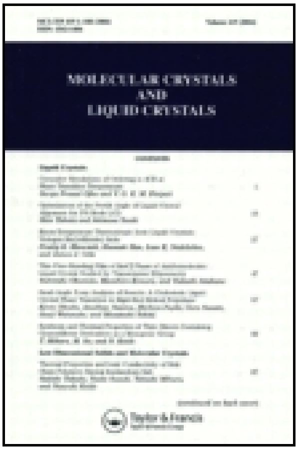

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The Field Emission Characteristics of a Unit Pixel of a 7 × 7 Array Oxidized Porous Polysilicon Field Emitter

Sung Won You [a], Jin Eui Kim [a], In Ho Jang [a], Sie-Young Choi [a] & Young-Soo Sohn [b]

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

[b] Daegu Gyeongbuk Institute of Science & Technology, Daegu, Korea

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Sung Won You
Jin Eui Kim
In Ho Jang
Sie-Young Choi
School of Electrical Engineering & Computer Science, Kyungpook National University, Daegu, Korea

Young-Soo Sohn
Daegu Gyeongbuk Institute of Science & Technology, Daegu, Korea

We fabricated oxidized porous polysilicon (OPPS) field emitters and investigated their field emission characteristics using a Ti/Pt multi-layer electrode of different thicknesses and OPPS emitters, which were patterned in a 7 × 7 array. Each unit pixel of the 7 × 7 array OPPS on the field emitter, with a structure of Pt/OPPS/n-type Si, was in operation and their field emission characteristics were investigated using a thermal oxidation process with a Ti/Pt multi-layer electrode. A non-doped polysilicon layer 1.75 μm is deposited on a heavily doped n-type silicon wafer and anodized in a solution of HF (50%):ethanol in a 1:1 ratio. The Ti/Pt multi-layer electrodes were formed with different thicknesses using a DC sputter. The achieved higher emission efficiency of the Ti/Pt electrode, with thickness of 2 nm/7 nm was 1.57% at $V_{ps} = 20\,V$*. The investigated field emission characteristics of the unit pixel also demonstrated good uniformity.*

Keywords: 7 × 7 array; field emission display; field emitter; porous polysilicon

INTRODUCTION

Various flat panel displays (FPDs) have overcome the limitations of a conventional cathode ray tube (CRT). The rapid progress of PDPs (plasma display panel), LCDs (liquid crystal display) and OLEDs (organic light emitting device) has been accelerating to replace

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

everything from CRTs to FPDs. There are still constant demands, however, for new FPD technology that can realize higher natural pictures, as well as utilizing lower power consumption. FEDs (field emission displays) [1,2] have been studied with various geometric structures, in order to obtain longer viewing time and higher resolution and luminance. Recently, a new type of emitter [3,4], oxidized porous polysilicon (OPPS), was proposed as being the most promising candidate for field emission displays because of its simple fabrication process, stable performance in a lower vacuum atmosphere, and highly directional electron emissions at a low voltage of 20 V [3,5]. Although OPPS looks promising, there are still many issues it has to overcome. Its emission efficiency is below 2% due to a large driving current, and the sample is not reliable because of a thin metal electrode of below 10 nm. Therefore, the OPPS field emitter [5,6] needs to improve if it wants to be viable as a display device.

In this study, we investigated the field emission characteristics of different thicknesses of Ti/Pt multi-layer electrodes and each 7×7 array OPPS pixel.

EXPERIMENTAL

Figure 1(a) shows the procedure for the fabrication of the OPPS field emitters used in this work. The field oxide was thermally grown on a p-type (100) Si wafer with a thickness of 700 nm. The field oxide was patterned, and the P_2O_5 source was coated on to the 7 line patterned Si wafer in order to define the bottom electrode. After diffusion at 1100°C for 1 hr, the phosphosilicate glass (PSG) was removed, and a second oxide layer was grown and patterned to define the porous polysilicon (PPS) region. Low-pressure chemical-vapor deposition (LPCVD) was used to deposit polysilicon with a thickness of 1.75 μm at 625°C. The polysilicon layer was anodized in a HF (50%):ethanol = 1:1 solution with a current density of 10 mA/cm^2 for 15 sec. The thermal oxidation of the PPS layer was performed in a dry O_2 atmosphere with an O_2 flow rate of 3 l/min at 900°C for 60 min. The Ti/Pt upper electrode, with three different thicknesses of 2 nm/5 nm, 2 nm/7 nm and 2 nm/9 nm, was deposited on the 7 line using a DC sputter.

