Development of Electron Beam Lithography using Vertically Aligned Carbon Nanotube (VACNT) as a new Electron Source

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ABSTRACT

We have developed on electron beam (e-beam) lithography system with novel electron source using vertically aligned Carbon Nanotubes (VACNTs). After the beam was exposed, the PMMA film on ITO glass was developed in MIBK: IPA developer (MIBK: IPA=1:3). As a result, we observed lithography pattern less than 100 mm without electric and magnetic lens. This emitter is differentiated from the previous electron source for e-beam lithography.

1 INTRODUCTION

Because the cold cathode based on CNTs has electrically superior properties, many studies have been conducted using CNTs as field emission electron sources for microscope or x-ray sources, [1].

Previously, our research team fabricated a freestanding emitter and evaluated the beam brightness and energy spread. As a result, we confirmed that our freestanding CNT emitter has narrow beam divergence and high brightness in comparison of the conventional thermionic tungsten emitter. Therefore, VACNTs are suitable for the electron source on e-beam lithography [2].

The commercialized electron beam lithography is based on the scan of focused electron beam. However, the single electron beam has poor process efficiency and the multi-beam requires complex optical designs [3].

In this research, we investigated e-beam lithography process using homemade VACNT arrays as an electron source. As a result, we made micro-size lithography pattern without any electrical and magnetical system.

2 EXPERIMENT

2.1 Fabrication of VACNTs emitter

VACNT emitters were fabricated DC plasma enhanced chemical vapor deposition (DC-PECVD). After depositing nickel catalytic layer on silicon wafer, we made preferred patterns through UV photolithography process and grew VACNT in selected location. The injection gas of C_2H_2/NH_3=16/160 sccm was supplied at 1.8 torr for 85 minutes at 700 ℃. We fabricated 3×3 VACNT emitter arrays and the CNT emitter height was about 46 μm as shown in Fig 1.

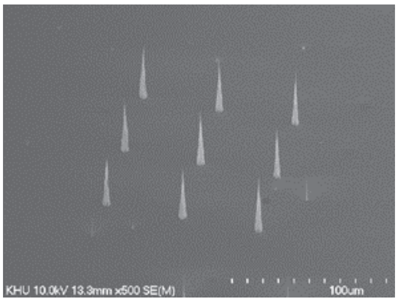

Fig. 1 SEM image of 3 × 3 CNT emitter array

2.2 E-beam lithography system.

To proceed the e-beam lithography experiment using VACNT emitters for electron source, the triode structure which consist of cathode, gate, anode was utilized. The source of electron was located at the cathode electrode and the gate electrode was fixed at upon the CNT emitters with 250 μm of gap. From VACNT emitters to ITO with PMMA (950K A4, NM tech) distance was 80 mm and the pressure inside chamber was 10^{-7} torr. The electron beam which passed through a 50 μm aperture was exposed on to the ITO substrate with a thin PMMA layer. The schematic of e-beam lithography structure represented in Fig. 2.

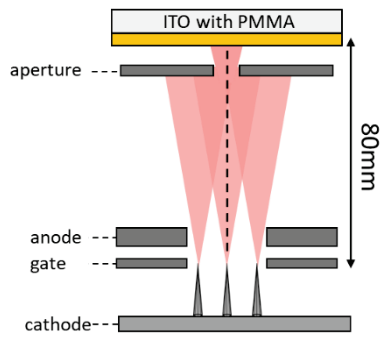

Fig. 2 Schematic of e-beam lithography structure

3 RESULTS & DISCUSSION

3.1 E-beam lithography using freestanding CNT emitter under diode structure

Initially, the e-beam lithography process was carried out with freestanding CNT cold cathode to confirm the possibility. Fig 3 is shown the schematic of e-beam lithography system under diode structure. These simple structures consisted of single emitter as a cold cathode, ITO with PMMA thin film as an anode. And the gap between cathode to anode is only 250 μm. As you can see EDS results, the amount of carbon which was exposed region has increased. since we applied low voltage and the e-beam was overexposed. We observed that the positive-tone PMMA was transformed into negative-tone PMMA because the overexposed PMMA is a carbonaceous material [4].

