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New type gate electrode of CNT-FED fabricated by chemical corrosive method

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Abstract: To obtain a triode structure canbon nanotube field emission display (CNT-FED), the glass plate which contains a glass channels matrix is designed and used as the triode part of the CNT-FED. Normally, the gate electrode can be fabricated with screen printing methods and a channels matrix can be fabricated by two-faced chemical corrosion. By adjusting the etch time and the concentration of acid in the process, different shapes of the tunnels can be obtained. The size and morphology of channels are observed by a scanning electron microscope (SEM), and the ingredients of the corrosion solution are detected by infrared ray (IR) analysis. Voltage is added to the triode structure for obtaining the brightness image of the spot on the screen. Eventually, the electron trace pulling from cathode to anode under an electric field is obtained by simulation. It is concluded that the simulation results accord with the experimental results which realize the optimized triode structure.

Key words: canbon nanotube field emission display (CNT-FED); gate electrode; chemical corrosion; glass hole

Nowadays, the CNT-FED has been drawing much attention. In principle, the FED shows a display quality that is very similar to that of the CRT. Another advantage is low power consumption due to a simple device scheme. Owing to high aspect ratios and small radii curvatures, the CNT exhibits excellent field emission characteristics[1–3]. In addition, the CNT can be mixed with other organic or inorganic materials and form a printable paste. By screen-printing and furring processes, the electron emission layer can be manufactured on a large substrate[4–5].

In a CNT-FED, a triode has to be designed to decrease the driving voltage. In recent years, the normal gate triode, the under gate triode, the remote gate triode and other triodes have been reported. This paper studies a CNT-FED with a novel gate electrode to improve the focus performance of the electrode beam.

1 Experiment

The CNT-FED device is composed of the cathode, the gate electrode, and the anode. Dielectric insulators and spacers are mounted between each electrode to avoid short circuits[6]. Magnesia is sputtering on the surface of the channels for high secondary electron emission. The triode structure is shown in Fig. 1.

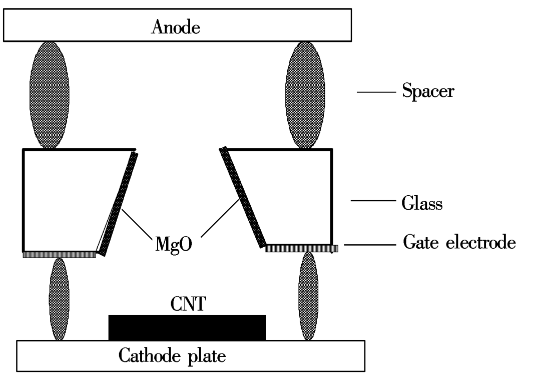

Fig. 1 The triode structure

In this paper, we report an efficient method to fabricate gate electrodes. This method represents a simple way to obtain glass channels.

We use HF mixed with sulfuric acid to etch the glass substrate. The concentration of HF is 40%. First, the glass substrate is cleaned with acetone, alcohol, some concentration of HF and de-ion water. The purpose of this step is to make the surface of the glass rougher and to obtain a good conglutination with the etching glue. Secondly, we put the etching glue on the surface and make the holes. Thirdly, the entire glass is put into the corrosion solution for about 100 min. Fig. 2 shows the relationship between time and the corrosion depth obtained by the experiments. After the corrosion, the glass substrates are removed from the solution. Finally, we clean the surface of the glass by removing the etching glue, and make the Ag electrodes on the glass substrate with matrix holes. Fig. 3 shows the infrared ray(IR) analysis of a glass substrate etched with holes. The SEM monograph of the hole is shown in Fig. 4.

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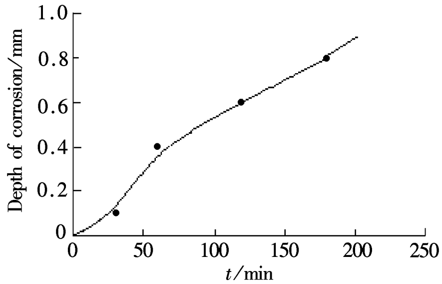

Fig. 2 The relationship between time and the depth of corrosion

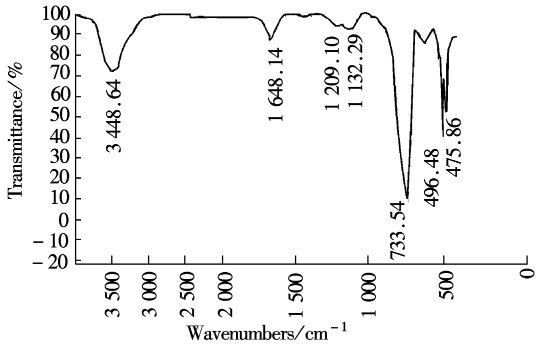

Fig. 3 Infrared ray analysis of product

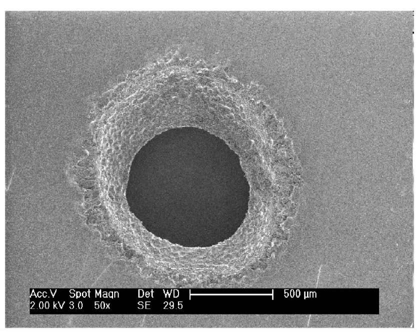

Fig. 4 Channel by chemical corrosion

2 Results and Discussion

As shown in Fig. 3, the IR spectrum has the absorb peaks of 3 468. 64, 1 648. 14, 1 209. 10, 1 132. 29 cm^{-1}, indicating that the chemical ingredient is sulfate. The method of corrosion used in this paper has two advantages. First, the reaction with sulfuric acid is an exothermic reaction. When the sulfuric acid injects into the corrosion solution, the speed of reaction can be accelerated. In Ref. [7], the chart shows that the velocity rises while the reaction temperature increases. Secondly, the product is a sulfate which means that it can dissolve in water immediately; this factor can also speed up the reaction. The hole is funnel-shaped (as shown in Fig. 4) and its diameter is less than 0. 5 mm and the corrosion time is about 100 min. When we put the glass in the corrosion solution for a longer time, we can obtain funnel of a lager diameter. So we can see a larger luminance area (as shown in Fig. 5). However, it will decrease the resolution of the display device. Therefore, it is necessary to fabricate smaller and more densely arrayed holes on the gate electrodes for high resolution display device.

