Evaluation of the ohmic contact resistivity in Plasma display panels

Seung Hee Yang, Cheol Hee Moon
School of Display Engineering, Hoseo University,
Baebang-myun, Asan-shi, Chungnam, 336-795 Korea
Phone: 041-540-5923, E-mail: chmoon@office.hoseo.ac.kr

Abstract

The contact resistivity of the black interlayer which has been introduced between BUS and ITO electrodes in a plasma display panel was evaluated using two kinds of specially designed test electrode patterns. Of the two, type 2 pattern was able to evaluate the contact resistivity more successfully, which was calculated as about 250 Ω in the suggested test pattern structure .

1. Objectives and Background

PDPs(Plasma display panels) are of great interest specially for large area flat panel displays. AC co-planar type PDPs which are most used consist of two glass substrates holding BUS and Address electrodes as shown in Figure 1. BUS electrodes are located on the ITO electrodes patterns on the front glass of PDPs. AC voltage is applied for BUS electrodes, which is transmitted to the ITO electrodes beneath BUS electrodes. Plasma is ignited between the two ITO electrodes x, y as shown in Figure 1 and the pixel turns on.

As is shown in Figure 2, BUS electrode and ITO electrode are electrically contacted, and in most cases, black interlayer is introduced between the two to enhance the bright room contrast of PDP. As the roles of each layer are different, they have different specifications in their composition, thickness and electrical resistivity as is shown in Table 1. BUS electrode plays a role as an electrical pathway, which has to conduct the current provided through terminal electrodes along the whole BUS line in a shortest time. From this reason, the material for BUS electrodes has to have the lowest electrical resistivity. Silver(Ag) is mostly used for base material for PDP BUS electrodes. ITO electrode has a role of igniting a plasma using a voltage difference delivered by x and y BUS electrodes.

Black interlayer plays a role of enhancing the blackness of the bottom of the BUS electrode line so that it may looks darker when the cell is not ignited. Black pigments or black conducting glass frits are used for the blackness. However, as they have poor electrical conductivity, they retard the electrical conductance between the BUS and ITO electrode, which results in degradation of the PDP performance(for example, increase in driving voltage or power consumption). Therefore, selection of the material and determination of the thickness of the layer have to be carefully done considering the blackness and the electrical properties at the same time.

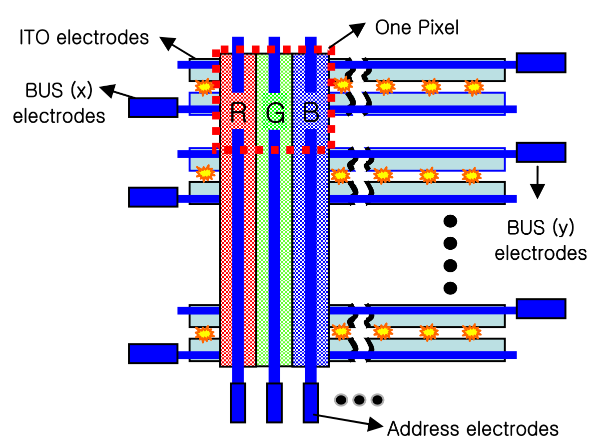

Figure 1. Structure of BUS, ITO and Address electrodes in plasma display panel

Table 1. Conventional specifications of the each layer shown in Figure 2

	Main composition	Thick -ness	Electrical Resistivity (Ω · cm)
Bus electrode	Ag	5 ㎛	$3*10^{-6}$
Black interlayer	PbO, SiO_2	2 ㎛	10^{1}~10^{2}
ITO electrode	In,Sn oxides	0.1 ㎛	10^{-2}~10^{-3}
Glass substrate	SiO_2 , Al_2O_3	2.8mm	10^{11}

Now we need to think about the interfacial properties between ITO and BUS electrodes as is shown in Figure 2. Good electrical conductivity between point A and D is highly required for high speed driving specially for large area, high resolution and high performance Plasma display panels. In the case of Figure 2, electrical resistivity between point A and D contains three different resistivities.

