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Patterning of Diamond Micro-Columns

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We have fabricated a patterned diamond field emitter on a silicon substrate. Fine diamond particles were planted on a silicon wafer using conventional scratch method. A silicon oxide film was deposited on the substrate seeded with diamond powder. An array of holes was patterned on the silicon oxide film using VLSI processing technology. Diamond grains were grown using a microwave plasma-assisted chemical vapor deposition. Because diamond could not grow on the silicon oxide barrier, diamond grains filled only the patterned holes in the silicon oxide film, resulting in an array of diamond tips.

Key words : Diamond field emitter, Diamond micro-columns

I. Introduction

Recently, diamond thin film, with its high therml conductivity and chemical stability, is attracting an attention as a candidate for field emitter material. Although the mechanism of field emission from diamond is not well understood, the advantage of using diamond is that it does not need to be formed in a needle shape. The emission from diamond film has been demonstrated,[1] and the theoretical investigation to explain the emission mechanism has been suggested.[2] Because diamond growth requires high temperature, a difficulty with diamond field emission array (FEA) is patterning. Hong and Aslam fabricated a patterned diamond field emitter by mixing diamond powder with photoresistive film and subsequent burning of the film.[3] In a mold technique, Okano *et al.* formed a pyramid-shape trench on a silicon substrate. After filling the trench with diamond, the silicon mold was etched away to leave an array of pyramid-shape diamond tips.[4] In this paper, we introduce a new simple procedure to fabricate an array of diamond grain. After seeding diamond powder on a silicon wafer, the substrate was covered with a silicon oxide film. An array of round holes was patterned in the oxide film until the silicon surface was exposed through the holes. Diamond was grown using microwave plasma-assisted chemical vapor deposition. Because diamond could not grow on the silicon oxide surface, it filled only the holes in the oxide layer, thus resulting in the array of micro-columns diamond field emitter.

II. Experimental Procedure

A fabrication sequence used in this research for the patterned diamond field emitter is shown in Fig. 1. A silicon (100) wafer was seeded with diamond powder using a ultrasonic agitation method. A silicon oxide film (4 μm thick) was deposited on the seeded silicon substrate by electron beam evaporation. While the substrate temperature, electron beam power, and chamber pressure were maintained at 200°C, 6 kw, 3×10^{-5} Torr respectively. An array of holes (1.5 μm in diameter) was patterned in the oxide film using a photholithograpy process. The silicon oxide film was etched until the seeded silicon surface was exposed by reactive ion etching process. Boran-doped diamond was grown using microwave plasma-assisted chemical vapor deposition while the substrate temperature, microwave power, and chamber pressure were maintained at 930°C, 600 Watt, 90 Torr respectively.

Boron was doped to 200 ppm by introducing B_2H_6 gas. because diamond could grow on the seeded silicon surface but not on the oxide surface and barrier, diamond grains started to grow from the silicon substrate in the bottom of the holes patterned and filled the holes. As a result, an array of micrometer-scale diamond field emitter was formed.

III. Results and Discussion

Figure 2 is the scanning electron micrograph (SEM) image of the top view of the film in which holes are patterned. The diameter of the holes is 1.8 μm. The size of the diamond column could be controlled by the growth time and oxide film thickness. Figure 3 shows a patterned diamond field emitter. Diamond grains grew starting from the silicon substrate seeded with diamond powd-

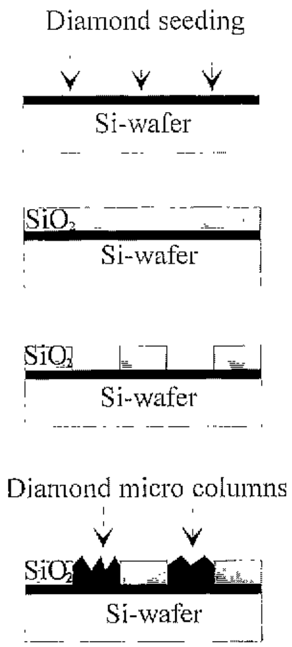


Fig. 1. Fabrication process of patterned diamond field emitter.