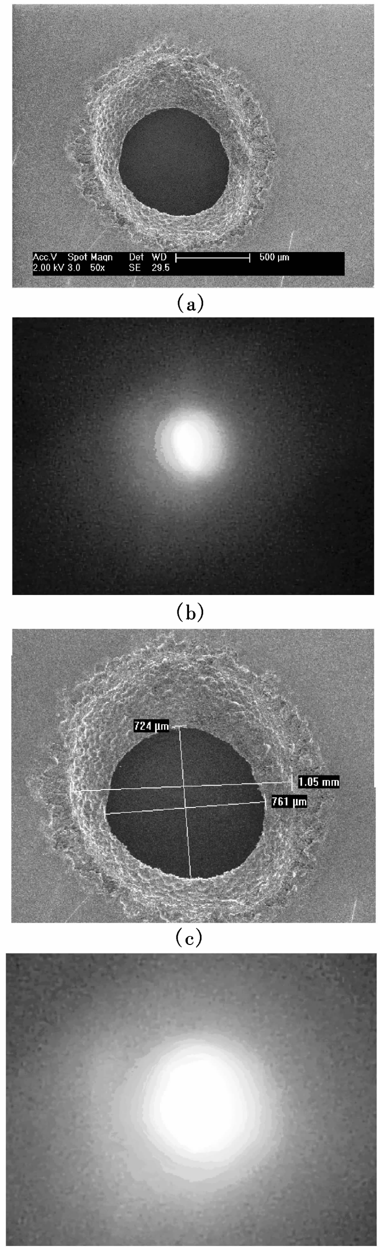

Fig. 5 The light spot with different funnels on the glass substrate. (a) Smaller funnel; (b) Smaller luminance area; (c) Larger funnel; (d) Larger luminance area

3 Simulations

The potential distribution and electron trajectories can be calculated by a numerical simulation program[8]. Fig. 6 and Fig. 7 give the potential distribution and electron trajectories, respectively.

As shown in Fig. 6 and Fig. 7, the performance of the electron beam is good. The electrons almost bombard the anode with a cylinder beam. However, the spot profiles on the phosphor screen are still influenced by

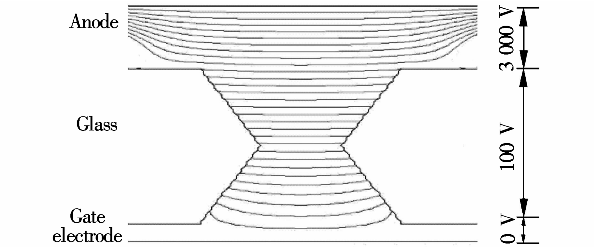

Fig. 6 Electrical potential distribution

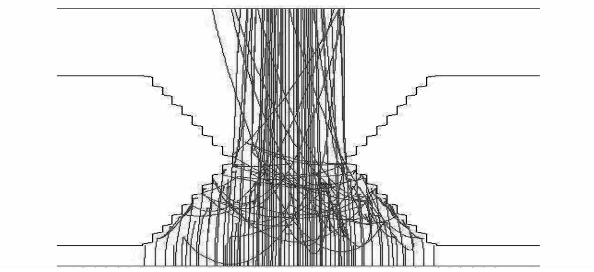

Fig. 7 Trajectories of electrons

the emission curve[9]. The spot size increases with the increment of the emission current. It is caused by the serious space charge effect and the large beam divergence angle when the emission current is large. Therefore, an additional focus electrode has to be used to get a good spot with high current.

4 Conclusion

In this paper, we propose a simple chemical method to fabricate a channel matrix on a glass substrate. As experimental results show, the size of the funnel can be controlled by changing the corrosion time. A novel triode has been designed with this glass substrate.

From the simulation and experimental results, it can be seen that the electron beam can be focused well in this triode. However, the light spot becomes large when the emission current is quite high. Therefore, an additional focus electrode has to be used at this moment.

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新型场发射器件中栅极的化学刻蚀制备

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摘要:为了得到碳纳米管场发射器件的三极结构,设计了一种新型栅极. 在电极的制作过程中使用普通的丝网印刷方法,然后运用化学刻蚀的手段进行双面刻蚀制备出带有小孔阵列的栅极. 在栅极制作过程中通过改变酸液刻蚀的时间和浓度,可以腐蚀出不同形状的小孔. 运用扫描电镜(SEM)和红外光谱(IR)分析,得到小孔的尺寸、形貌和刻蚀液的成份,然后在三极结构上加电压显示出孔的亮度图像,最后对器件结构进行模拟,算出在电场条件下的电子从阴极拉到阳极基板的轨迹. 模拟结果和实验结果一致,从而实现了对场发射三极器件的优化.

关键词:碳纳米管场发射器件;栅极;化学腐蚀;玻璃小孔

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