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Ultra-Low Biased Field Emitter Using Single Wall Carbon Nanotube Directly Grown onto Silicon Tip by Thermal CVD

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1. Introduction

The new carbon nanotube field emitter which has single wall carbon nanotube with a diameter of 1~2nm grown directly onto the Si tip by thermal CVD is developed. Owing to the 10 to 20 times smaller diameter of nanotube than the conventional Si tip, the developed carbon nanotube field emitter showed the ultra-low threshold voltage of 10V for the field emission of electron which is more than 10 times smaller value than the conventional Si emitter.

2. Structure and fabrication process

Figure 1(a) shows the schematic structure of the carbon nanotube field emitter, and Fig. 1(b) the magnified figure of the one silicon tip with a single wall carbon nanotube. The fabrication process is as follows; The n-type silicon was etched by SF_6 gas using the SiO_2 as an etching mask and 10900 silicon tips were formed. After the chemical catalyst was spin coated on to the patterned SiO_2 substrate, the sample was set in the furnace and hydro-carbonate gas was flowed at high temperature. The single wall carbon nanotube then started to grow and followed up the wall of the silicon tip to the top and protruded from the silicon tip. The anode electrode was made by Au/Ti coated Si. The distance between the anode and the silicon substrate with carbon nanotube emitter was changed by the Si3N4 spacer layer. Three kinds of spacers of 6mm, 10mm, 21mm were prepared.

Figure 2(a) shows the SEM image of the Si tip where the carbon nanotube was grown at the top (in the white circle). The trace of catalyst was seen in the middle of the Si tip where the carbon nanotube start to grow. Figure 2(b) is the SEM image of a single wall carbon nanotube protruded from the top of the Si tip. the size of the Si tip is as large as ~30nm. On the other hand, the size of the single wall carbon nanotube is more than ten times smaller than the Si tip.

3. Electrical property of single wall carbon nanotube field emitter

The electrical properties were measured in the vacuum. Figure 3 shows the current-voltage characteristics of the carbon nanotube field emitter. The distance between the anode and the silicon substrate (spacer) was used as a parameter. When the spacer is 21mm, the electrons began to emit from the applied bias of ~25V. The narrower the spacer, the threshold bias of emitting current becomes smaller. When the spacer is 6mm, the electron starts to emit at the applied bias of as small as 10V. This is 10 ~50 times smaller value than that of the conventional Si emitter. Figure 4 shows the Fowler-Nordheim plot of the current-voltage characteristics of Fig. 3 in order to check whether the electron is really field emitted from the tip. In Fig. 4, the current follows the linear lines in 4~5 orders of magnitudes even at the different spacer thickness, which means the electrons are realy field emitted from the carbon nanotube through the Fowler-Nordheim tunneling.

4. Conclusions

We have succeeded in fabricating the ultra-narrow field emitter using the single wall carbon nanotube grown directly onto the Si tip. The threshold voltage for the field emission becomes 10~50 times smaller than the conventional ones and is as small as 10V because of the smaller diameter of the carbon nanotube emitter. This single wall carbon nanotube field emitter could be applicable to the low power consumption flat panel display of wide view TV or mobile monitor, etc.

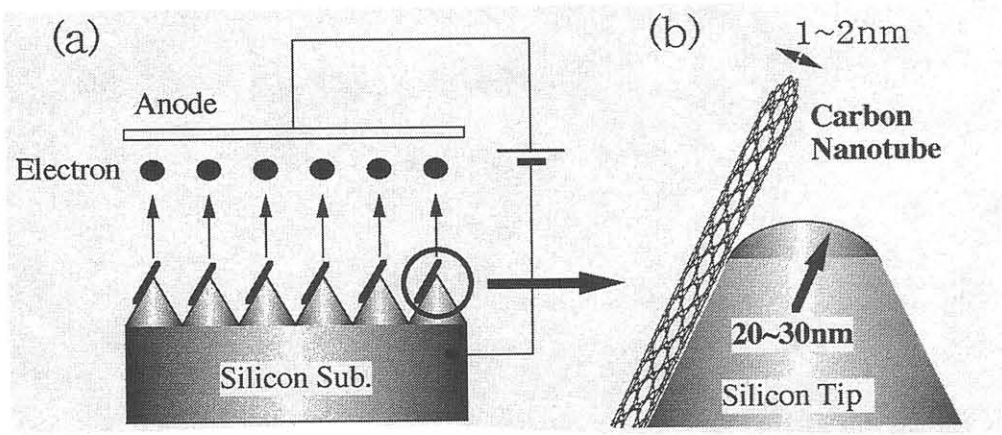

Fig. 1, (a) Schematic structure of single wall carbon nanotube field emitter.
(b) Magnified figure of carbon nanotube tip.