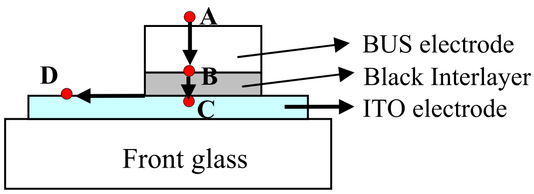

Figure 2. Multi-layer structure of ITO and BUS electrode on front glasses in Plasma display panel

$$R_{A\text{-}D}=R_{A\text{-}B}+R_{B\text{-}C}+R_{C\text{-}D} \text{ ---- (eq.1)}$$

Where $R_{A\text{-}B}$ is a line resistivity of BUS electrode, $R_{B\text{-}C}$ is a contact resistivity of the interlayer and $R_{C\text{-}D}$ is a line resistivity of ITO electrode. It is very important to measure $R_{B\text{-}C}$ because it directly affects on the response time and driving voltage characteristics. Moreover, if we can measure $R_{B\text{-}C}$, the interlayer introduced to enhance the blackness of BUS electrodes can be optimized so that it may satisfy not only blackness but also electrical properties.

However, it is very difficult to measure the contact resistivity $R_{B\text{-}C}$, electrical conductance between the point B and C, because the black interlayer is very thin (about 2 ㎛in Table 1) and the measuring points (B and C) are not exposed. From these reasons, no results have been reported in measuring the contact resistivity. In this paper, the contact resistivity $R_{B\text{-}C}$ has been evaluated using various kinds of the specially designed electrode patterns, and the effect of the black interlayer on the overall electrical conductance within the PDP cell has been investigated.

2. Experimental procedure

ITO coated PD-200 glasses substrates were cleaned with chemical agent and dried upon the hot plate. The thickness of the ITO layer was about 0.1 ㎛ and ITO test pattern was formed using photomask which has specially designed pattern. Black colored paste used for interlayer and Ag based paste were printed, dried and the test pattern was formed using photomask. After the photolithography process was finished, the paste material was sintered at 550℃ inside the firing furnace. Electrical line resistivity was measured at the surface of BUS electrode or ITO electrode using multi meter.

As the black interlayer is very thin, it is impossible to measure the contact resistivity $R_{B\text{-}C}$ directly. In this experiment, we measured the electrical resistivity $R_{A\text{-}D}$ and calculated the contact resistivity $R_{B\text{-}C}$ using eq.1. As is shown in Table 1, $R_{A\text{-}B}$ is negligible compared to $R_{C\text{-}D}$, so eq.1 can be expressed as

$$R_{A\text{-}D}=R_{B\text{-}C}+R_{C\text{-}D} \text{ ---- (eq.2)}$$

In this experiment, to reduce the measurement error range, multiple measurement of the $R_{A\text{-}D}$ was done using different lengths of the ITO electrode lines. So, we can get the relationships

$$R_{A\text{-}D}(1) = R_{B\text{-}C} + R_{C\text{-}D}(1) \text{ ---- (eq.3)}$$
$$R_{A\text{-}D}(2) = R_{B\text{-}C} + R_{C\text{-}D}(2)$$
$$R_{A\text{-}D}(3) = R_{B\text{-}C} + R_{C\text{-}D}(3)$$

.

where $R_{A\text{-}D}$ and $R_{C\text{-}D}$ are varied in proportional to $D_{C\text{-}D}$, the distance between the points C and D along the ITO electrode line, but $R_{B\text{-}C}$ is a constant not related to $D_{C\text{-}D}$.

If we draw a graph using the relationships in eq.3, the gradient is related to the line resistivity along the ITO electrode line ($R_{C\text{-}D}$) in figure 3. Y axis intercept means the contact resistivity $R_{B\text{-}C}$, because this is the case that the distance along the ITO electrode line is zero (that is, $R_{C\text{-}D}$ is zero) so only the component of $R_{B\text{-}C}$ is remaining in eq.2. From this basic concept, in this experiment, two kinds of electrode patterns have been designed to be able to evaluate the contact resistivity $R_{B\text{-}C}$ as correct as possible.