Figure 1(b) shows the schematic diagram and electrical setup that was used to investigate the electrical characteristics of the OPPS field emitter. Electrical characteristics were examined in a vacuum chamber at a pressure of 1×10^{-4} Torr, 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 between 0 V and 20 V, and

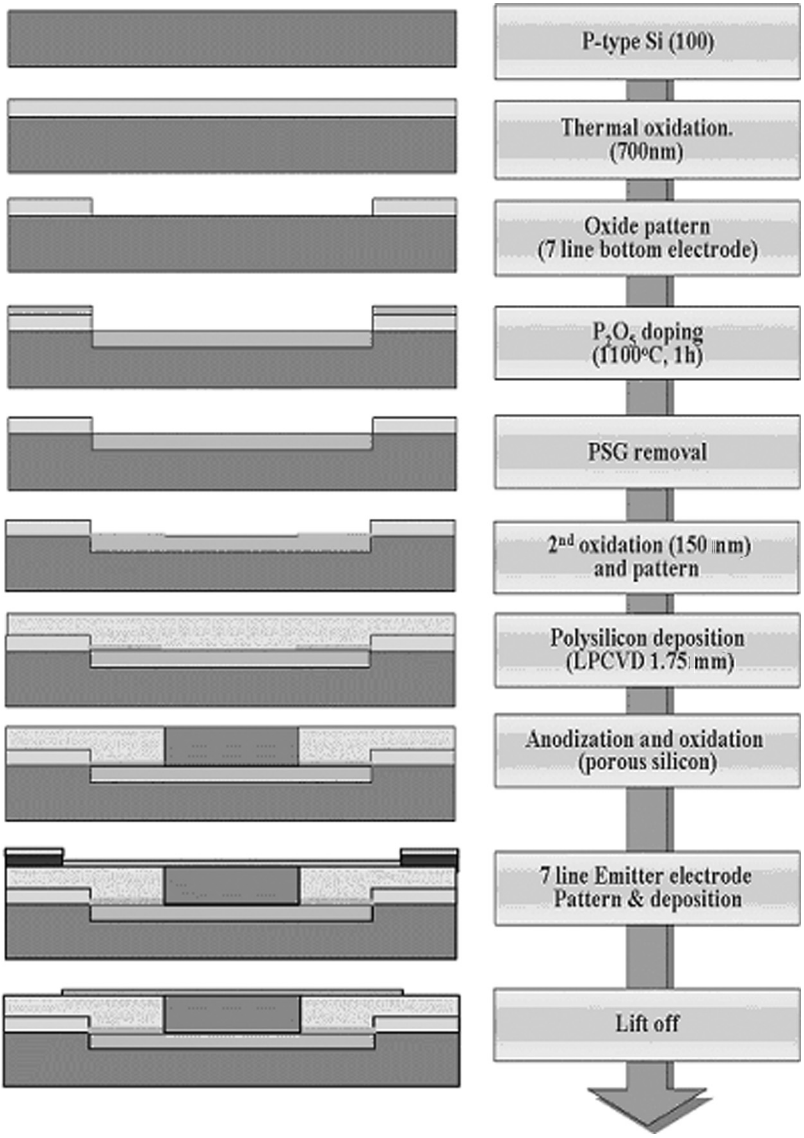


FIGURE 1 (a) The fabrication step of an OPPS field emitter and (b) a schematic diagram of the OPPS field emitter and the electrical connection for the analysis of its field emission characteristics.

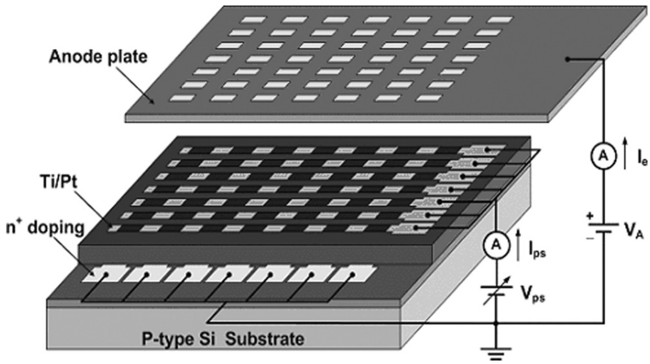


FIGURE 1 Continued.

the emission efficiency was calculated from the ratio of the emission current (I_e) to the diode current (I_{ps}, current flow through the OPPS layer). The light-emitting pattern was observed on a green phosphor-coated ITO (indium tin oxide) glass plate with an anode voltage of 3 kV. In addition, there was a space of 9 mm between the collector plate and the OPPS samples.

RESULTS AND DISCUSSION

To optimize the thickness of the Ti/Pt electrode, we investigated the field emission characteristics by varying electrode thicknesses. Figure 2(a) shows the relationship between I_{ps} and I_e for the different thicknesses of a Pt/Ti emitter electrode. Regarding the best sample, the electron emission in a vacuum starts at 7 V for V_{ps} and the amount increases with an increase in the V_{ps}. The starting point of the electron emission is in accordance with the abrupt increase of I_{ps}, which means that the hot electron generated by an applied electric field tunnels through the OPPS field emitters. The emission efficiency also increases with an increase in the V_{ps}, the emission efficiency is saturated 1.57% at a V_{ps} of 10 V. The 2 nm/7 nm Ti/Pt electrode showed the best emission efficiency.

