FIELD EMISSION CHARACTERIZATION OF THE 10x10 SINGLY-ADDRESSABLE DOUBLE-GATED POLYSILICON TIP ARRAY

N.N. Chubun, A.G. Chakhovskoi, M. Hajra, and C.E. Hunt,
Electrical and Computer Engineering Department, University of California, Davis, CA. 95616,
Phone (530)-752-2735, Fax (530)-754-9217, e-mail: nchubun@ece.ucdavis.edu

INTRODUCTION

A conventional field-emission cell, which usually consists of an emission tip surrounded by a small aperture in an extracting electrode (grid), has very complicated electron-optical characteristics. Electron beam trajectories are influenced not only by the electric field formed between the emission tip and the gate, but also by the field in the proximity of the emission site. This problem can be effectively resolved by controlling the shape of the individual electron beams

It has been proposed in [1] that by fabricating the lens electrodes coaxial with each tip to form an electrostatic lens system, one could force all the electrons emitted from every tip of the array to travel in the same direction. Several researchers [2, 3] have calculated the design parameters (spacing, aperture radii and voltages) to meet these conditions. Focusing effect can be achieved by two approaches of integrating the focusing lens to the conventional gated field emission arrays. The first approach is a "coplanar type" focusing [4]. The focusing lens of the coplanar type is located around the gate electrode surrounding an emissive tip in the same plane. The other approach utilizes a vertical arrangement of an extraction and a focusing electrodes resulting in coaxial focusing [5].

Most of the modern electron beam-control systems for field-emission sources reduce the number of focusing electrons only to the first two grids. In this work, we also performed an attempt to fabricate a double-gated thin-film focusing system for addressable silicon-on-insulator field-emission structures, which we have developed using a subtractive technique [6].

EXPERIMENT

The schematic of the second gate integration into a polysilicon field-emission cell is shown in Fig. 1 a-d. After oxidation sharpening, the structure is coated with a polysilicon layer with a thickness of about 0.5 micron (Fig. 1 a). This layer is oxidized, producing an oxide thickness up to 0.5 micron on the top of the polysilicon. The oxidation changes the size and the shape of the tip, which is illustrated by the SEM micrographs (Fig. 1 b). The tip cap acquires an almost perfect spherical shape. This shape changes the shadowing effect of the cap, affecting the parameters of the next step - the deposition of the gold focusing grid (Fig. 1 c). The sequence of several etching steps removes the cap from the top of the structure and opens up the final emission cell (Fig. 1 d).

It has been found that with variation of the film thickness and the process conditions, two different types of emission cells could be fabricated. The first configuration is very close to the coaxial electron-optic type. Fig. 2 illustrates this configuration by the SEM micrograph (a) and the geometric depiction (b). Another type of the double-gated emission cell, of the coplanar type, is illustrated by Fig. 3 a, b. These two types of double-gated cells have significant differences in electron-optical properties, but both of them can be utilized in various types of microelectronic devices.The goal of the work is not limited by double-gated cathode cell fabrication, but also involves the design and fabrication of the 10x10 matrix test device along with packaging suitable for vacuum chamber tests. Fig. 5 shows the optical micrographs of the 10x10 field emission matrix device. The matrix consists of 10 vertical polysilicon stripes as cathode columns, and two layers of grid rows. The cathode columns have contact pads on both (upper and lower) ends, which is necessary for resistivity control. Contact pads for polysilicon extracting grids are located on the left side of the chip, and for the focusing gold grids - on the right side. The actual size of the matrix is 500 μm, with each stripe of 34 μm in width and 16 μm gap between them. The measured cathode line resistance was about 1 MΩ, extracting grid stripe resistance was nearly 200 kΩ, and gold stripe resistance did not exceed 6 Ω.

To provide a fair comparison, the focusing measurements were performed at constant anode current of 80 nA. The diameter of the observed light spot changes following the variation of the second gate voltage under constant anode current. Diffused spot of light of 2 – 2.5 mm in diameter is obtained under the same positive potential for the extracting and the focusing grids. The extracting and the focusing grid potentials were set to 15 V; the anode voltage was 500V. This condition is similar to the electron optics of a single-gated cell. Sharp and bright focused spot with the diameter of ~0.6 mm is obtained as a result of applying the ground potential (which is equal to the cathode potential) to the focusing grid. Under these conditions, the extracting grid voltage had to be increased to 230 V, and the anode voltage had to be increased to 800 V to keep the anode current constant. A visual linear size of the focused light spot was reduced by a factor of four. We consider this observation as a promising result demonstrating a proof of principle for the focusing technique.

