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Advanced Operation of Microcolumn by Introducing Misalign Corrector†

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We introduced an advanced operation of a microcolumn to recover electron beam properties caused by electrodes misalign. The misalign corrector consists of a pair of electrodes and each electrode is divided by four even parts. We confirmed that by applying appropriate bias voltage to some parts of the corrector, electron beam trajectory could be adjusted. As a result, it is found that the corrector can be an useful electron unit to obtain fine electron beam properties.

Keywords: Microcolumn, Source lens, Einzel lens, Misalignment, Electron beam.

INTRODUCTION

A miniaturized microcolumn is an attractive device because of its small size and application possibility in various fields[1-8]. Fig. 1 is a simulation model of a miniaturized microcolumn in this study. A microcolum has two electron lenses, source lens and Einzel lens. The source lens controls electron beam to enhance electron beam properties and the Einzel lens plays a role of optical focusing lens for the electron beam[9]. Source lens of a conventional microcolumn consists of three electrodes and each electrode has a hole on its center[10-12]. However, the source lens of this simulation model has an additional pair of electrodes. The additional double electrodes, misalign corrector, are divided up into four even parts. We anticipate that the corrector could play a role of electron beam trajectory compensator, since we can assign bias voltage on each part of the electrode, independently.

Fig. 2(a) and (b) are the top views of aligned electrodes, a pair of corrector and limiting aperture (green layer). We intentionally made misalignment of the limiting aperture from the optical axis in Fig. 2(b) in this study. Fig. 2(a) is the exactly aligned electrodes. Electrodes of a microcolumn have very small holes on their centers from a few hundreds of micrometers to a few micrometers diameter. Furthermore, the diameter

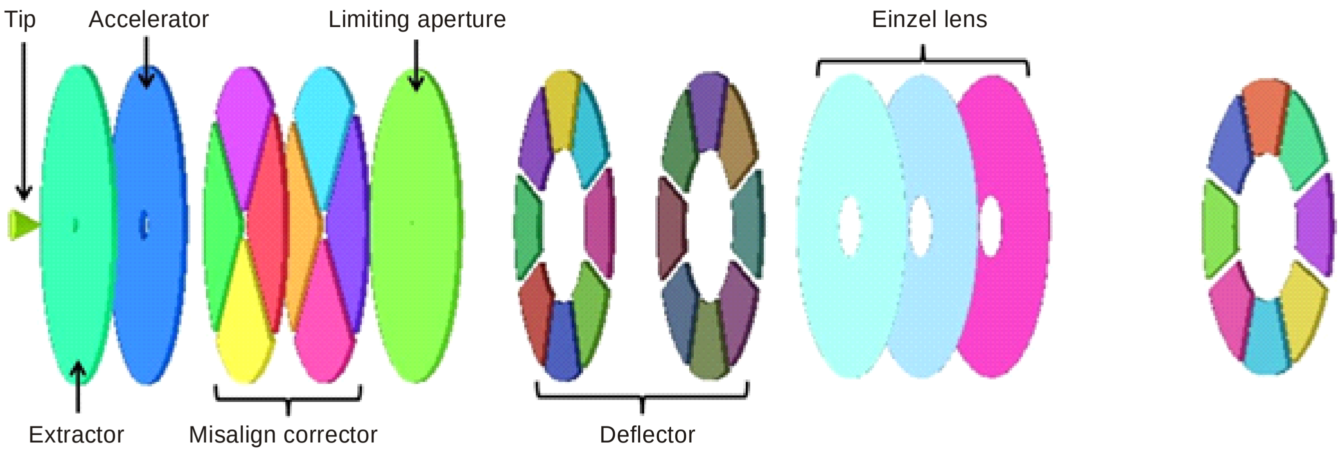

Fig. 1. Simulation model of a microcolumn with misalign corrector

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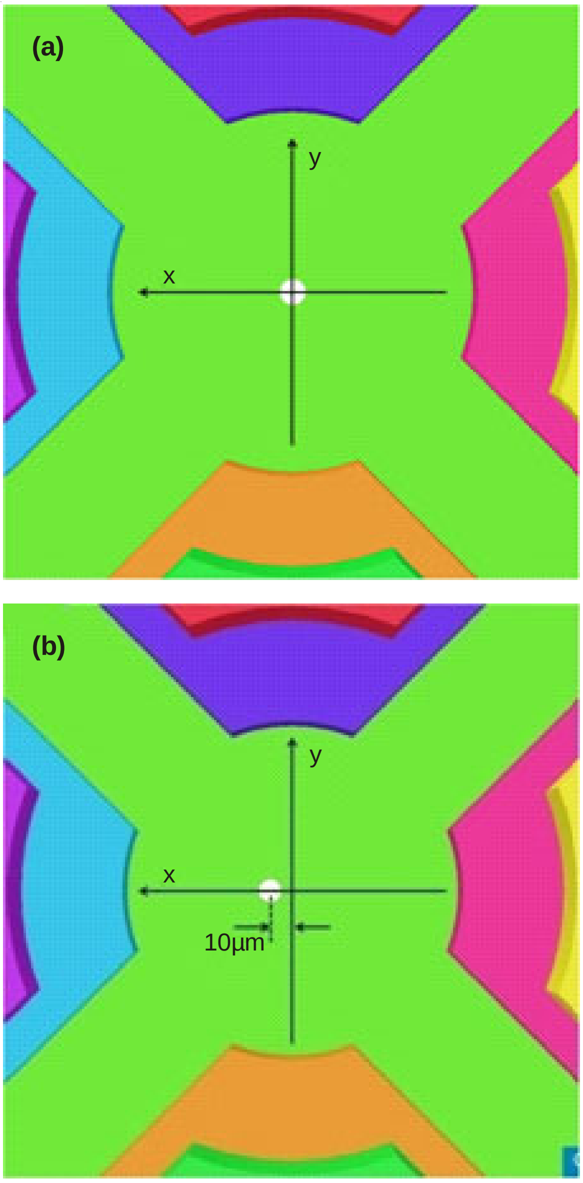

