Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Field Emission Characteristics of Oxidized Porous Poly-silicon Field Emitters Using a Tungsten Bottom Electrode

In-Ho Jang [a], Jin Eui Kim [a], Gwon-Heon Ryu [a] & Sie-Young Choi [a]

[a] School of Electrical Engineering & Computer Science, Kyungpook National University, Daegu, Korea

Version of record first published: 18 Mar 2009

To cite this article: In-Ho Jang, Jin Eui Kim, Gwon-Heon Ryu & Sie-Young Choi (2009): Field Emission Characteristics of Oxidized Porous Poly-silicon Field Emitters Using a Tungsten Bottom Electrode, Molecular Crystals and Liquid Crystals, 499:1, 160/[482]-168/[490]

To link to this article: http://dx.doi.org/10.1080/15421400802620105

Mol. Cryst. Liq. Cryst., Vol. 499, pp. 160/[482]–168/[490], 2009

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400802620105

Taylor & Francis
Taylor & Francis Group

Field Emission Characteristics of Oxidized Porous Poly-silicon Field Emitters Using a Tungsten Bottom Electrode

In-Ho Jang, Jin Eui Kim, Gwon-Heon Ryu, and Sie-Young Choi
School of Electrical Engineering & Computer Science, Kyungpook National University, Daegu, Korea

We fabricated oxidized porous polysilicon (OPPS) field emitters to apply a large device using a metal bottom electrode instead of the n^+ doping method and in process condition below 600°C. An OPPS field emitter that has minute pixel structures was operated by individual unit pixels. A non-doped polysilicon layer 1.5 μm was deposited on tungsten as a bottom electrode and anodized to form OPPS structures in a solution of HF (49%): ethanol in a 1:1 ratio for the porous process and 1 M H_2SO_4 for the electrochemical oxidation (ECO). The porous process and ECO process for poly-silicon were performed with various current densities and process times due to altered polysilicon film properties. The highest emission efficiency was investigated when the porous condition was 5 mA/cm^2, 5 sec and the oxidation process was 5 mA/cm^2, 30 sec.

Keywords: electrochemical oxidation; field emission display; field emitter; porous polysilicon; tungsten bottom electrode

INTRODUCTION

To overcome the limitations of a conventional cathode ray tube (CRT), various flat panel displays (FPDs) have been developed. Although the rapid progress of PDPs (plasma display panel), LCDs (liquid crystal display) and OLEDs (organic light emitting device) technologies have been accelerating to FPDs in order to replace CRTs, there are still constant demands for a new FPD technology that can realize a higher natural picture as well as a lower power consumption. Field emission

Address correspondence to Sie-Young Choi, School of Electrical Engineering & Computer Science, Kyungpook National University, Sangyuk-dong, Bukegu, Daegu 702-701, Korea (ROK). E-mail: sychoi@ee.knu.ac.kr

displays (FEDs) [1–2] with various geometric structures have also been studied intensively to obtain a longer viewing time and a higher resolution and a luminance. Recently, a new field emitter [3–5], OPPS (oxidized porous poly-silicon), was proposed as the most promising candidate for the field emission display because of its simple fabrication process, stable performance at a lower vacuum atmosphere, and a highly directional electron emission at a low voltage of 20 V [3–7]. Although OPPS has been proposed, there are still many issues to overcome. Emission efficiency is below 1% due to a large leakage

