reference resistance constant while measuring temperatures. We studied the temperature dependence of resistance of oxide material to apply it to the bridge type temperature sensor which is insensitive to the environmental temperature. We made bridge type temperature sensor with oxide material and metal. The novel temperature sensor does not need a reference resistor, and composed of oxide and metal. Therefore, we could remove error induced by environmental temperature variation. Moreover, the novel bridge type temperature sensor provides higher sensitivity than conventional sensor structure. By different thermal coefficient of the oxide material, it was possible to remove an external reference resistance. The proposed bridge type temperature sensor is a self-reference temperature sensor which is insensitive to the environmental temperature.

Introduction

Performance of flat panel display (FPD) depends on temperature. For instance, an optical characteristic of thin film transistor (TFT) liquid crystal display (LCD) depends significantly on panel temperature. For instance, the rotational viscosity of liquid crystals decreases at low temperature, leading to slow response time and motion blurring. Ambient conditions and the internal backlight cause the LCD panel temperature to change. LCD panel temperature changes can lead to unbalanced pixel driving voltage, which can result in flicker noise [1]. Temperature sensor utilizing metal needs external reference resistance. However, external resistor makes accurate detection difficulty, because external resistance which should be constant varies according to ambient temperature variation. Heat of back light unit (BLU) and driving circuit can increase the temperature of external resistor.

OLED display is current driving display which is different from LCD which is voltage driving display. Therefore, we should keep the current uniform during 1 frame.

Since the OLED current depends on temperature, temperature compensation is necessary to keep the brightness constant. For the temperature compensation, we need temperature sensor to defect panel temperature.

We suggested temperature sensor on the panel with the indium tin oxide (ITO) and molybdenum (Mo) metal. The sensor has the bridge structure, which is a self-reference temperature sensor.

Experimental

The thermal sensor integrated on the panel was reported [1]. They made metal as a temperature sensor because the resistance of the metal depending on temperatures.

However, it is complex to put on an external resistor and it can make error by the temperature change of external resistor. Therefore, we suggested new structure in which ITO and Mo were connected bridge-type. This sensor does not need an external resistor.
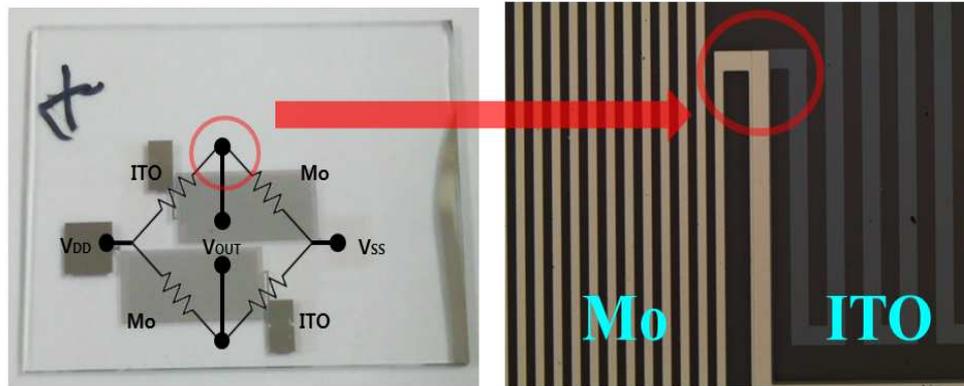

Fig 1. Fabricated ITO and Mo bridge type temperature sensor.

Temperature sensor is bridge-type connected with ITO and Mo resistor. The Mo was deposited by sputtering and patterned at first. And then, ITO was deposited by sputtering and patterned as shown in Fig 1.
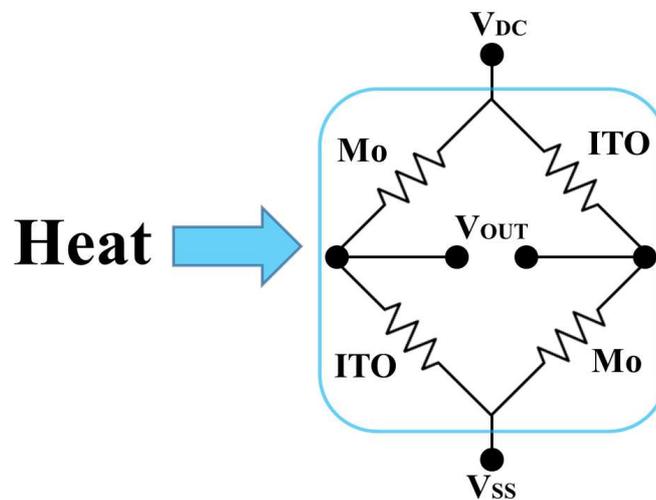

Fig 2. Schematic of bridge type temperature sensor.

