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Microchannel plates for field emission displays

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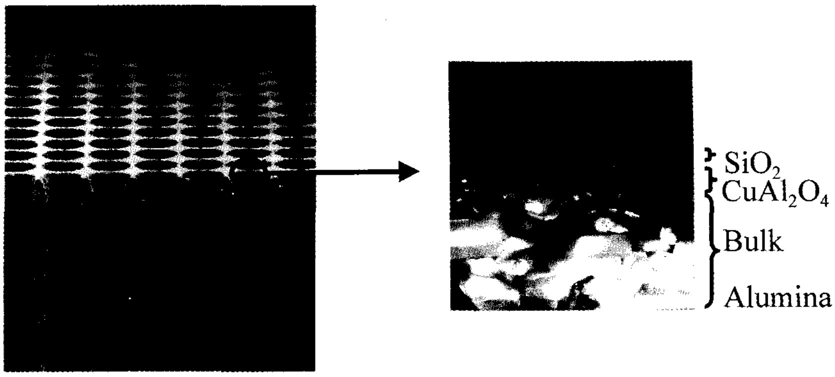
Abstract – Microchannel plates (MCPs) have been developed by introducing new materials and process technologies. Main body was made of alumina by programmable punching, laminating, and firing. The channel walls of pore arrays of an MCP were deposited with thin films by electroless copper plating and sol-gel process. Our MCP has advantages such as easy fabrication, durability, high temperature endurance, and applicability to the large size comparing with the conventional MCPs. Experiments on the brightness of an MCP incorporated FED revealed that the FED with a MCP is three to four times brighter than a conventional FED. Moreover, the focusing in a FED is improved. Incorporating an MCP into a FED is one of promising methods to enhance the characteristics of the FED. In addition, amplification yield of the MCP is measured for varying the aspect ratio and the input current.

Many flat panel displays (FPDs) have been proposed and manufactured these days, since cathode ray tubes (CRTs) are considered to have numerous problems for a wide area display due mainly to their large size and heavy weight [1]. One of important candidates for FPDs is a field emission display (FED). FEDs typically consist of a planar substrate with an array of field-emitters (cathode), extracting grids (gate), a phosphor plate (anode). One of the problems of such a FED [2, 3] is that relatively small numbers of electrons are incident from the cathode, and thus, the brightness of a FED is not sufficient. Additionally, unsatisfactory focusing of field-emitted electrons at the phosphor glass plate, resulting in blurred images and poor resolution.

In this work, a specifically developed electron multiplying microchannel plate (MCP) was incorporated into a FED to overcome the problems mentioned above. MCPs are two-dimensional arrays of microscopic channel multipliers and are operated by avalanche multiplication of secondary electrons. Typically conventional MCPs are aimed for amplifying input currents in the range of a few pA/cm^2 [4]. Thus, conventional MCPs may be inappropriate for amplifying electrons in a FED, since the typical current density of a FED is several μA/cm^2 [5]. Consequently, we have developed a new type of an MCP, which incorporates novel materials and the necessary manufacturing technology. The key features of our MCP is as follows; (a) bulk alumina is used as a substrate material, (b) channel location is defiend by a programmable-hole puncher, and (c) thin film deposition is conducted by electroless plating followed by a solgel process.

The body of an MCP was made of alumina from the tape casting method [6]. Dispersed alumina slurry was passed through a doctor blade to produce a greensheet. Micrometer-sized holes were made through the blank greensheets by a computer-programmable puncher (UHT, MP7150). The perforated layers of greensheets were stacked, aligned, and laminated in a flat-plate press. The laminated greensheet was fired at 1600°C to become poly-crystalline alumina. Using this process, we produced the body of the MCP, with 2 mm deep pores of 170 μm diameter on 220 μm centers, where the aspect ratio of the length to the diameter of the pore was chosen to be eleven (Fig. 1).

