Characteristics of the closed microhollow cathode discharge for DC Plasma Display Panels

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Abstract

The positive slope of the current-voltage characteristic at pressure up to 850 torr was obtained using the closed microhollow cathode without the individual and/or distributed ballast. This indicates that the stable parallel operation of the discharge was also achieved using the closed microhollow cathode. The parallel operation makes it possible to manufacture dc plasma displays with high pressure, small discharge current, and long lifetime.

Introduction

DC Plasma display panels are considered as the most promising option for meter wide and wall hanging HDTV due to the feasibility of large panel production, fast operation speed. etc [1]. In spite of these advantages, DC plasma displays have experienced some problems with short lifetime due to the dc sputtering, resulting in poor output maintenance [2]. The sputtered cathode materials deposited on the surface of the front glass reduce not only the transmission through the glass but also the coupling of the gas radiation and the phosphor, which decreases the luminance [1]. Also, geometric complexity including a current limiting resistor to control the discharge current in each cell or auxiliary cells is an obstacle to commercialize the dc plasma display panels. One way to prevent the sputtering is to increase the pressure, which reduce the sputtered cathode materials to reach the front glass. The other way is to decrease the discharge current, which not only limits the glow to arc transition but also keeps the power level reasonable. In addition, the pressure is related to the lifetime of dc plasma displays. There has been some researches related to discharge that is operated at the high pressure. The microhollow cathode discharge is operated at the atmospheric pressure and even higher pressure. But microhollow cathode discharges are operated at the hollow cathode discharge mode showing the negative slope of current-voltage characteristic. Although the microhollow cathode discharge showing the positive current-voltage slope is discovered, its gas pressure is below 100 torr and it then operate at townsend discharge mode [3]. Recently, parallel operation of microhollow cathode discharge was achieved at the high pressure. But it needs the distributed ballast [4]. This letter mainly focuses on the closed microhollow cathode having the positive slope at pressure over 760 torr and then the stable parallel operation without the individual current limiting resistor and/or distributed ballast. And it shows that the change of the diameter in hole results in the control of discharge current. This means that microhollow cathode discharges with closed structure make it possible to manufacture the DC PDP with high pressure, small discharge current, and long lifetime

Experimental

The electrical and optical measurements of the closed micro hollow cathode discharges were performed to confirm the characteristics of the discharge in the range of 70-850torr pressure. Two closed spaced electrodes with the cylindrical cathode openings of 200 and 500μm in diameter respectively with one and four holes have been fabricated in metal/dielectric/metal system. All of the electrodes were electroplated with 30μm thickness and separated by an alumina spacer of 200 μm. These were operated in the Helium ambient. The current was recorded directly by computer interfacing varying the voltage at a speed of 1.0V/s. 100kohm was used to measure the IR drop by the product of current and resistance in the electrical circuit. And discharge cell voltage was calculated by IR drop to observe the resistive behavior of discharge as follows.

$$V_{cell} = V_{source} - IR$$

Results and Discussion

The current-voltage characteristics of a He gas discharge in the closed and the open microhollow cathode with 200 and 500 μm respectively are compared in Fig.1 and Fig.2.

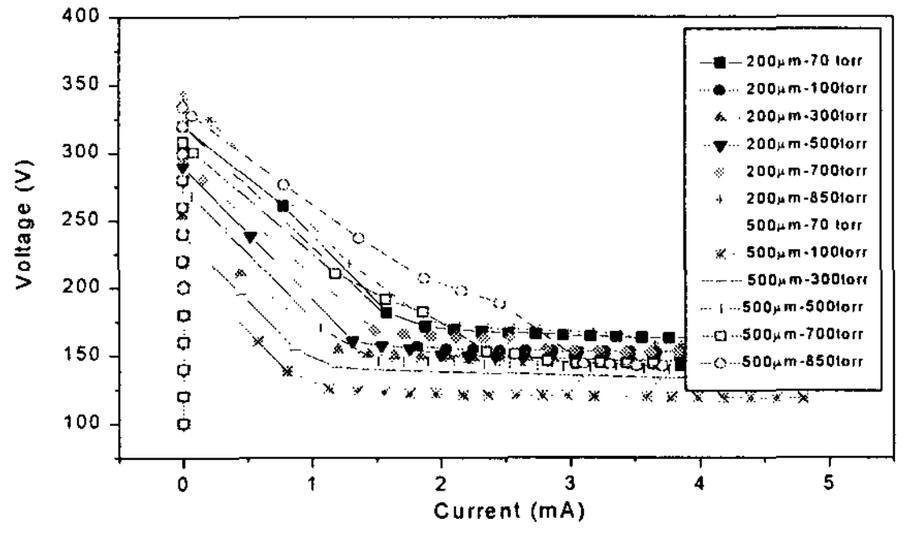


Fig.1. The current-voltage characteristics of the open micro hollow cathode discharge with 1 hole over the range of 70-850 torr in 200 and 500μm

