# Electron Emission Mechanism in the Surface Conduction Electron Emitter Displays

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**Abstract**

The origin of the display current in the surface conduction electron emitter displays has been verified in the calculation of the electron trajectory. Some electrons move directly toward the display surface as an anode current which is generated due to the inertial force of electron motion along the curved electric field lines with a small curvature near the fissure area..

## INTRODUCTION

A new type of cathode-luminescent flat panel display based on the surface conduction electron emitter (SCE) has been developed [1-4]. Since the SCE display (SED) requires only a simple fabrication process and low operating voltage (~16V), it is a promising technology to realize the large area flat panel displays. However, the electron behavior in SCE has not been clearly understood yet. Even if a multiple scattering model of the electron emission mechanism of the SCE has been proposed [1-4], it is not clear to consider the electrons of an energy 10eV scattered elastically about a few $\mu m$ on the electrode top surface in a high electric field. The electron trajectory calculation [2] has shown that all electrons emitted at the edge of the fissure fall onto the film (do not arrive at the display anode plate) unless the anode voltage is extremely large. However, the electrons cannot follow the electric field lines which are not straight and have a small curvature over the inter-edge of the fissure. Since the field curvature scale is the same as the 10 nano-meter of the fissure, electrons even a few eV energy have a strong centrifugal force. In this study, we will calculate the electron trajectories including the electron inertial term of the centrifugal force in the SED.

## ELECTRON TRAJECTORY CALCULATION

The equation of the electron motion in the electric field is written as

$$m(d\vec{v}/dt) = -e\vec{E} \qquad (1)$$

The above equation is separated into the parallel and the perpendicular direction of electron velocity with $\vec{v} = v\hat{v}_{\parallel}$ and $d\hat{v}_{\parallel}/dy = (v/R)(-\hat{v}_{\perp})$ where $R$ is the curvature radius at a position of electron motion. Using, $E_{\perp} = \vec{E}\cdot\hat{v}_{\perp}$ we have the perpendicular components of equation (1) as

$$-eE_{\perp} + mv^2/R = 0, \qquad (2)$$

which means that the electron's curved motion is balanced by the centrifugal force and the electric force normal to the direction of the electron motion.

The electric field lines and the electron trajectory are traced along the force field lines by the deflection angle $\Delta\theta$ in each calculation steps. The calculation step of the unit infinitesimal length $l$ is taken a constant value as $l = v\Delta t$ by adjusting a time step $\Delta t$ for a velocity $v$ at a calculation point. The electric field lines are simply traced in the direction of the electric field as $\Delta\theta = \Delta\theta_E$ which is the deflection angle of the electric field at the calculation point. Taking the electron trajectory into account the inertial force, the deflection angle is determined by balancing the forces in Eq. (2). With the curvature $R$ in Eq.(2), the energy conservation $mv^2/2 = eV$, and the perpendicular component of the electric field strength $E_{\perp} = E_o \sin(\Delta\theta_E)$, we obtain the deflection angle as

$$\Delta\theta = \frac{lE_o \sin(\Delta\theta)}{4V} \qquad (3)$$

with Eq. (3), the electron trajectory is traced from a point to next point.

Figure 1 shows the electric field lines (a) and the electron trajectories (b) in SED electrode structure with the model fissure of 10nm gap and the same size of the depth, the film voltage $V_f = 16V$, and the anode voltage $V_a = 6KV$ at the display surface located at 1mm height from the film surface. In Fig. 1 (a), the electric field profiles are shown to be oblate over the bridge of the inter-edge electrode and a circular shape between both top electrode surfaces. In the Fig. 1 (b), each electron trajectory is numbered according to it's emission position. Trajectories numbered from 1 to 6 reach to the display surface. Those number 1-5 correspond to the emission position on the top cathode surface, and the number 6 is just to the cathode edge, and the number 7 and

