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Enhancement of anode current in an HOPFED

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Abstract

In a HopFED, most electrons which get through the hop funnel and land on the anode are secondary electrons. The intensity of the anode current is largely determined by these electrons. In this paper, an extraction electrode is introduced to increase the number of secondary electrons. The influence of the extraction electrode voltage and the gate voltage on the anode current is also studied.

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Keywords: Field emission display; Field emission electron source

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1. Introduction

A HopFED [l] structure has been proposed to improve the performance of a field emission display (FED). In HopFED, electrons from each sub-pixel are transported in a hopping mode via secondary electron emission over the wall of an insulating funnel placed above the sub-pixel electron spot. Compared to FED, HopFED has several advantages. The luminance of the spot is increased. At the same time, the contrast and the colour purity are improved. The other advantage is the influence of the field emitters by ion-bombardment is reduced [1][2].

The electrons which travel in the hop funnel may hit the hop glass wall. If the collision happens, it can be elastic, inelastic or penetrate into the hop glass wall. When the incoming electron penetrates into the insulating wall, it heats up the surrounding electrons inside the wall. These heated up surrounding electrons start diffusing through the material. Some of them may reach the surface and leave the wall. The primary electron is lost, but in turn it generates a new set of secondary electrons [3].

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2. Algorithm and simulation model

In our simulation study, the electrical potential distribution of the hop wall and hop funnel is obtained by solving the Poisson equation with finite difference method. The electron trajectories are obtained using a program which is based on the Monte-Carlo method to calculate the secondary electron emission in HopFED.

Normally, the secondary electron emission yield δ is defined as $\delta = i_s/i_p$, where i_p is the primary current of the impinging electrons and i_s is the secondary electron current leaving the insulating surface [3]. The secondary emission process is illustrated in Fig. 1. A typical secondary electron emission yield curve δ as a function of the incoming primary electron energy E_p has been plotted in Fig. 2. When $\delta \neq 1$, the surface becomes charged. While $\delta = 1$, the charging of the insulating wall becomes stationary [4][5].

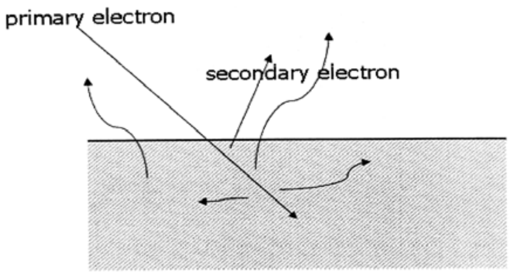

Fig. 1. The secondary electron emission process.

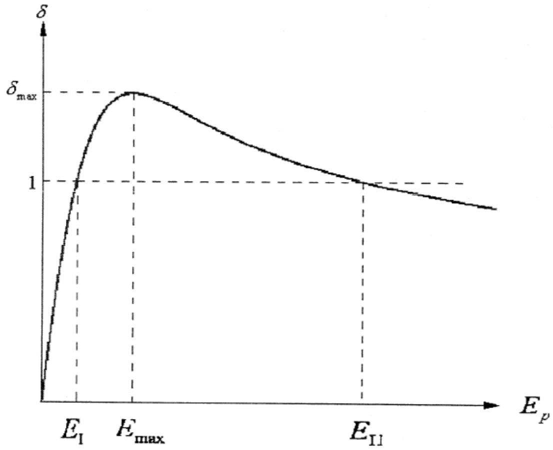

Fig. 2. Plot of the secondary electron emission yield curve δ.

In our simulation study, the basic model is a normal HopFED (Fig. 3). In order to increase the anode current, we introduce an extraction electrode base on the normal HopFED. Fig. 4 shows the structure of the HopFED with extraction electrode.

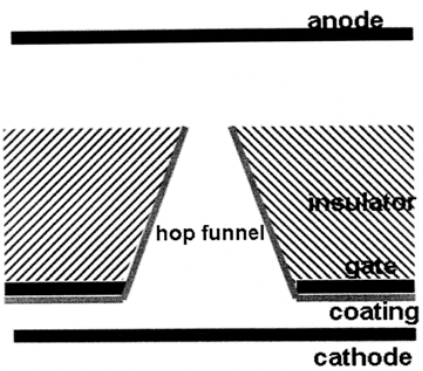

Fig. 3. Basic model of normal HopFED.

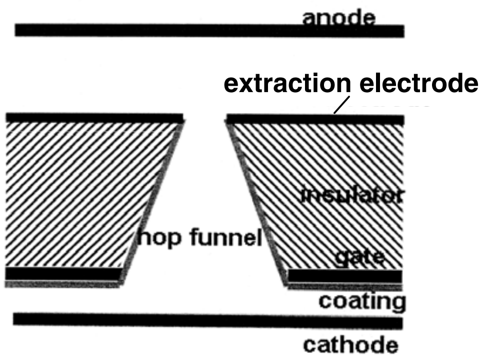

Fig. 4. HopFED with extraction electrode.

To simplify the fabrication process, the gate electrode is deposited on the bottom surface of the hop glass plate and the extraction electrode is deposited on the top surface of the hop glass plate, as shown in Fig. 3 and Fig. 4. The gate electrode and the inner wall of the glass plate are coated with a secondary electron emission material to avoid the gate electrode absorbing primary electrons under it and increase the probability of secondary electron emission.