Within a capillary hole, the wall acts as a continuous dynode that supports avalanche multiplication of electrons when a bias voltage is applied between two end planes. The inside of walls is coated with an electron emissive layer on a resistive layer. Functionally, the emissive layer is responsible for emitting secondary

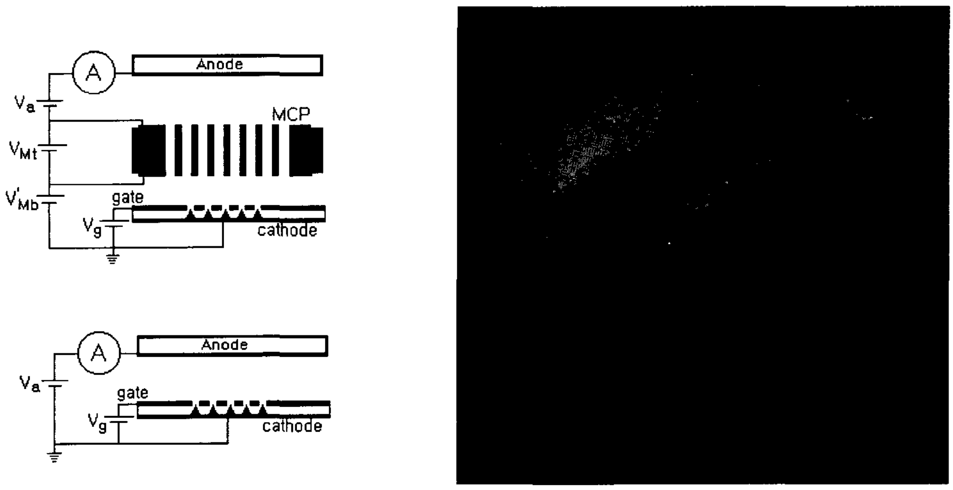


(a) (b)

Fig. 1. (a) Photograph of the pore arrays of our newly fabricated MCP and (b) an SEM cross-sectional view of the surface coatings on the pore wall, which is composed of an emissive layer (SiO_2) and a resistive layer ($CuAl_2O_4$) on an alumina substrate.

electrons upon bombardment of primary electrons, and the resistive layer facilitates the replenishment of electrons to the emissive layer.

Electroless copper plating [7] and a successive heat treatment formed a resistive layer of $CuAl_2O_4$ on the channel walls of each MCP pore. The efficacy of the coating, in terms of layer integrity, resistivity, and its ability to enhance the electron multiplication factor of the final unit, was proved to be significantly dependent upon the thermal treatment. The emissive layer (SiO_2) was formed upon the resistive layer using a sol-gel process [8], which was performed using an aqueous solution of tetraethyl orthosilicate containing alcohol and small amount of HCl. Successive heat treatment was used to remove the organic materials leading to the SiO_2 layer. The existence of $CuAl_2O_4$, and SiO_2 was confirmed by X-ray diffraction, thermal gravimetric analysis, scanning electron microscopy, and infrared spectroscopy (Fig. 1). Finally, both faces of the MCP were chemically-mechanically polished and coated with metal in an electron beam evaporator.



(a) (b)

Fig. 2. (a) Schematic circuit diagrams for a FED with and without an MCP (V_g = 80 V, V_a = 1200 V, V_{BOT} = 200 V, and V_{TOP} = 800 V). (b) The image of a 5.2-inch full-cathode panel with an MCP inserted in the upper half only. The upper half is brighter than the lower half due to the amplification and focusing effect of an MCP.

The MCP was incorporated into a FED and was characterized in terms of brightness and degree of focusing of a FED. A schematic diagram of the driving circuits for field emission measurement is shown in Fig. 2(a). A square wave pulse of width 100 μs, amplitude 80 V, and a duty ratio of 100 was applied to the gate. For a FED, DC voltages of 200 and 800 V were applied to the bottom (V_{BOT}) and top (V_{TOP}) faces of the MCP, respectively. Figure 2(b) shows a FED image with (upper half) and without an MCP (lower half). To make the comparison as direct as possible, only the upper half of the 5.2-inch full-cathode panel had an MCP inserted while the lower half did not. The brightness increased from 7.2 cd/m^2 for a FED without an MCP, to 25 cd/m^2 for one with an MCP. This comparison was performed on the same anode voltage for the two cases, that is, the kinetic energies of electrons arriving at the anode plate are the same regardless of presence of an MCP. The amplification of the number of electrons is confirmed by the brightness increase in a FED under the assumption that brightness is caused by multiplication of the number of electrons and their kinetic energies.