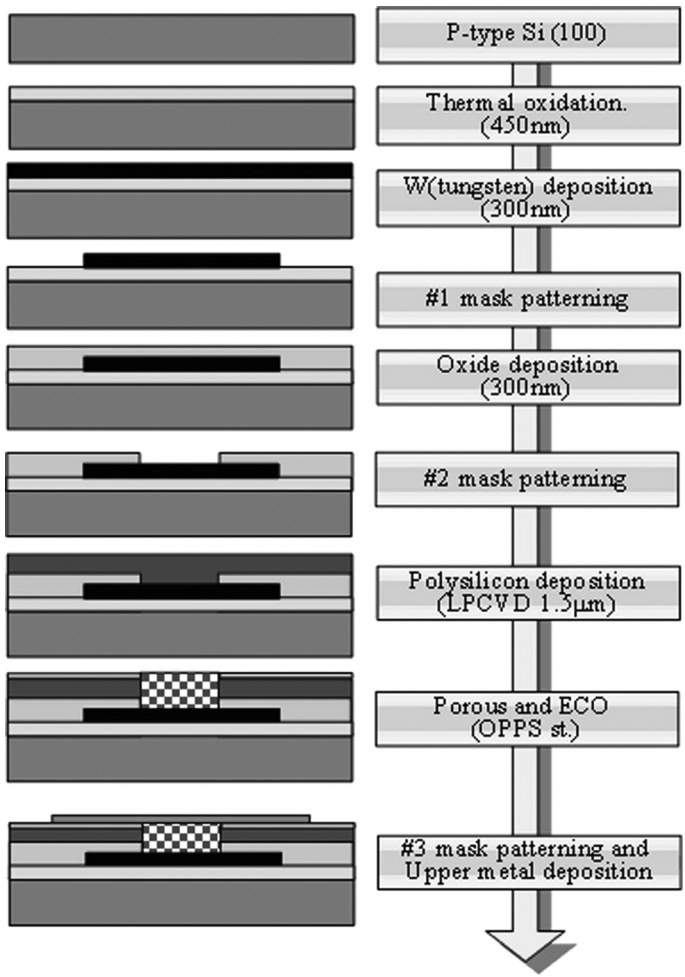


FIGURE 1 Fabrication procedure of the OPPS field emitter.

current and the device doesn't have functional reliability because of a thin top electrode of below 10 nm. Therefore, the OPPS field emitter needs to be investigated on its application as a display device. In this study, we investigated the field emission characteristics in accordance with various porous and electrochemical oxidation conditions of an OPPS field emitter as they apply to a large area display device using tungsten as a bottom electrode.

EXPERIMENTAL

Figure 1 shows the process procedure for the fabrication of the OPPS field emitters used in this work. To isolate between the substrate and bottom electrode, the field oxide was thermally grown on a p-type silicon wafer with a thickness of 450 nm. A tungsten (W) layer with a thickness of 300 nm was deposited on oxidized p-type silicon wafer by the DC sputtering method. Subsequently, to define the OPPS region, silicon dioxide was deposited and patterned on the 177 lines patterned as a W using a plasma enhanced chemical vapor deposition (PECVD) method. Figure 2 shows optical photograph of minutely patterned pixels. The size of an each pixel is $110 \times 400\,\mu m$. To deposit polysilicon with a thickness of 1.5 urn on minutely patterned pixels, a low pressure chemical vapor deposition (LPCVD) was used at 585°C. The high temperature processes have to consider the properties of substrate. So, this temperature which was used to deposit polysilicon

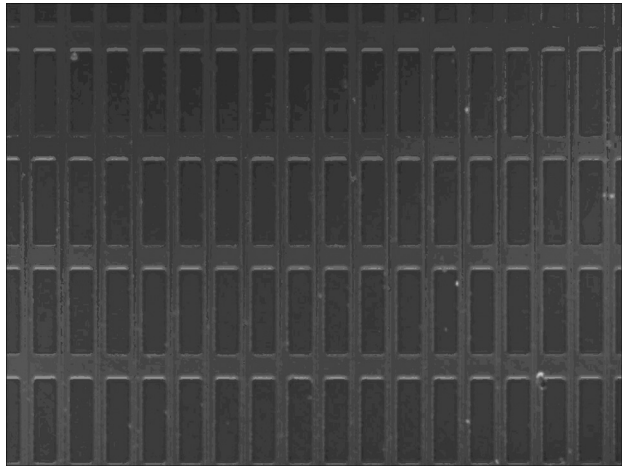


FIGURE 2 The optical photograph of minutely patterned OPPS pixels ($400 \times 110\,\mu m$ in size).

means the limitation degree that the glass can bear up against heat mechanically. The polysilicon layer was anodized in HF (49%): ethanol = 1:1 solution at a current density and process time with various conditions. After the porous process, porous polysilicon was oxidized by an ECO process, a low temperature oxidized process, to apply the glass substrate [7]. The ECO process was processed at $5\,mA/cm^2$, for various times. To improve the field emission characteristics of the OPPS emitter, we performed the thermal annealing at 580°C, 2 h with O_2 atmosphere. Finally, the top electrode (Pt/Ti = 7 nm/2 nm) was deposited by the DC sputtering method.