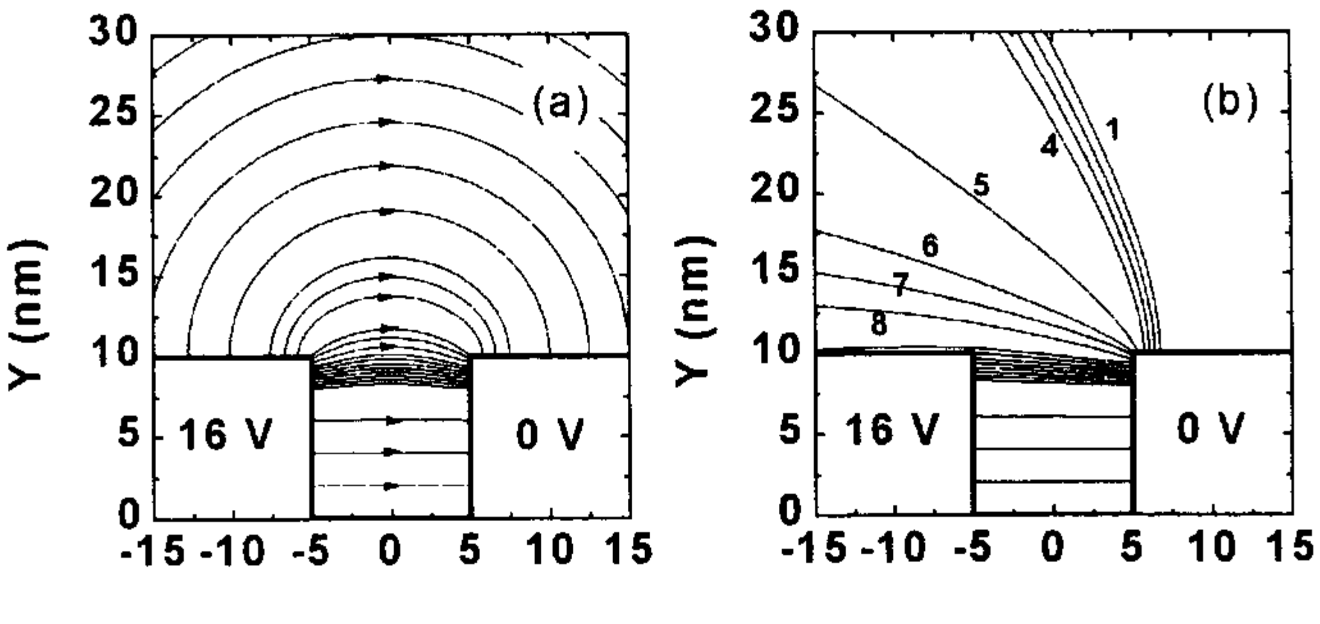


Figure 1. The electric field lines(a), and the electron trajectories are plotted for the SED electrode structure with the model fissure of 10nm gap and the same size of the depth. The film voltage is $V_f = 16V$, and the anode voltage is $V_a = 6KV$ at the display surface located at 1mm height from the film surface. Each cross sectional area is zoomed by $30nm \times 30nm$. Electrons corresponding to the numbered 1 to 6 emit from the top cathode surface (1~5) and the cathode edge (6). These electrons directly move into the display anode surface, while electrons from the inner side edge(Number 7 and 8) go to the opposite upper side surface.

8 are the positions at the cathode down side surface inner fissure. The electrons numbered 1 to 6 directly move into the anode display surface, while all the electrons emitted from the inner side fissure arrive at the other side surface in the fissure.