0-7803-7197-6/01/$10.00

CONCLUSION

Double-gated focused field-emission arrays fabrication technology has been developed using the polysilicon-on insulator structure and subtractive technology previously designed. Both coaxial and coplanar double-gated focusing structures can be fabricated with minor variation of thin film thickness. The design of the field-emission cathode matrix with a wide range of built-in loading resistors and two independent gate electrodes was developed and tested. Significant focusing effect was experimentally observed under constant anode current conditions.

ACKNOWLEDGEMENTS

The Authors acknowledge the helpful input of Dr. Si-Ty Lam, Dr. Jim Brug and colleagues of Hewlett Packard labs. This work was funded through the DARPA-MTO MEMS program under contract agreement F30602-98-3-0232, administered by the US Air Force Material Command.

REFERENCES

1. D.L. Fraser, , U.S. Patent 3,753,022.
2. Chubun, JVST B, vol.13(2), 1995. pp. 589-92.
3. C.E. Hunt, IEEE Trans. Electron Devices, 42 (2), 1995, pp. 340-347,.
4. Y.Tohma, JVST B, 14(3), 1996, pp. 1902-1905,.
5. C.E. Hunt, , JVST B, 11, 1993, p. 518,.
6. N.N. Chubun, Solid State Electronics (to be published in 2001).

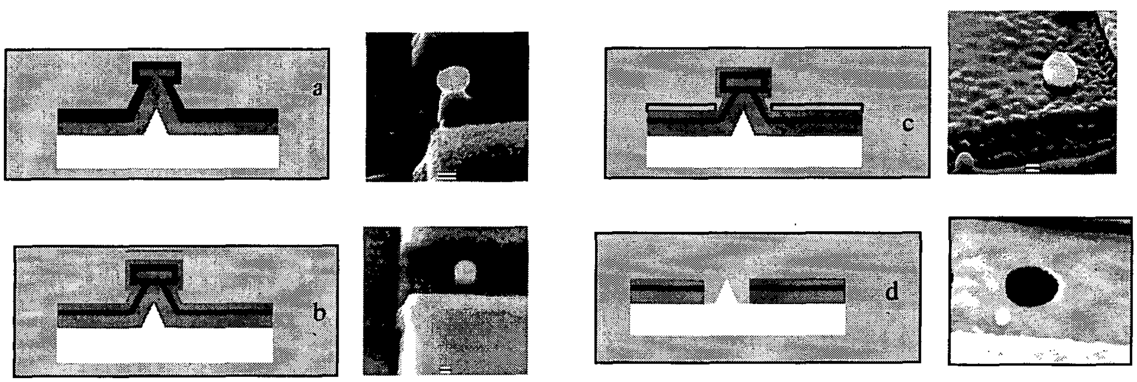

Fig. 1 The schematic diagram of the double-gated cell fabrication process.

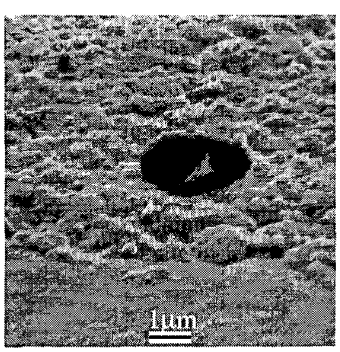

Fig. 2 . The coaxial type of focusing system

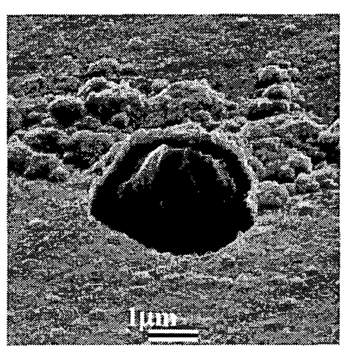

Fig. 3 . The coplanar type of focusing system

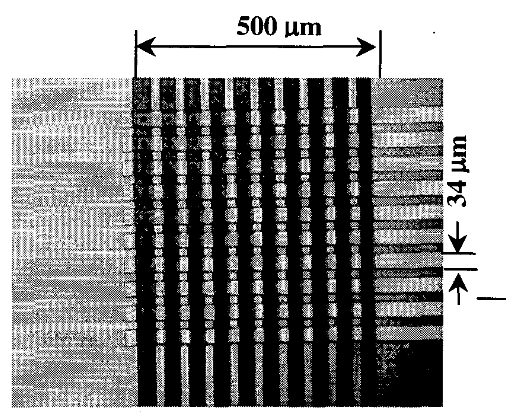

Fig. 4 . Optical micrograph (100X) of the 10x10 matrix.