Figure 3 shows the schematic diagram and electrical setup for the investigation of the electrical characteristics of the OPPS field emitter. The electrical characteristics of OPPS field emitters were investigated in a vacuum chamber at a pressure of 1×10^{-4} Torr and with a space of 3 mm between the anode ($V_A = 1.2\,kV$) plate and the OPPS samples. The diode-voltage (V_{ps}) across the OPPS layer was varied from 0 to 20 V, and the emission efficiency ($100 \times I_c/I_{ps}$) was calculated from the ratio of the emission current (I_c) to the driving current (I_{ps}), current flow to the top electrode through the OPPS layer.

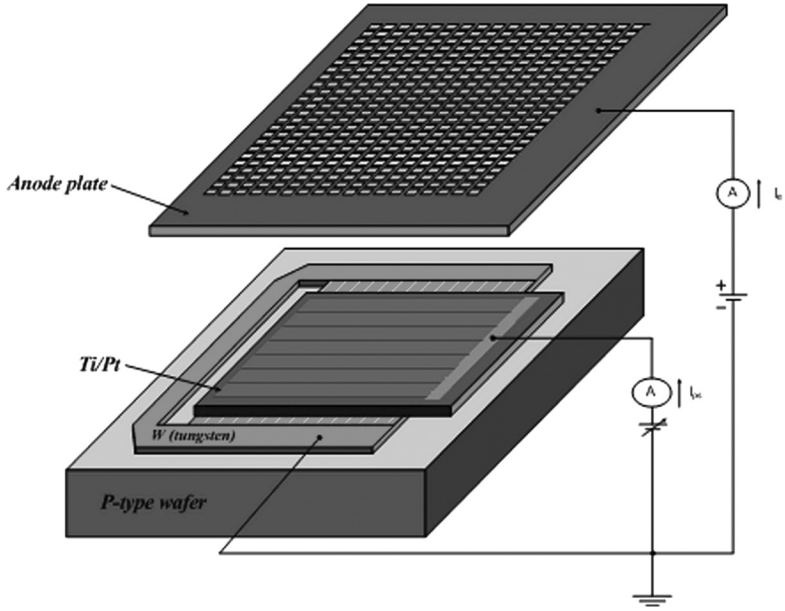


FIGURE 3 Schematic diagram of the OPPS field emitter and the electrical connection for the analysis of field emission characteristics.

RESULTS AND DISCUSSION

Figure 4(a) shows the relationship between the current flow through the OPPS layer (I_{ps}) and the emission current (I_c) according to the time of the ECO process. Figure 4(b) shows the electron emission efficiency