Figure 3 shows the field emission characteristics of the unit pixels of a 7×7 array OPPS. We investigated the field emission characteristics of each unit pixel in order to confirm the uniformity. These characteristics were relatively uniform in each pixel. The uniformity error was about 40%. This amount was due to emission electron damage.

To demonstrate the applicability of the display devices, we measured the brightness of the green phosphor-coated ITO glass plate in

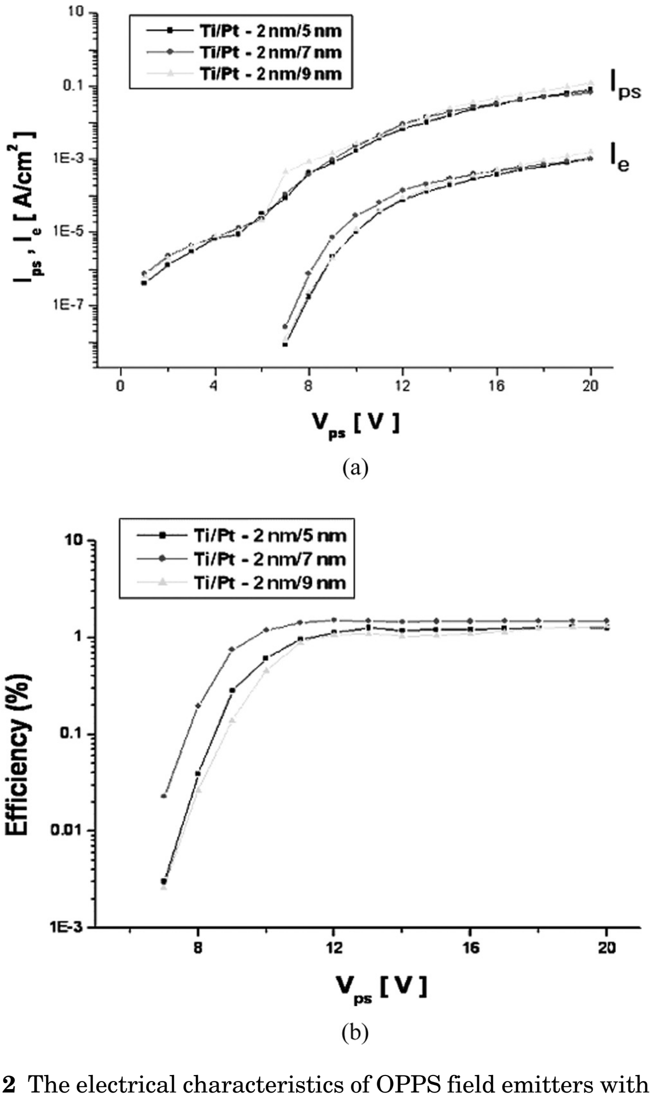
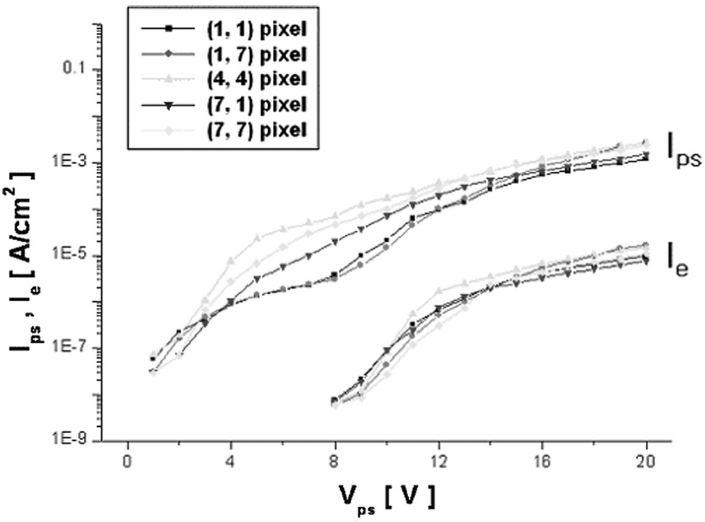
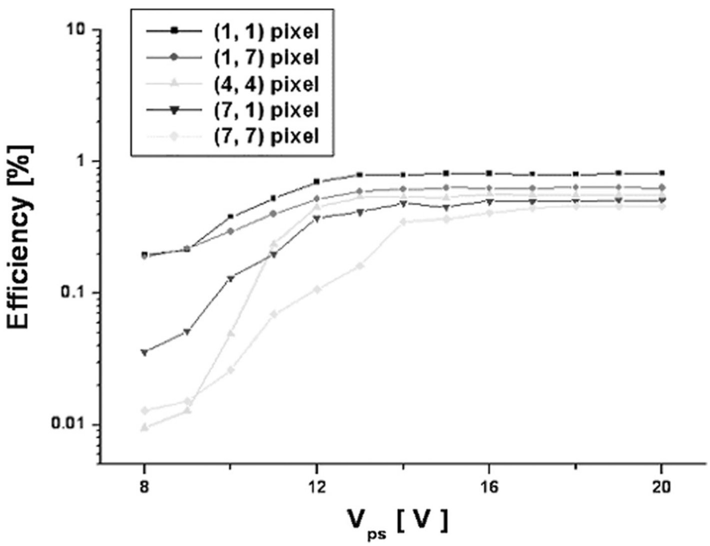