The cell current is the current flowing through one discharge cell. The cell voltage is the discharge voltage applied between the anode and cathode. In Fig.1, the open microhollow cathode discharge has an almost flat current-voltage characteristic at the entire pressure. Generally speaking, the plasma volume is reduced due to the smaller mean free path at high pressure and the area of the cathode covered by the plasma is small. Increasing the current through the discharge results in an increase of the area covered by the plasma. Cathode fall and discharge voltage is relatively constant. Discharge current increases but discharge voltage is constant. This region is referred to as a normal glow discharge [5]. Compared with the closed microhollow cathode, the open microhollow cathode has very wide cathode area. The flat and the negative slope of open

micro-hollow cathode result from the large area of the cathode due to the open structure. As a result, increasing the voltage is used to broaden the cathode surface covered by the plasma and therefore shows an almost flat current-voltage characteristic.

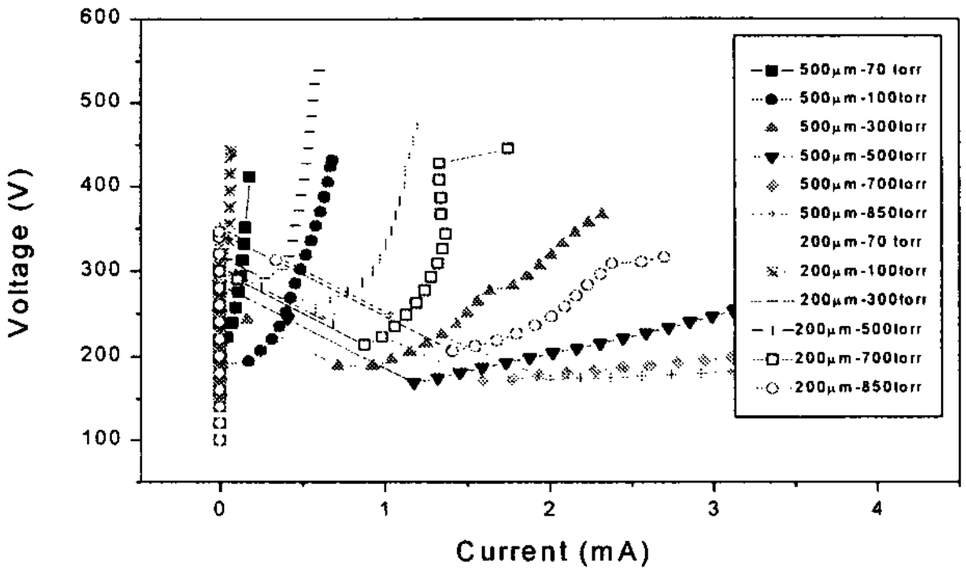
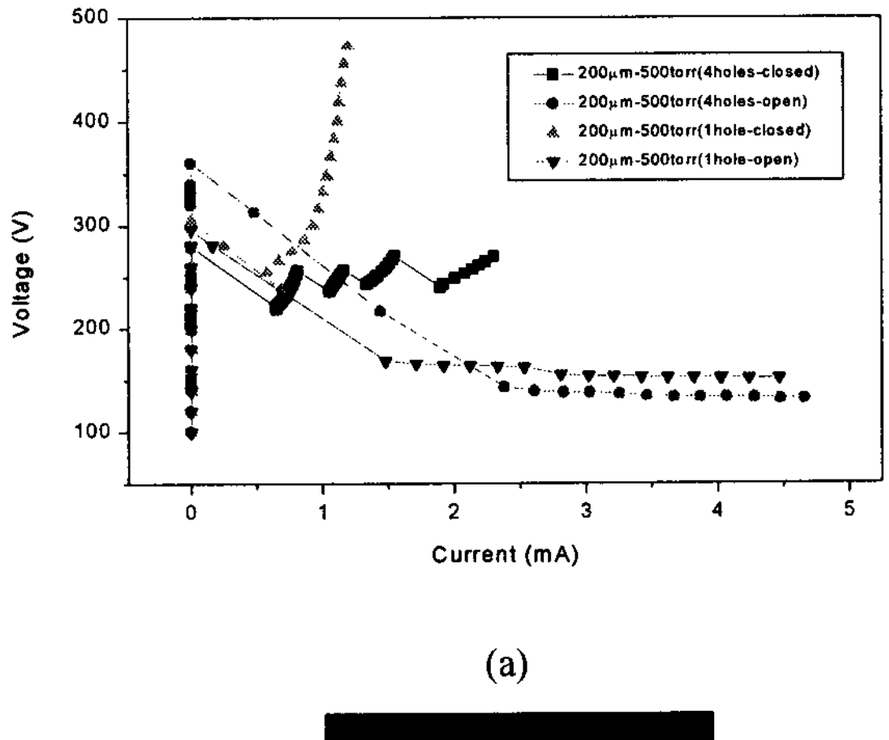