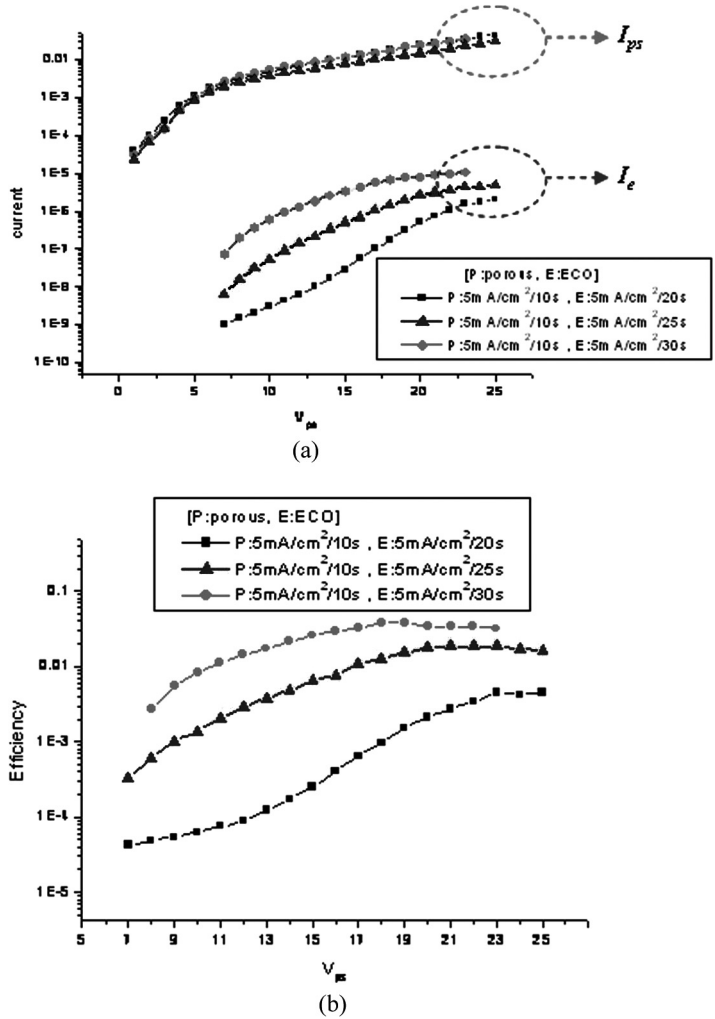
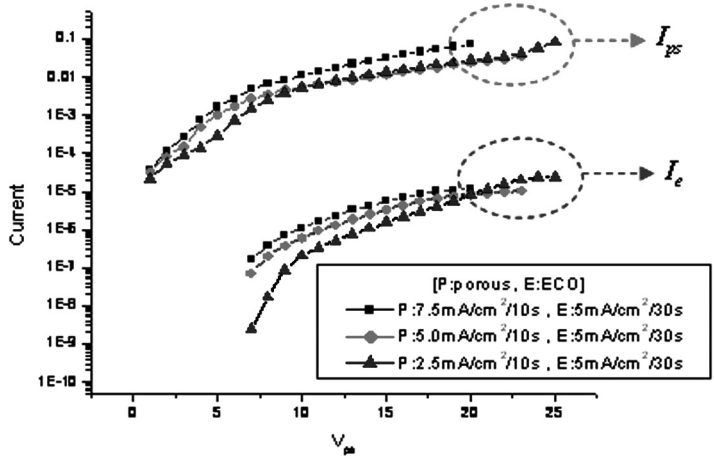
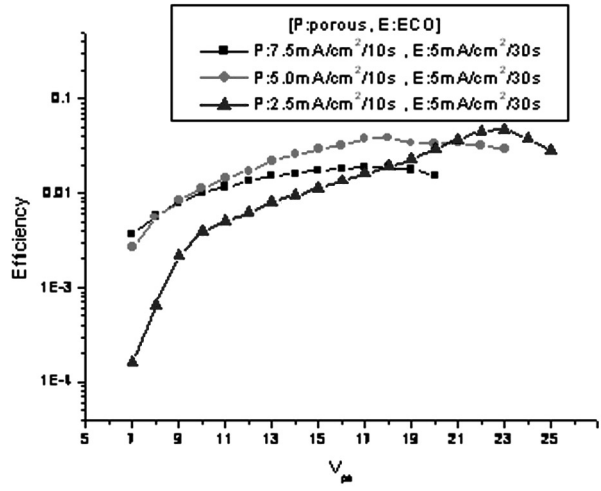


FIGURE 4 The electrical characteristics of the OPPS field emitters with various times of the ECO process, (a) Relationship between the driving current I_{ps} and emission current I_e, and (b) emission efficiency.



(a)



(b)

FIGURE 5 The electrical characteristics of the OPPS field emitters with various current densities of the porous process. (a) Relationship between the driving current I_{ps} and emission current I_c, and (b) emission efficiency.