## CURRENT AND VOLTAGE CHARACTERISTICS

To obtain the current-voltage (I-V) characteristics, we use the Fowler and Nordheim relations as

$$I = \oint aE^2 \exp[-b/E] ds, \qquad (4)$$

where the current $I$ is in the unit of Ampere, the constant values are $a = 6.2\times10^6$, $b = 6.8\times10^7\phi^{3/2}$, respectively, the electrode work function $\phi$, and $ds$ is the integration segment of electron emission surface with the electrode's lateral width $100\mu m$. The critical field strength for cold cathode electron emission is known as to be $E_c \sim 3\times10^9 V/m$. In Fig. 2, the field strength at the cathode edge top and the inner side surfaces in the fissure are shown. The electric field strength at the inner side surface of cathode edge fissure is shown to be larger than that at the top-edge surface. If the film voltage is as low as $V_f = 10V$, there is no emission region where the field strength is less than critical field strength $E_c$. At $V_f = 16V$, the emission region is less than 5Å on he top surface and less than 10Å at the inner side surface. As the voltage is increased to $20V$, the emission region is expanded and more current is generated. Generally most of the film current $I_f$ comes from the inner side surface of the fissure and the anode current $I_a$, detected at the display surface, comes from the top surface of the cathode edge. The I-V characteristics are represented in Fig. 3, where both the film current $I_f$ and the anode current $I_a$ versus $V_f$ with $V_a = 6KV$ are shown.

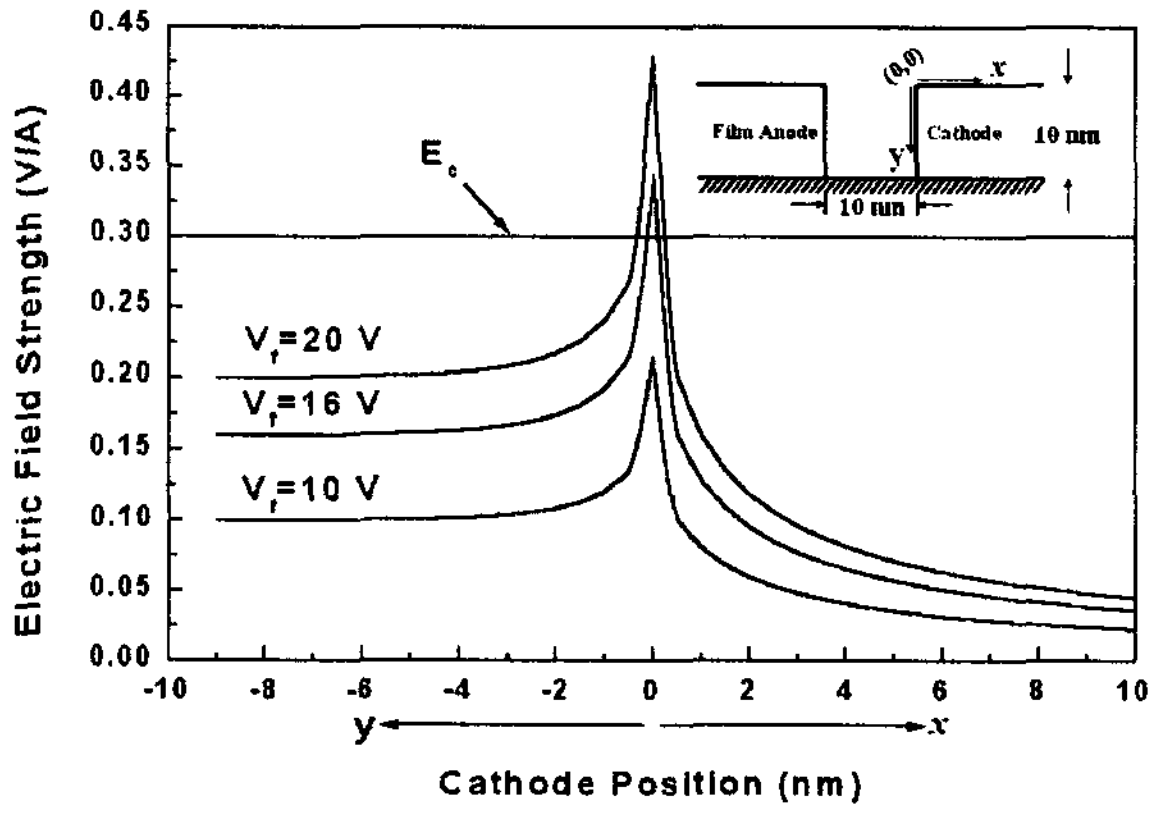


Figure 2. The field strength at the cathode top surface near edge region and the side surface in the fissure is calculated. The field strength at the side surface of the cathode fissure is larger than that at the top edge surface. The electron emission region where the field strength is higher then the critical field strength $E_c \sim 3\times10^9 V/m$, expands gradually on the top edge surface as the film voltage ($V_f$) is increased. The more the emission region expands, the more the film current $I_f$ and the anode current $I_a$ are generated.