FIGURE 2 The electrical characteristics of OPPS field emitters with different electrode thicknesses; (a) relationship between I_{ps} and I_e, and (b) emission efficiency.

a vacuum. Figure 4 shows the light emission pattern of the Pt/Ti OPPS field emitter at a V_{ps} of 10 V, 15 V, and 20 V. With a 9 mm distance between the OPPS sample and phosphor plate, we could observe a uniform and clear array of squares, which show the vertical electron emission of the OPPS field emitter. An increase in the V_{ps} varies the



(a)



(b)

FIGURE 3 The electrical characteristics of each pixel in a 7×7 OPPS field emitter; (a) relationship between I_{ps} and I_e, and (b) emission efficiency.

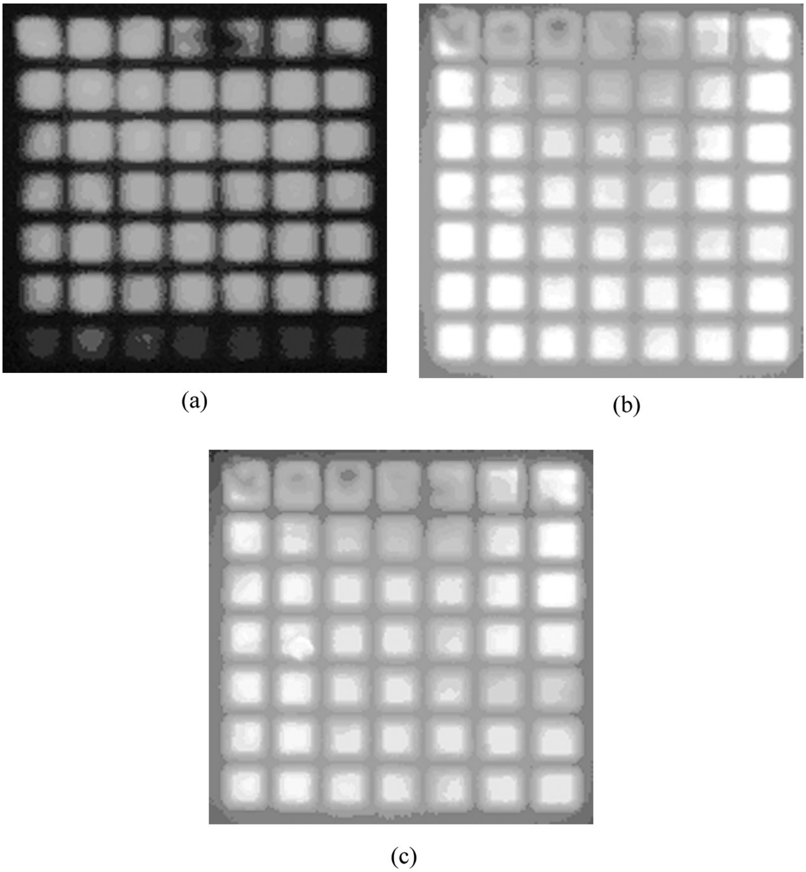


FIGURE 4 An emission photograph of OPPS field emitters with green phosphor; the V_{ps} is (a) 10 V, (b) 15 V and (c) 20 V. (See COLOR PLATE XVIII)

brightness of the emitter. The brightness increases linearly with the V_{ps}. These results show that the Pt/Ti OPPS field emitter is applicable to display devices.

CONCLUSIONS

We fabricated OPPS field emitters and investigated their field emission characteristics with a Ti/Pt multi-layer electrode of different thicknesses. The OPPS emitters were patterned in a 7×7 array. We could confirme that the most efficient thickness was 2 nm/7 nm. The sample showed the highest efficiency rate of 1.58% at a V_{ps} of 20 V.

Also, we could determine stable I_{ps} and I_e values for each pixel. Accordingly, the patterned 7×7 array can be applied to high quality field emission display devices.

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