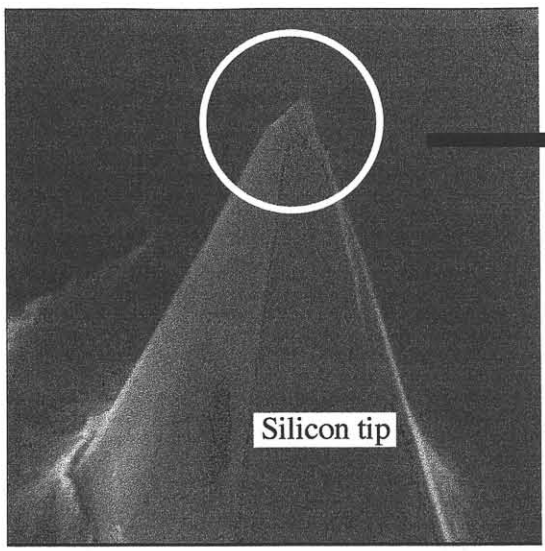

Fig. 2(a), SEM image of Si tip where single wall carbon nanotube is grown.

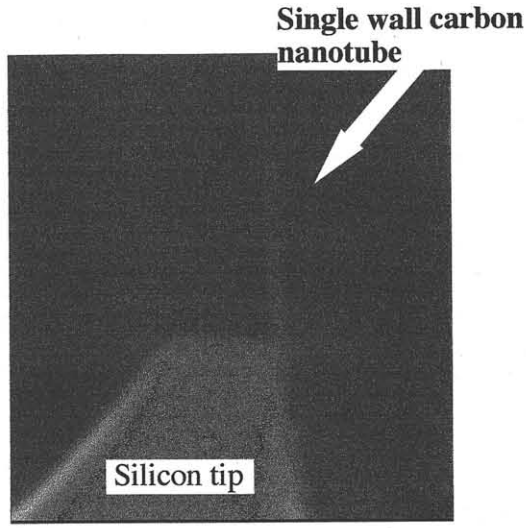

Fig. 2(b), SEM image of single wall carbon nanotube grown onto Si tip.

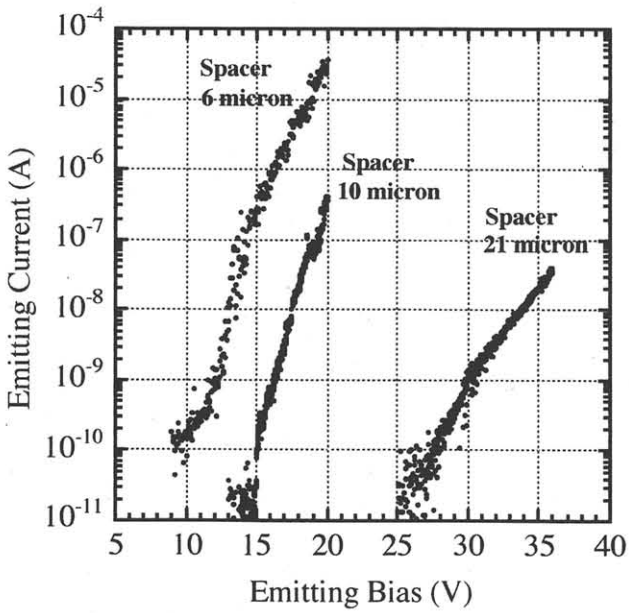

Fig. 3, Current-voltage characteristics of carbon nanotube field emitter. Spacing between Si substrate and anode is used as parameter.

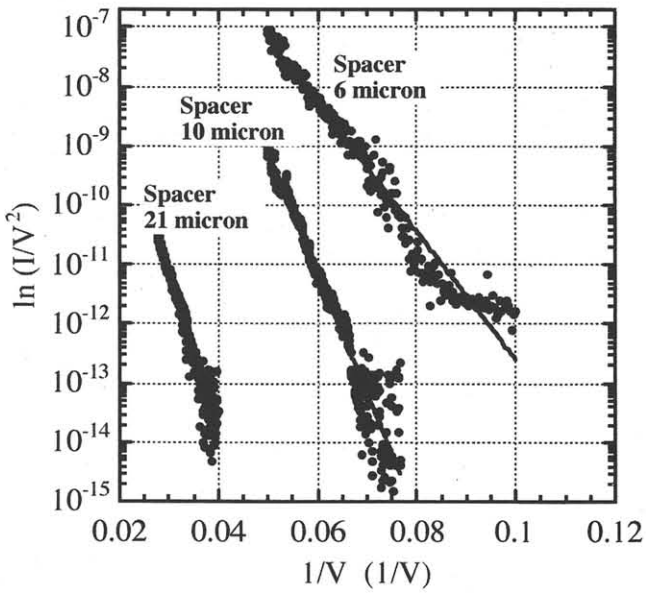

Fig. 4, Fowler-Nordheim plot of emitted current from carbon nanotube emitter.