## DISCUSSION S AND CONCLUSION

Field profiles are oblate and circular shape between over the fissure of the $10nm$ gap electrodes over the fissure. In the rough estimation of the forces on the electron motion near the fissure with the same scale of the curvature radius $10nm$ and the operating voltage about $10V$, both the electric force and the centrifugal force are the same magnitude as $eE \sim mv^2/R \sim 1eV/nm$ so that the inertial force cannot be negligible. Most electrons emitted from the inner side edge of cathode surface flow toward the opposite side of anode surface in the fissure, which is the film current. The electrons from the upper-side edge surface directly flow to the display electrode surface due to the high centrifugal force, which is the anode current. The film current and the anode current are about $\sim\mu A$ and $nA$, respectively, with the film voltage $16V$ and the anode voltage $6KV$. Both currents are increased as the film voltage increase. Specially, the anode current occurs even with the small anode voltage of a few $100V$ and it increases as the anode voltage increases. These current-voltage characteristics agree well with previously reported datal [4].

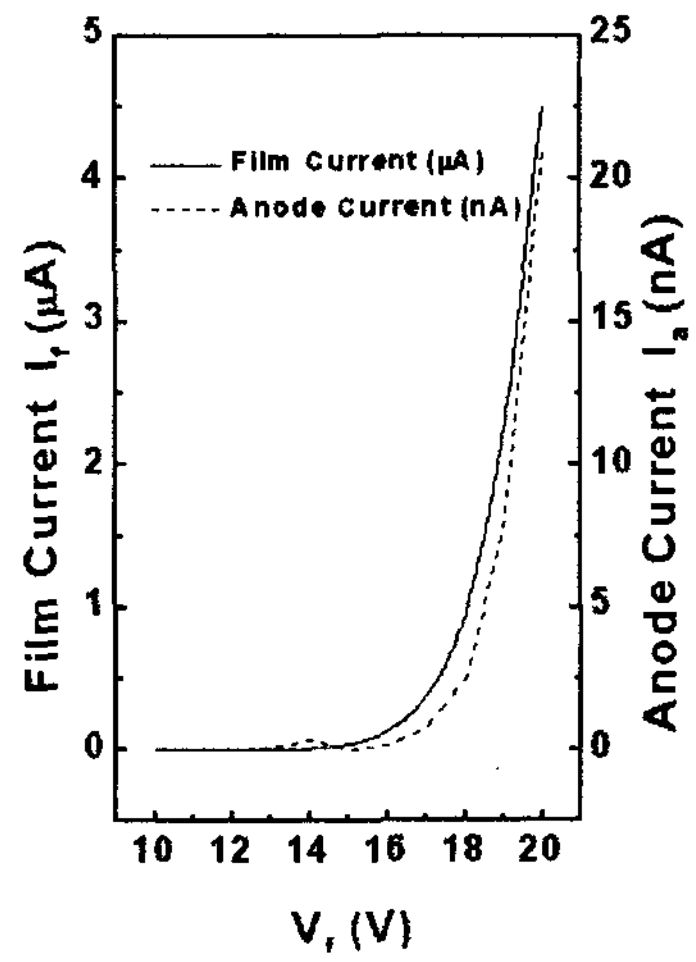


Figure 3. The film current and the anode current versus the film voltage ($V_f$) is plotted with $V_a = 6KV$. $I_f$ and $I_a$ is about $\mu A$ and the $nA$, respectively.


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