3. Results and discussion

The gate electrode is used as a modulation electrode to control the primary electrons which are emitted from the cold cathode. Different gate voltages cause different primary and secondary electron emission. If the extraction electrode voltage is suitable, the introduction of the extraction electrode increases the secondary electron emission. More secondary electrons are produced. In addition, the electrons which get through the hop funnel are accelerated with the proper extraction electrode voltage. As a result, more electrons reach the anode and the focus capability is improved.

3.1. Basic model

The basic model for normal HopFED is shown in Fig. 3. It consists of a cathode, a gate electrode, a insulating hop funnel and a anode. The voltage added on the cathode, gate electrode and anode are 0V, 100V and 3000V respectively. Fig. 5 gives the electron trajectories and the potential distribution in a normal structure HopFED. Different gate voltages produce different electron trajectories, leading to different anode currents. Fig. 6 shows the relationship between the gate Voltage (V_{gate}) and the normalized anode current density.

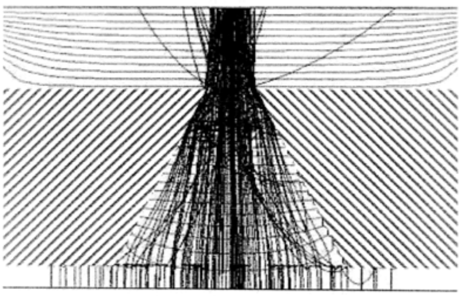

Fig. 5. The equipotential lines and electron trajectories of a normal HopFED.

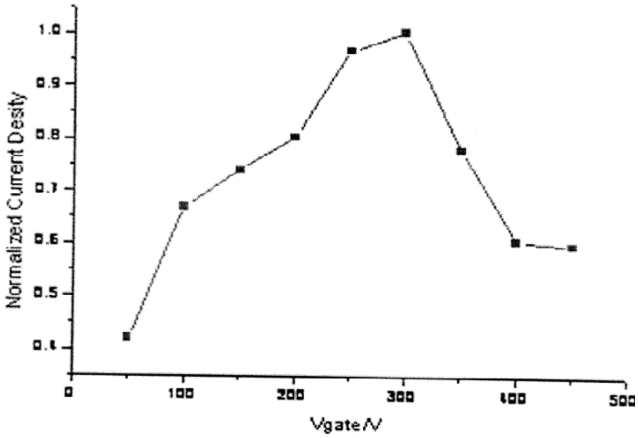

Fig. 6. I-V curve of basic model.

3.2. HopFED with extraction electode

Fig. 4 shows the other structure in this paper, the HopFED with the extraction electrode. It consists of a cathode, a gate electrode, a insulating hop funnel, an extraction electrode and an anode. The voltages applied on the cathode, gate electrode, extraction electrode and anode are 0V, 100V, 700V and 3000V respectively. Fig. 7 shows the electron trajectories and the potential distribution in a HopFED with extraction electrode. Different extraction electrode voltage values influence the performance of the electrons. So the electrons landing on the anode have also been affected. Fig. 8 shows the relation between the extraction electrode voltage and the normalized current density, while the gate voltage is fixed.

Comparing the electron trajectories of Fig. 5 and Fig. 7, we can see that the extraction electrode increases the number of secondary electrons landing on the anode and also improves the focus performance. Fig. 6 and Fig. 8 show that without the extraction electrode, the suitable modulation gate voltage is about 300V and with the extraction electrode, about 100V gate voltage and 500V to 700V extraction electrode voltage are available.

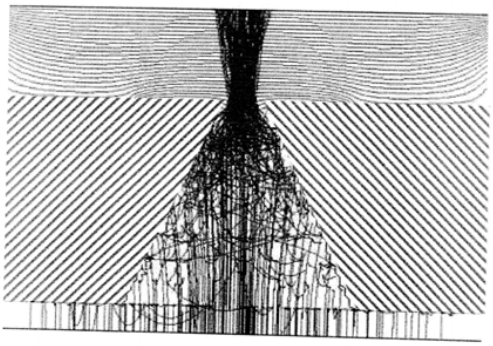

Fig. 7. The equipotential lines and electron trajectories of HopFED with extraction electrode.

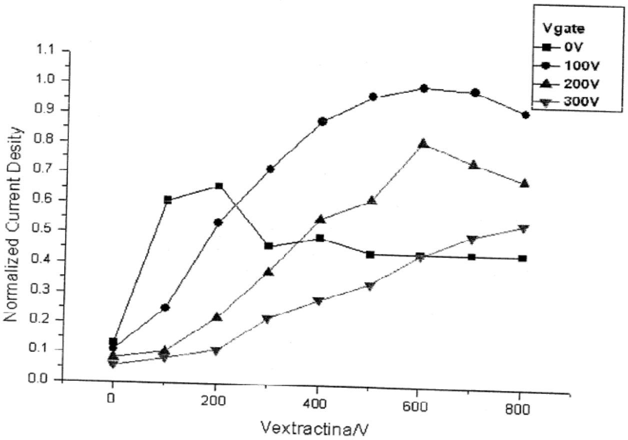

Fig. 8. I-V curve of HopFED with extraction electrode.

4. Conclusion

By simulating the secondary electron emission in HopFED with and without extraction electrode and analyzing the simulation results. We can conclude that the anode current is enhanced and the focus capacity is improved in HopFED with extraction electrode.

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