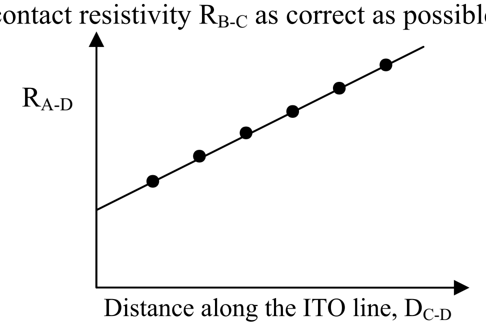

Figure 3. Basic consept of evaluating the contact resistivity $R_{B\text{-}C}$

3. Results and Discussion

3.1 Evaluation using type 1 pattern

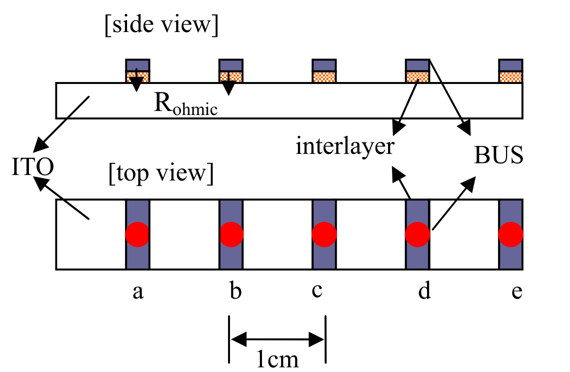

Figure 4. Type 1 pattern used for evaluating the contact resistivity of black interlayer

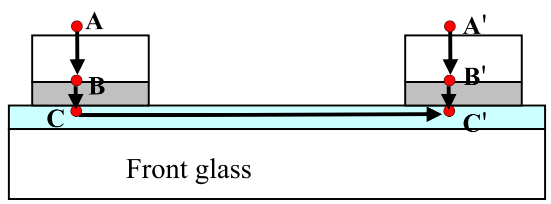

Figure 5. Schematic drawing which shows the composition of the resistivities in type 1 pattern

Figure 4 shows double layered structure, where Ag based BUS layer (dot pattern) is located above the black colored interlayer on ITO coated glass substrate. Electrical line resistivity between the dot patterns a, b, c, d and e (which were 1cm separated each other) had been measured. This case is expressed as in Figure 5, where the measured value is $R_{A\text{-}A'}$, the line resistivity measured at points A and A'. In Figure 5,

$$R_{A\text{-}A'} = R_{A\text{-}B} + R_{B\text{-}C} + R_{C\text{-}C'} + R_{A'\text{-}B'} + R_{B'\text{-}C'} \text{ -- (eq.4)}$$

Supposing that

$$R_{A\text{-}B} = R_{A'\text{-}B'} \text{ ----- (eq.5)}$$

$$R_{B\text{-}C} = R_{B'\text{-}C'} \text{ ----- (eq.6)}$$

Putting eq.5 and eq.6 into eq.4,

$$R_{A\text{-}A'} = 2R_{A\text{-}B} + 2R_{B\text{-}C} + R_{C\text{-}C'} \text{ -- (eq.7)}$$

As $R_{A\text{-}B}$ is negligible compared to $R_{C\text{-}C'}$, so eq.7 can be expressed as

$$R_{A\text{-}A'} = 2R_{B\text{-}C} + R_{C\text{-}C'} \text{ -- (eq.8)}$$

Figure 6 is a graph which was drawn with the measured data using type 1 pattern. The measured values don't show linearity in the figure, so we cannot draw a straight line on the measured points. This means that the measured resistivities have large error. We can explain that, because the thicknesses of the layers are very thin, the sharp probe cannot touch only the surface of the BUS electrode but also the black layer material inside. So, we designed type 2 pattern on which the probe doesn't touch the two layers at the same time.

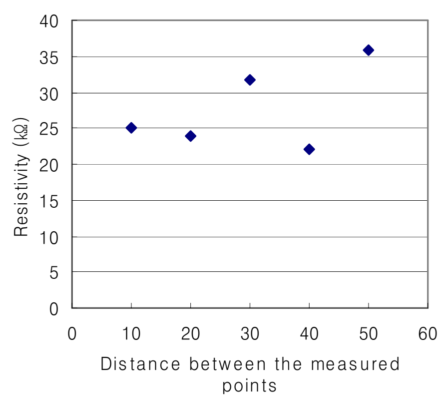

Figure 6. Measured resistivity $R_{A\text{-}A'}$ as a function of distance between the points in Figure 4

3.2 Evaluation using type 2 pattern

Figure 7 shows test electrode pattern which was used for evaluating the contact resistivity of black interlayer without touching the black interlayer material directly with the probe. The area which BUS electrode, black interlayer and ITO electrode overlaps is 3mm in length and 0.5mm in width. In the same panel, the above 6 patterns consists of 3 layere structure, BUS/black/ITO, and the below 6 patterns consists of 2 layer structure, BUS/ITO, as is shown in figure 8.