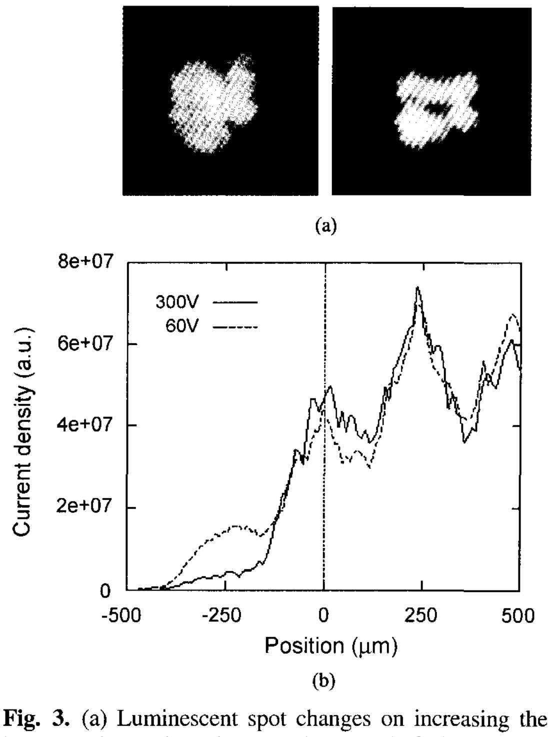


Fig. 3. (a) Luminescent spot changes on increasing the bottom voltage (the voltage on the cathode-facing side) of the MCP, i.e., V_{BOT} = 60 V and 300 V. (b) Monte Carlo simulation of electron profile for two V_{BOT}. The V_{BOT} = 300 V case clearly focused the field-emitted electrons through a MCP.

Experiments on electron focusing were also conducted using a newly fabricated MCP, and the results are shown in Fig. 3. Six pixels corresponding to an area 1650 μm×750 μm were chosen for the experiment. When the bottom voltage of the MCP was increased, the luminescent spots became smaller, brighter, and more clearly focused [Fig. 3(a) and (b)]. This implies that the electron beam was focused between the gate and the bottom of an MCP. In order to confirm this, brightness profiles of emission spots were calculated using the Monte Carlo simulation based upon the secondary electron emission model [9, 10]. When V_{BOT} was increased from 60 V to 300 V, the simulation demonstrated that the number of electrons passing through the edge pore decreased more rapidly. Thus, this simulation verified that the electron focusing is enhanced by inserting an MCP within a FED. We believe that the above results demonstrate that the MCP is eminently suitable for the enhancement of FED efficiency.

In order to characterize the MCP amplification factor itself, the amplification gain was also measured in the vacuum chamber [Fig. 4(a)]. The primary current (I_p) was supplied by an electron gun (Kimball Physics, EFG-7), and the amplified curent was detected at the anode which was biased 200 V higher than the MCP. Gains were measured by varying the aspect ratio of the MCP [Fig. 4(b)] or by varying the primary current [Fig. 4(c)]. The gain increased from 1.5 to roughly 125 as the aspect ratio of the MCP increased from 11 to 30. This is mainly due to the increase of the number of collisions within the micrometer-sized channel, which can be simply confirmed by the calculation [11]. However, only the qualitative agreement was obtained between the calculational and experimental results, that is, the calculated gain is roughly one hundred times higher than experimental one. It is mainly due to the fact that the high primary current was used to test performance of MCPs, since the output current at the anode (I_{anode}) was limited by the wall current of the MCP (I_{MCP}) which flowed through the resistive layer of the MCPs channel. This can be explained by the gain measurement by varying the primary current [Fig. 4(c)]. When the