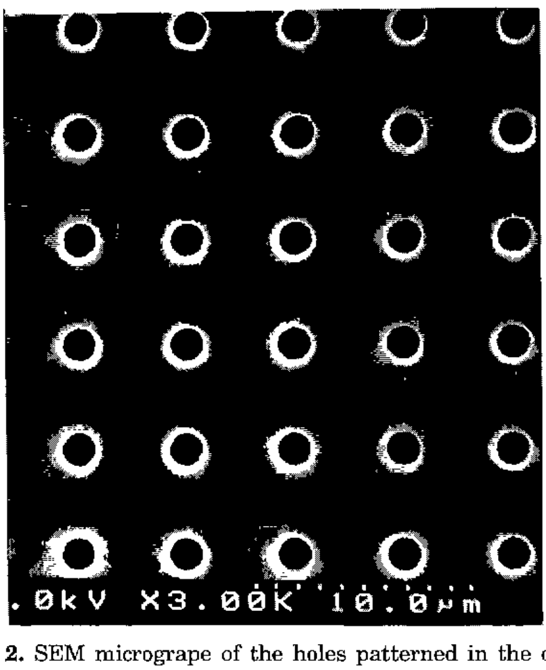
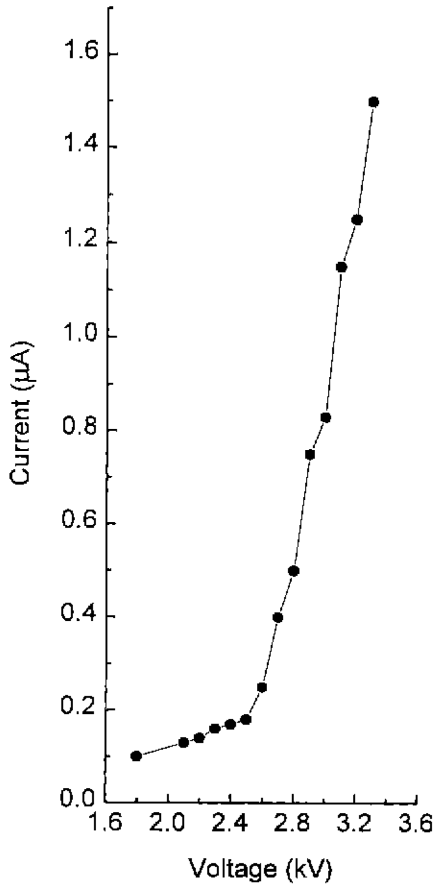


Fig. 2. SEM microgrape of the holes patterned in the oxide film.

Fig. 3. SEM microgrape of the patterned diamond micro-column.



P=2.4×10^{-7} Torr
Cathode-anode gap=100 μm

Fig. 4. I-V curve obtained from the patterned diamond field emitter. Number of field emitter is 10,000 in the area of 0.5×0.5 mm^2.

er, but they didn't grow on the silicon oxide surface. Although the original hole diameter was 1.8 μm, the diameter of diamond column became 3.75 μm because of the oxide etching during the diamond growth. The height of the oxide film was also reduced to 3.03 μm. The rate of the oxide etching was estimated to be 90 Å/min for every direction. The I-V curve measured using the diamond micro-columns is shown in Fig. 4.

There are 100×100 diamond field emitters in the area of 0.5×0.5 mm^2. An anode (polished Mo plate) was placed above the diamond emitter using a thin film of mica spacer between the two electrodes. The emission current was detected at the onset field of 18 V/μm.

IV. Conclusion

We have fabricated a patterned diamond field emitter on a silicon substrate. Fine particles of diamond were planted on a silicon wafer using a scratch method. A silicon oxide film was deposited on the substrate seeded with diamond and an array of micro-holes was patterned in the oxide film. Diamond grains were grown using microwave plasma-assisted CVD. Because diamond could not grow on the silicon surface diamond filled only the holes, resulting in an array of micro-meter diamond field emitter. The onset current from the diamond micro-columns occurred at 18 V/μm.

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