Fig 2 shows schematic of bridge type temperature sensor. Temperature sensor was evaluated in vacuum chamber while adjusting temperature. With applied DC voltage, the output voltages were measured at the node between ITO and Mo while changing temperature.
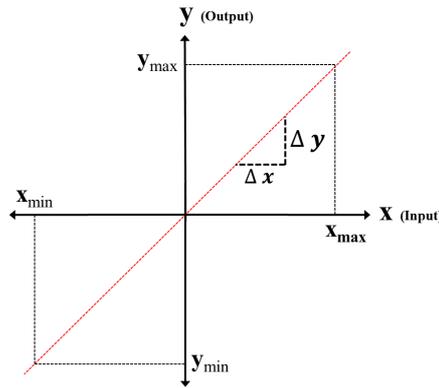
Results and discussion

Fig 3. Ideal curve and sensitivity

Fig 3 shows ideal curve and sensitivity. The straight line is ideal curve and $\Delta y / \Delta x$ is sensitivity.

The sensitivity of the sensor is defined as the slope of the output characteristic curve. More generally, it is the minimum input of physical parameter that will create a detectable output change.

In some sensors the sensitivity is defined as the input parameter change required to produce a standardized output change. In still other it is defined as an output voltage change for a given change in input parameter [3]. Measured sensitivity was 1.8mV/℃ for the proposed temperature sensor. The measured value was obtained without amplifier circuit.
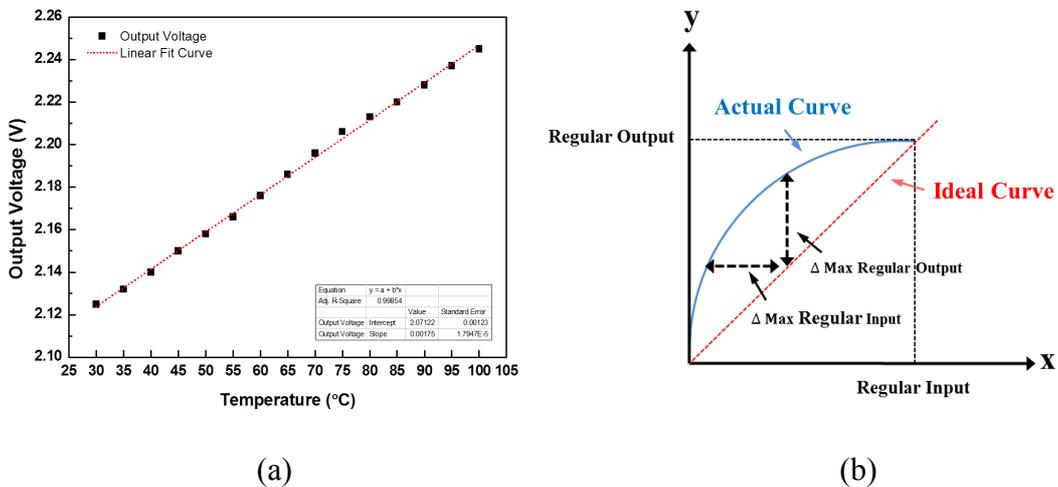

Fig 4. (a) Measured output voltage and linear fit curve.
(b) Definition of linearity.

Fig 4 (a) shows measured output voltages symbols and linear fit curve. Fig 4 (b) shows linearity which is often specified in terms of percentage of nonlinearity. Nonlinearity is defined as

$$\text{Nonlinearity } (\%) = \frac{\Delta \text{Max Regular Output}}{\text{Regular Output}} \times 100\% \text{FSO (Full Scale Output)} \qquad (1)$$

Linearity of the sensor is an expression of the extent to which the actual measured curve of a sensor departs from the ideal curve. The static non linearity defined by equation (1) is often subject to environmental factors, including temperature, vibration, acoustical noise level, humidity, and so on. It is important to know under what conditions the specification is valid [3].

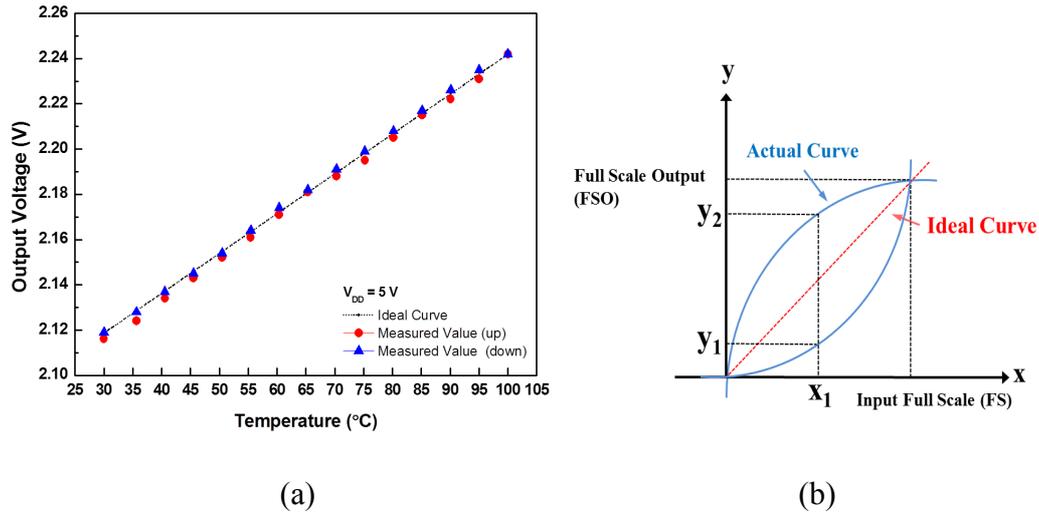(a)   (b)