$(100\, I_c/I_{ps})$ of the OPPS emitter. The emission characteristics were investigated at 20, 25, and 30 sec at $5\,mA/cm^2$. Also, the porous process was operated at 5 mA/cm, 10 sec as the same condition. The emission current (I_c) and the emission efficiency were increased in accordance with an increase in the time of the ECO process

respectively. Although a similar I_{ps} appeared, the number of the accelerated electron was fewer due to the thinner oxide layer.

Figures 5(a) and (b) show the field emission characteristics according to the current density of the porous process conditions which were investigated at current densities of 7.5, 5.0 and 2.5 mA/cm^2 for 10 sec. The best stable emission efficiency was observed when the current density was 5.0 mA/cm^2. To obtain a stable electron emission, the

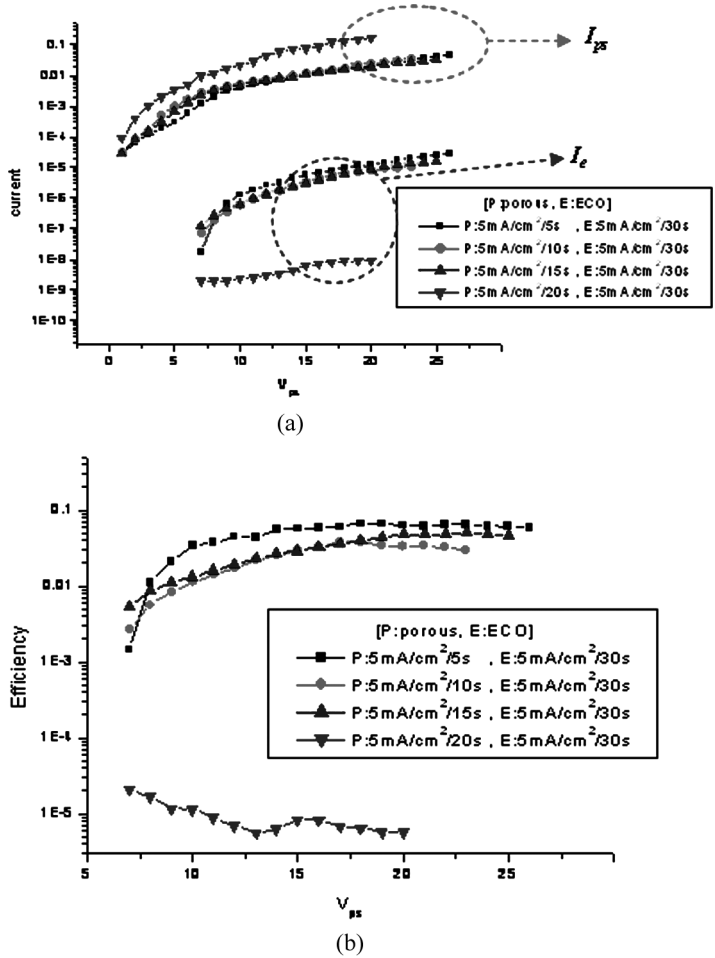


FIGURE 6 The electrical characteristics of the OPPS field emitters with various times of the porous process. (a) Relationship between the driving current I_{ps} and emission cuirent I_c, and (b) emission efficiency.

relatively high V_{ps} was required at 2.5 mA/cm^2 because the porous poly-silicon was not deeply formed. Figures 6(a) and (b) show the field emission characteristics according to the porous process times such as 5, 10, 15 and 20 sec. The emission efficiency was getting worse at 20 sec in comparison with 5, 10, and 15 sec because the pore area expanded in accordance with the increase in the porous process time. Therefore, the highest emission efficiency was observed at 5 sec due to the increased emission area. To demonstrate the applicability of the display devices, we measured the brightness on the green phosphor-coated ITO glass plate in a vacuum. Figure 7 shows the light emission pattern of the OPPS field emitter using a tungsten bottom electrode at V_{ps} = (a) 8 V, (b) 12 V, (c) 16 V, respectively. At that time, the brightness is 320 cd/m^2 at V_{ps} = 16 V. At a distance of 9 mm between the OPPS sample and phosphor plate, we can observe a uniform array of squares which show the vertical electron emission of the OPPS field emitter.