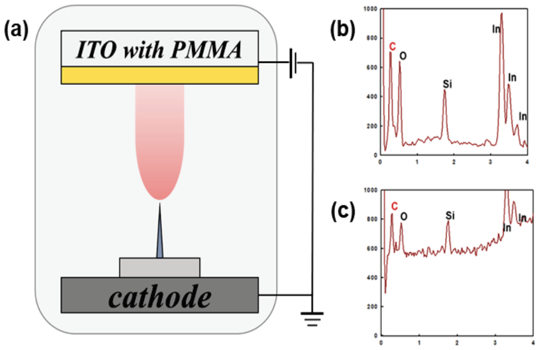

Fig. 3 (a) The schematic of e-beam lithography under diode structure. (b) before the electron beam exposure, (c) after the electron beam exposure

3.2 The beam characteristic of 3x3 CNT emitters

Before we implemented the e-beam lithography using VACNT emitters, we observed the emitted e-beam shape through the phosphor screen. Fig 4 represented the beam shape after the beam was passed through the 50 μm aperture and the beam diameter was 70 μm. The pattern shape depends on the irradiated energy of the beam and the electron emission current.

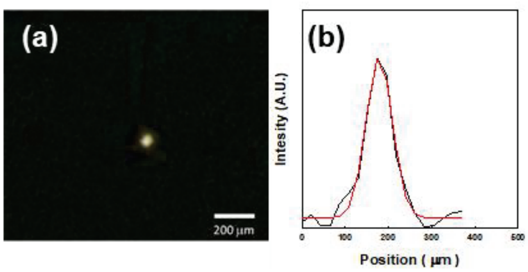

Fig.4 (a)The emitted e-beam image (b) The beam gaussian fitting

3.3 E-beam lithography using VACNT emitters under triode structure

The e-beam lithography experiment was conducted under DC negative operation ($V_{cathode}$= -3kV, V_{anode}= -2kV) and the beam current we applied on PMMA film was nano-ampere level. The emitted electrons which come from the VACNT emitters were accelerated with 3 kV and they reached the PMMA thin film. These high energy electrons could break the PMMA bonding structure [5]. Micro scale e-beam lithography pattern was obtained after the PMMA film was immersed to MIBK developer. After the beam was exposed, by analyzing the surface of the PMMA film using energy dispersive spectroscopy (EDS), we observed that carbon elements were removed at the electron beam exposed area. This result proved that the e-beam lithography is successful, and Fig. 5 shows the results of the EDS before and after the beam was exposed.

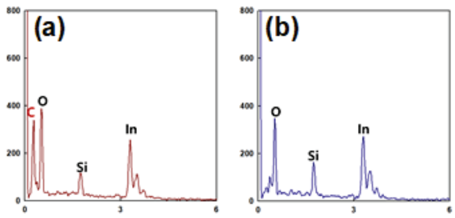

Fig.5 PMMA thin film; (a) before the electron beam exposure, (b) after the electron beam exposure

4 CONCLUSIONS

We utilized VACNTs as a new electron beam source for e-beam lithography. This is distinctive from the emitter used in traditional e-beam lithography. Our emitter is characterized by high electron emission efficiency and relatively low energy spread value. We fabricated lithography pattern and obtained micron scaled patterns with the VACNT emitters (<50μm). In addition, we can draw out e-beam lithography system in very compact design compared to existing e-beam system. Because the distance from cathode to PMMA film is only 80 mm without complex optics. Based on the result of these experiments, we will introduce additional electric and magnetic system to produce nanoscale patterning. If we optimize the exposure condition, it is expected to be used as a source for future e-beam lithography.

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Acknowledgment *(Heading 5)*

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