Fig 5. (a) Characteristic of hysteresis measurement for the proposed temperature sensor.
(b) Definition of hysteresis.

Fig 5 (a) shows hysteresis of the proposed temperature sensor. The measured hysteresis was 4.49% FSO for the proposed temperature sensor in Fig 5(a). Hysteresis is defined as

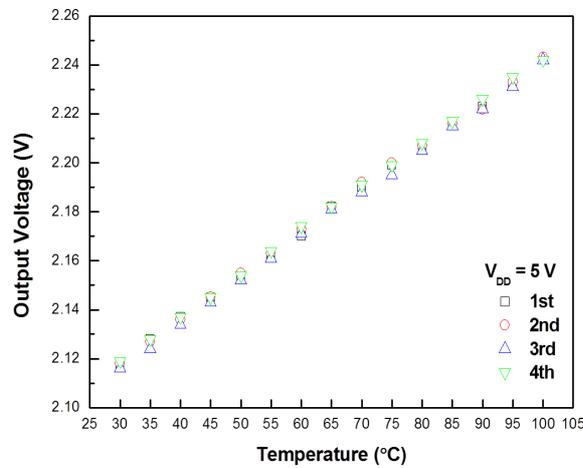$$\text{Hysteresis } (\%) = \frac{y_2 - y_1}{FSO} \times 100\% \text{ FSO} \qquad (2)$$

Fig 6. Characteristic of repeatability for the proposed temperature sensor.

Fig 6 shows the measurement of repeatability. Repeatability is short time interval measurement to check the agreement between measured value with the same people, same place, same environment, and same condition. Measured repeatability was 0.006 %FSO for the proposed temperature sensor.

Another characteristic of sensor is accuracy. Accuracy of the sensor is the maximum difference that will exist between the actual value and the indicated value at the output of the sensor. We get measured value of 1.01%FSO.
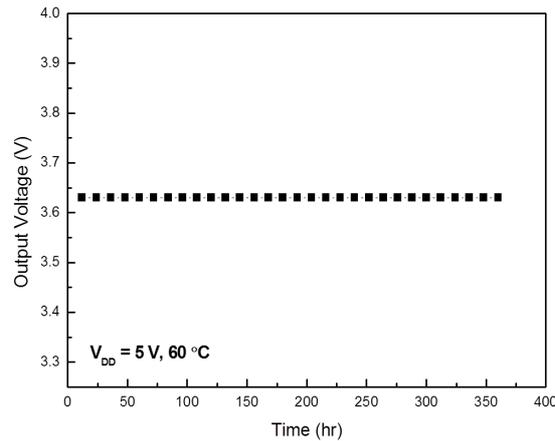
Fig 7. Characteristic of stability for the proposed temperature sensor.

Fig 7 shows measured stability. The output voltage was measured up to 360 hours at 60℃. Stability the ratio of variation of output voltage during operation time compared to initial output voltage.

The fabricated sensor characteristics show good linearity, repeatability, and stability as summarized in table 1, as well as it is insensitive to environmental temperature due to the absence of an external reference resistor.

Table 1. Characteristics of bridge type temperature sensor.

Parameters	Value
Input Voltage	5 V
Sensitivity	1.8 [mV/℃]
Hysteresis	4.49 [% FSO]
Repeatability	0.06 [%FSO]
Stability	Less than 0.27 [%FSO]@360hr
Linearity	2.3 [%FSO]
Accuracy	1.01 [%FSO]
Test Range	30℃ ~ 100℃

Conclusion

We have proposed new ITO and Mo metal electrode temperature sensor which were bridge type. It has good sensitivity, hysteresis, repeatability, stability, linearity, and accuracy.

Generally temperature sensor utilizing metal needs an external resistor which is sensitive to environment. We have proposed temperature sensor which does not need an external resistor and remove error induced by environmental temperature variation. Moreover, the novel bridge type temperature sensor provides higher sensitivity than conventional sensor structure. The proposed bridge type temperature sensor is a self-reference temperature sensor which is insensitive to the environmental temperature.

Reference

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