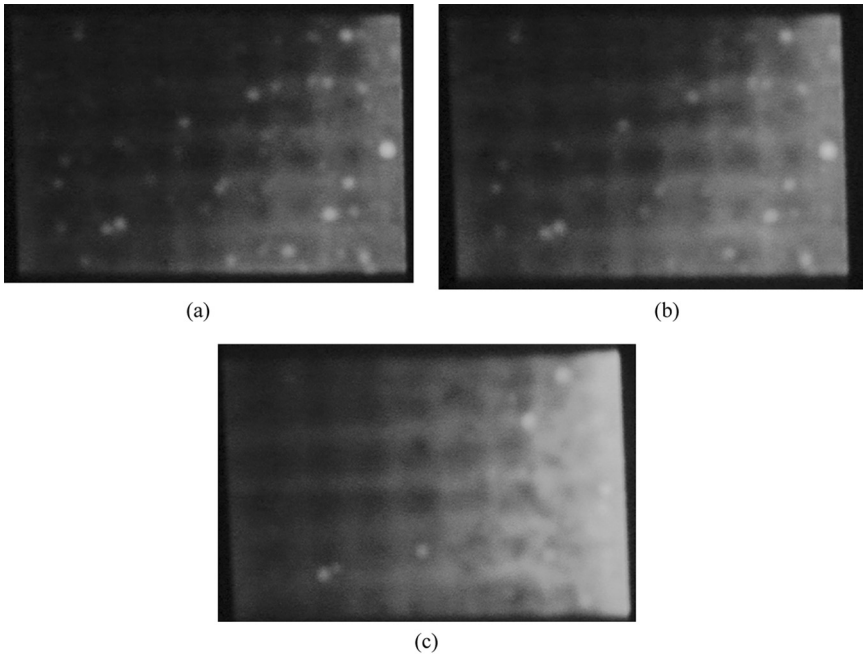


FIGURE 7 Excitation characteristics of P22 green phosphor using OPPS field emitter when the V_{ps} is (a) 8 V, (b) 12 V, (c) 16 V.

CONCLUSIONS

We fabricated OPPS field emitters to apply a large device such as glass using a metal bottom electrode and low temperature processes. The OPPS field emitter has an individually operating minute pixel with Pt/OPPS/W/Substrate structures. The polysilicon was deposited at 585°C to form OPPS. This temperature means that the glass can bear up against heat mechanically. The porous process and ECO (electrochemical oxidation) process for poly-silicon were performed with various current densities and process times due to altered polysilicon film properties. The highest emission efficiency was observed when the porous process was $5\,mA/cm^2$, 5 sec and the ECO process was $5\,mA/cm^2$, 30 sec. As a result of the excitation characteristics of P22 green phosphor, the field emission characteristics of the OPPS emitter also demonstrated good uniformity for pixel size of $110 \times 400\,\mu m$. Accordingly, the OPPS field emitters using a tungsten bottom electrode will be sufficiently applicable on glass using the same condition.

REFERENCES

[1] Spint, C. A., Brodie, I., Humphrey, L., & Westerberg, E. R. (1976). *J. Appl. Phys.*, *47*(12), 5248–5263.
[2] de Heer, W. A., Chatelain, A., & Ugarte, D. (1995). *Science, New Series*, *210*, 1179.
[3] Koshida, N., Sheng, X., & Komoda, T. (1999). *Applied Surface Science*, *146*, 371.
[4] Bae, S. C., Han, S. K., & Choi, S. Y. (2003). *Journal of the Korean Physical Society*, *43*, 1053.
[5] Bae, S. C. & Choi, S. Y. (2006). *Microelectronics Journal*, *37*(2), 167–173.
[6] Nakajima, Y., Toyama, H., Uchida, T., Kojima, A., & Koshida, N. (2003). *Japan Journal of Applied Physics*, *42*, 2412.
[7] Cho, Y. S., Kown, S. I., Bae, S. C., & Choi, S. Y. (2006). *Mol. Cryst. Liq. Cryst.*, *459*, 179–190.