For 3 layer pattern, the measured line resistivity $R_{A\text{-}A'}$ which is measured at points A and A' can be expressed as below similarly to eq.7.

$$R_{A\text{-}A'} = 2R_{A\text{-}B} + 2R_{B\text{-}C} + R_{C\text{-}C'} \text{ -- (eq.9)}$$

For 2 layer pattern, there is no black interlayer between BUS and ITO layer. So, the difference of the measured resistivies for 3 layer pattern and 2 layer pattern equals to $2R_{B\text{-}C}$.

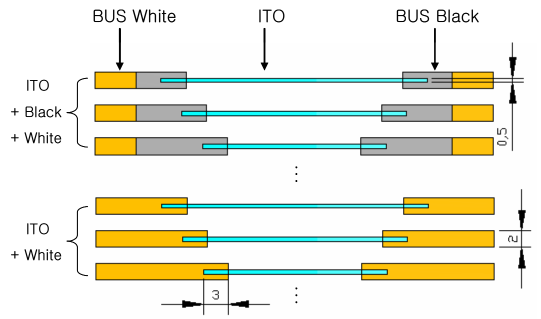

Figure 7. Type 2 pattern used for evaluating the contact resistivity of black interlayer

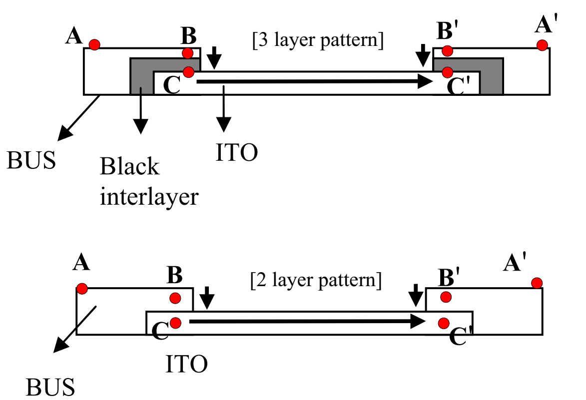

Figure 8. Schematic drawing which shows the composition of the resistivities in type 2 pattern

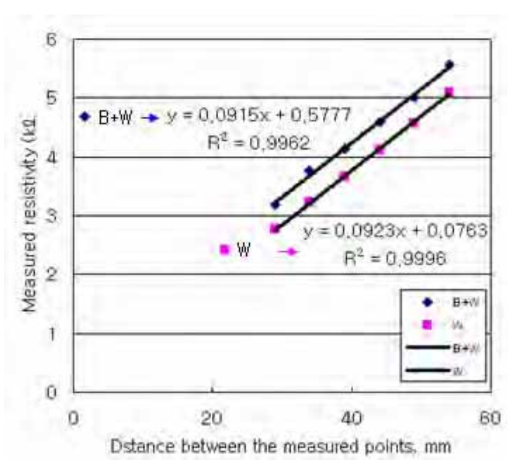

Figure 9. Measured resistivity $R_{A\text{-}A'}$ as a function of distance between the points in Figure 7

Figure 9 shows the measured data with type 2 pattern, where the difference of the measured value for each cases were evaluated as about 500Ω. So, $R_{B\text{-}C}$ is a half of 500 Ω, that is 250Ω.

This is large value considering that for 42" PDP panel, the line resistivity between the two terminals for 1m long BUS electrode line is 50~100 Ω.

4. Conclusion

The contact resistivity of the black interlayer between BUS and ITO electrode was evaluated using two kinds of the test electrode patterns. Type 2 pattern was more successful to show the contact resistivity, which was calculated as 250 Ω for the test pattern.

This result offers a quantitative way of evaluating the contact resistivity between ITO and BUS electrodes, which enables us to optimize the black interlayer in a way of combining blackness and electrical properties.

5. Acknowledgements

This work was supported by the academic research fund of Hoseo University in 2006.

6. References

[1] Lawrence E. Tannas, “Flat panel displays and CRTs”. Van nostrand reinhold company, New York, 1985.

[2] M. A. Lampert and A. Rose, “Transient Behavior of the Ohmic Contact”. RCA Laboratories, Princeton, New Jersey, 1958