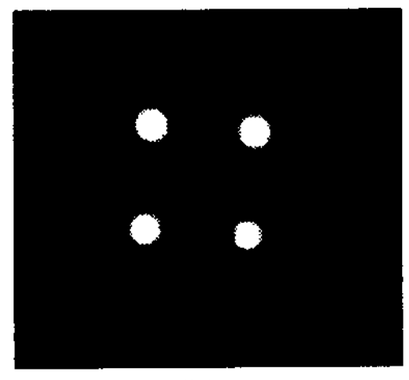
Fig.2. The current-voltage characteristics of the closed micro hollow cathode discharge with 1 hole over the range of 70-850 torr in 200 and 500μm.

Apart from the open microhollow cathode discharge, the closed microhollow cathode discharge shows the positive characteristics of current-voltage at the entire pressure. As shown in Fig.2, reduction of the cathode area originated from the closed structure results in the direct transition to the abnormal region without passing through the normal discharge regime. Because of the smaller cathode area, microhollow cathode discharge confined inside the holes has already spread to the entire cathode surface. Increasing the discharge power results in an increase of current without any increase of discharge area, so the cell voltage also increase [5]. The current-voltage characteristic therefore shows the positive slope. This means that the discharge itself plays a role of the resistor having the resistance corresponding to the slope of current-voltage characteristic. It is self-stabilized. The change of the slope generated from the shrinkage of plasma through the increase of pressure can be avoided by the decrease of microhollow cathode surface. In general, the lifetime is longer for lower cell currents and voltages, which reduce the sputtering, and high pressure, which reduces the transport of the sputtered material. So the discharge current is controlled without any current limiting resistors. This allows manufacturing the dc PDP without the individual resistor in each cell using the closed microhollow cathode. Also fig.2 shows that the smaller diameter has the more positive slope than that of the larger one. And as the pressure increases, the slope of current-voltage decreases. Considered the same resistivity as a property of gas at the same gas and pressure, the discharge resistance is inversely proportional to the cathode area. The increase of the amount of ionization accounts for the decline of current-voltage slope induced by the increase of pressure

Fig.3 shows the parallel operation of the closed microhollow cathode discharge in the array of holes. When the slope of current-voltage characteristic is positive, the parallel operation is obtained. But the negative slope of current-voltage characteristic of the open microhollow cathode discharge makes plasma ignite in a hole. In case of the positive characteristic, because the discharge itself plays a role of resistor, current is distributed to the array of holes.



(a)



(b)

Fig.3. (a) The current-voltage characteristics of the open and the closed micro hollow cathode discharge with 4 holes for 200μm and 500torr (b) A photograph of the parallel operation of the closed microhollow cathode discharge in four holes

Conclusion

The positive slope of current-voltage characteristic is obtained using the closed microhollow cathode at pressure up to 850 torr for 200μm diameter. It indicates that individual current limiting resistor and distributed ballast are not required in each cell of dc PDP. And reduction of the cathode dimension can control the discharge current. Hence, the closed micro hollow cathode discharge makes it possible to attain the dc plasma display panels with high pressure, small discharge current, and long lifetime.

References

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