Quintet-Gated FEA to Form Crossover Beam

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Abstract:

In this report, we have described about new field emission array (FEA) structure built-in micro-column. This newly proposed FEA has multi-gated structured and is designed to form a crossover. We had already demonstrated the quad- and quintet- gated FEA. A crossover formation by was successfully observed for the first time. by the quintet-gated FEA Furthermore electron beam lithography was demonstrated.

1. Introduction

We have developed FEA with focusing function. To overcome an electrical field reduction during focusing in conventional double-gated FEA, the volcano-structured double gated FEA was proposed. It was demonstrated that emission current could be kept constantly under focusing operation. But it was found that a potential barrier surly was built under strong focusing operation and any emitted electron could not achieve to the anode in the result [1]-[3]. In order to form fine electron beam crossover, multi-gated FEA was designed. In our previous report, the quad-gated FEA was demonstrated its superior performance [4]. But quad-gated FEA need high operation voltage which is nearly breakdown of an insulator layer. To improve the characteristics, quintet-gated FEA was designed. And in this report, we talk that a clear crossover formation was successfully observed. And electron beam lithography without any other electrical optics was demonstrated.

2. Quintet-gated FEA

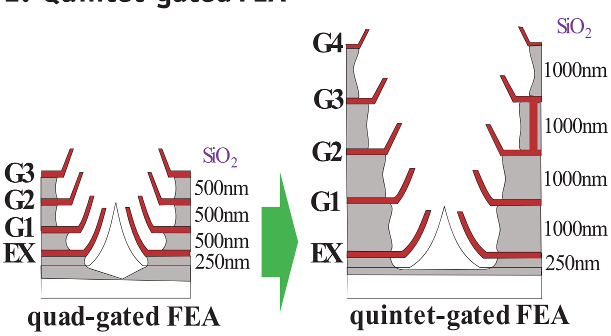
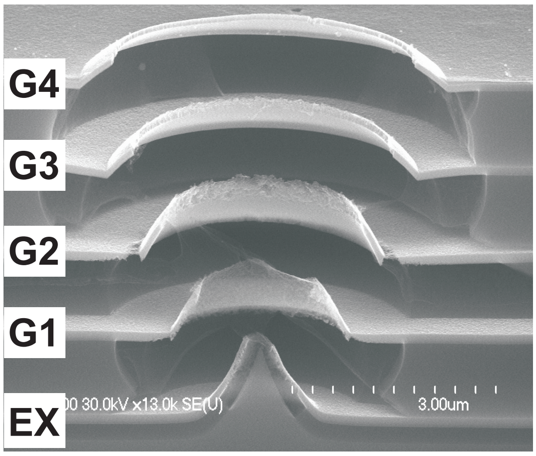


Fig. 1. Schematic of multi-gated FEA. Quintet-gated FEA was designed to improve focusing property.

Figure 1 shows the schematic of the improved multi-gated FEA. In order to improve the multi-gated structure, the thickness of insulator was increased to 1000 nm, comparing with quad-gated FEA. And intermediate electrode at einzel lens consists of two gates. With this structure, effective thickness of the lens was increased and the load of lens was reduced in results. Figure 2(a) shows the fabricated the quad-gate FEA in which einzel lens consisted of upper four electrodes. The focusing characteristics with this structure were simulated by SIMION 8.0 as shown in figure 2(b). It was cleared that the needed voltage at intermediate electrode of einzel lens was reduced over 60V at crossover point.

(a)



(b)

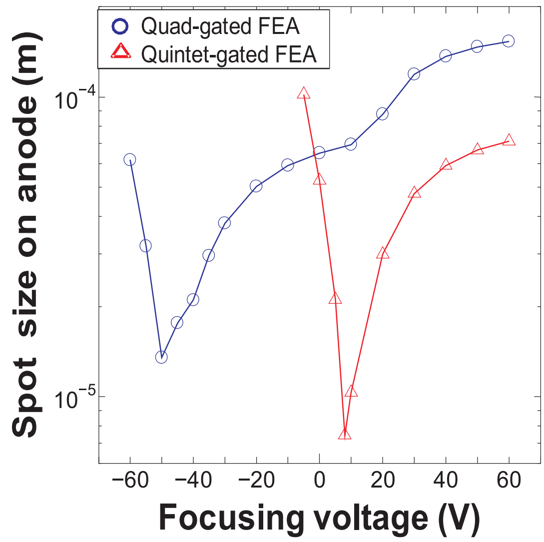


Fig. 3. The simulated results of focusing characteristics and applying voltages at intermediate electrode.

3. Experiment

Figure.3 shows the fabrication processes of the quintet-gated FEA. We used etch-back method [1-4]. By using this technique, multi-gated structure was exactly self-alignment integrated without any other alignment.

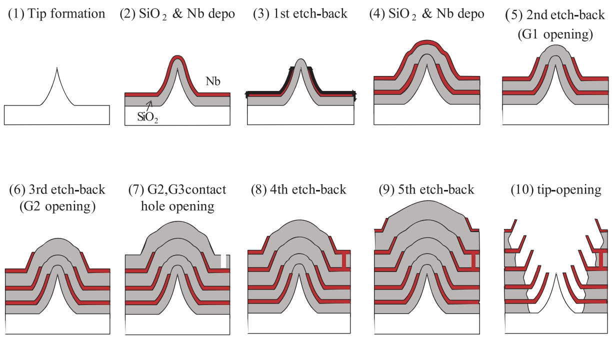
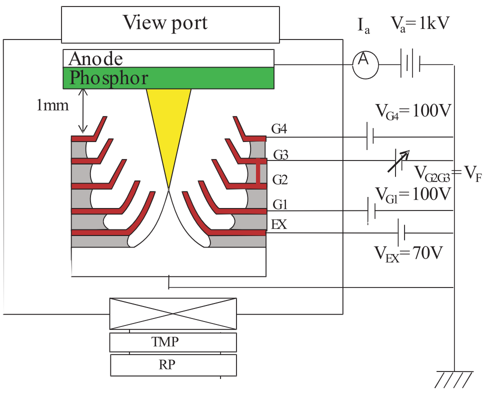


Fig. 3. Fabrication processes of quintet-gated FEA.