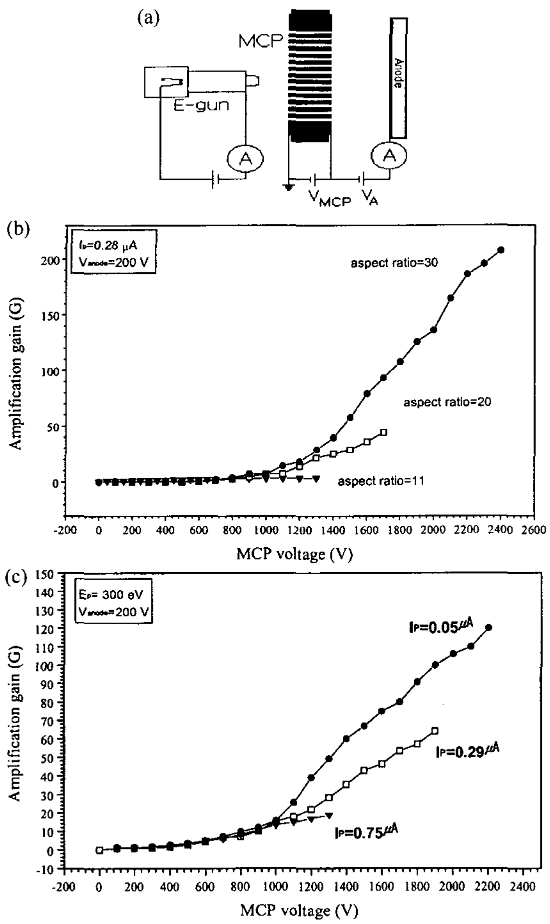


Fig. 4. (a) Schematic diagram for MCP gain measurement. (b) Amplification gain as a function of the voltage applied to the MCP. The aspect ratio of the MCP was varied from 11, to 20 and 30. The energy of the primary electron was chosen to be between 300 and 600 eV which yield the highest amplification gain. (c) Amplification gain by varying the primary current. The aspect ratio of the MCP was chosen to be 20.

primary current decreased from 750 nA to 50 nA, the amplication gain increased by six times. Thus, if the samller primary current was used, the amplification gain for our MCP will be much larger than the results of Fig. 4 (Experiment adopting a smaller primary current is undergoing.). The ratio of I_p to I_{MCP} was obtained to be less than 1%, while the ratio for the good MCP is reported to be around 10%. Consequently, this means that optimization processes is necessary and further experiments are required.

In concluding, we have developed an alumina based MCP in order to improve the characteristics of a FED. With the MCP inserted in a FED, the brightness of the FED increase three to four fold, and focusing of field-emitted electrons is enhanced. Therefore, incorporating an MCP into a FED is one of promising methods to improve the characteristics of a FED. In addition, amplification gain of a MCP was measured. It was found that the gain was dependent upon the aspect ratio of the MCP and the primary current.

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References

[1] L. E. Tannas Jr., *Flat-panel displays and CRTs* (Van Nostrand Reinhold, New York, 1985).
[2] H. F. Gray, Information Display **9**, 9 (1993).
[3] D. Cathey Jr., Information Display **11**, 16 (1995).
[4] J. L. Wiza, Nucl. Instrum. and Methods **162**, 587 (1979).
[5] A. Ghis, R. Meyer, P. Rambaud, F. Levy, and T. Leroux, IEEE Trans. Electron Devices **38**, 2320 (1991).
[6] J. U. Knickerbocker, Am. Ceramic Soc. Bull. **71**, 1393 (1992).
[7] O. B. Dutkewych, US patent 4695505 (1987).
[8] M. Langlet *et al.*, Thin Solid Films **221**, 44 (1992).
[9] Y.S. Choi and J.M. Kim, IEEE Trans. Electron Devices **47**, 1293 (2000).
[10] M. Ito, H. Kune, and K. Oba, IEEE Trans. Nucl. Sci. **NS31**, 408 (1984).
[11] J. Adams and B.W. Manley, IEEE Trans. Nucl. Sci **NS13**, 88 (1966).