Figure 4 shows the scheme of measurement system. All experiments were carried out under an ultra vacuum below 10^{-7}Pa. To estimate the electron beam spot sizes, phosphor screen was used as anode and located 1 mm apart from the quintet-gated FEA. The irradiated area on screen was measured by charge-coupled camera.



condition	
Interval (emitter - anode) [mm]	1
Degree of vacuum [Pa]	8.0× 10^{-7}
Acceleration voltage [kV]	1

Fig. 4. A schematic of measurement chamber and examination condition.

Figure 5 shows the focusing characteristics. When focusing voltage is changed from 100V to -10V, it was found that anode current kept constantly. It indicated that any electrical field reduction at tip and building a potential barrier were removed. And the insets show the sequence of formation crossover processes under focusing operation. As shown in Fig. 5, the bright spot gradually became small and it was minimized by applying 13V at intermediate gate. Under over focusing condition by increasing the strength of lens, the spot size started spread again. Judging from this spot size behavior, it was indicated that electron beam crossover was formed.

Figure 6 shows electron beam lithography system with the quintet-gated FEA. ZEP-520 of the thickness of 50 nm was coated on Si substrate as resist. The Si substrate was set in front of 10 mm apart from the FEA. Si substrate could be moved by stepping motor with the speed of 3µm/sec. The acceleration voltage of 5 kV was applied to Si substrate.

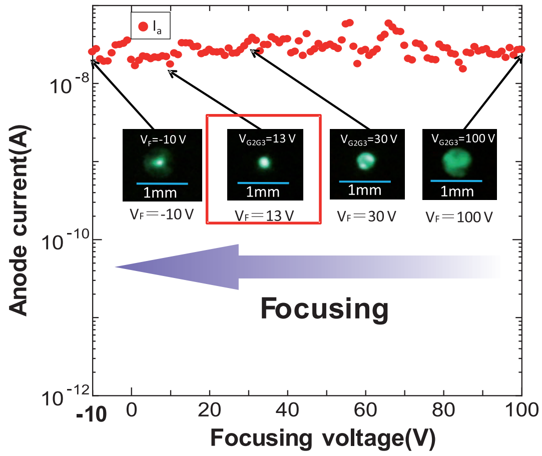
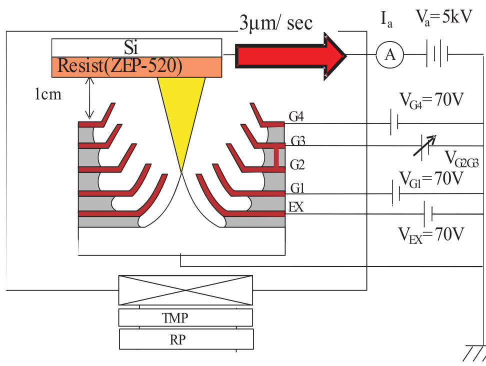


Fig. 5. The focusing characteristics and observed irradiated area by focused electron beam.



condition	
Interval (emitter - anode) [cm]	1
Degree of vacuum [Pa]	8.0× 10^{-7}
Acceleration voltage [kV]	5
Anode velocity [µm/ sec]	3

Fig. 6. A schematic of electron beam lithography setup and exposure condition.

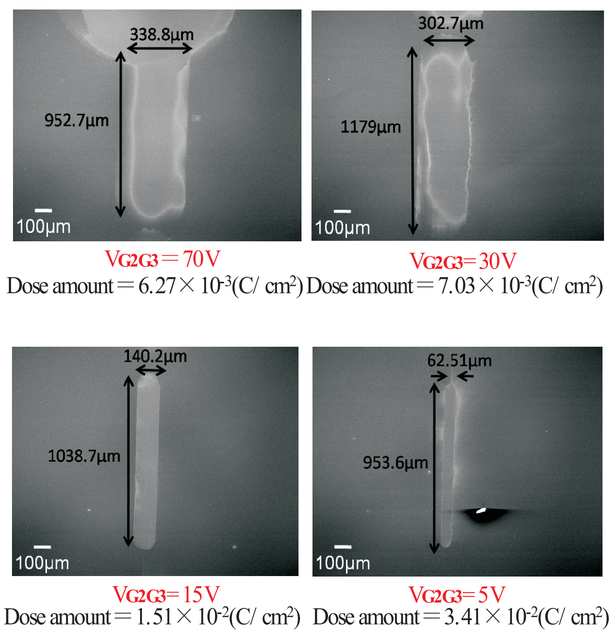


Fig. 7. the SEM images of developed resist pattern. Dose and focusing conditions were specified.

Figure 7 shows the SEM images of after electron beam exposure and developing resist on Si. As a result, under focusing operation, the width of developed areas was narrowed. The electron beam lithography was successfully demonstrated. But the patterned sized was relatively difficult from experiment in Fig. 5 and simulation result. Further considerations are needed.

4. CONCLUSION

The quintet-gated FEA has been fabricated and shows the excellent characteristics. The reduction of electric field and building potential barrier under strong focusing condition were completely removed. And clear forming process of electron beam crossover could be observed for the first time with lower operation voltage, comparing with quad-gated FEA.

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