Fig. 2. A fabricated hole on the limiting aperture with 10 µm diameter (a) exactly aligned (b) 10 µm misaligned

of the limiting aperture electrode is just a few micrometers for precision electron inspection equipment. Thus alignment of the electrodes is an exceedingly difficult process and it causes a little misalignment. A misalignment lowers the qualities of electron beam, beam shape distortion, spot size enlargement, beam center position shift from the optical axis and reduction of beam current. Thus, an appropriate control of electron beam trajectory is very important to recover the beam properties.

In this study, we introduced a misalign corrector and investigated the functionality of this misalign corrector as a beam property compensator.

Bias voltage effect: Even though the limiting aperture is misaligned from the optical axis, a part of electron beam emitted from tip can pass the limiting aperture. However, the electrons are not from center of electron beam but from off-center position. Fig. 3(a) and 3(b) are the electron beam trajectories for the misaligned limiting aperture of Fig. 2(b). While Fig. 3(a) is the full region trajectory, Fig. 3(b) is the electron impact position on a transverse plane, the focal plane

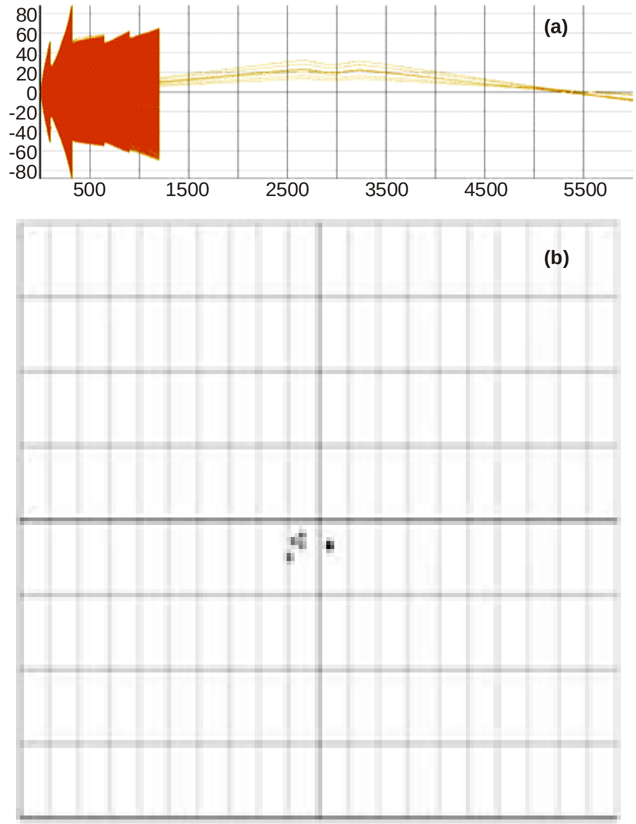

Fig. 3. (a) Full region electron beam trajectories for V1=V2=0V (b) electron beam position on a transverse plane

of the exactly aligned microcolumn. The electron impact positions are scattered and also enlarged. Since the beam spot size is enlarged, we can't use the microcolumn as a precision electron equipment.

Thus we should compensate the electron beam properties by advanced operation. Fig. 4 represents applied bias voltages on the electrodes. We fixed -300V, -240V and +500V on the tip, accelerator and Einzel lens, respectively. The accelerator bias voltage plays a role of making parallel beam, reduction of diverging angle. And the Einzel lens focuses electron beam on the sample plane by the assigned voltage. Electron beam tuning is achieved by applying proper voltages of V1 and V2.

Fig. 5 presents transverse electric field strength, Ex distributions. For the conventional operation mode, black line and represented with 0V_0V (*i.e.* V1=0V, V2=0V), the field strength just follows the optical axis. Thus electrons passing through this region are keeping their incident direction without change. In other operation modes, electric field strength and direction are varied with z-axis. To fix the misalign defect, electrons should change their direction toward the limiting aperture hole. Therefore, it is necessary to investigate various operation modes.

Electron beam trajectory analysis: Fig. 6 shows full region electron beam trajectories for the exactly aligned microcolumn. The electron beam has symmetrical distribution and the beam center keeps optical axis. A large portion of electrons are filtered by electrodes consisting of source lens, extractor, accelerator and limiting aperture. After the limiting aperture, survived electrons are focused on the sample plane by the focusing lens.

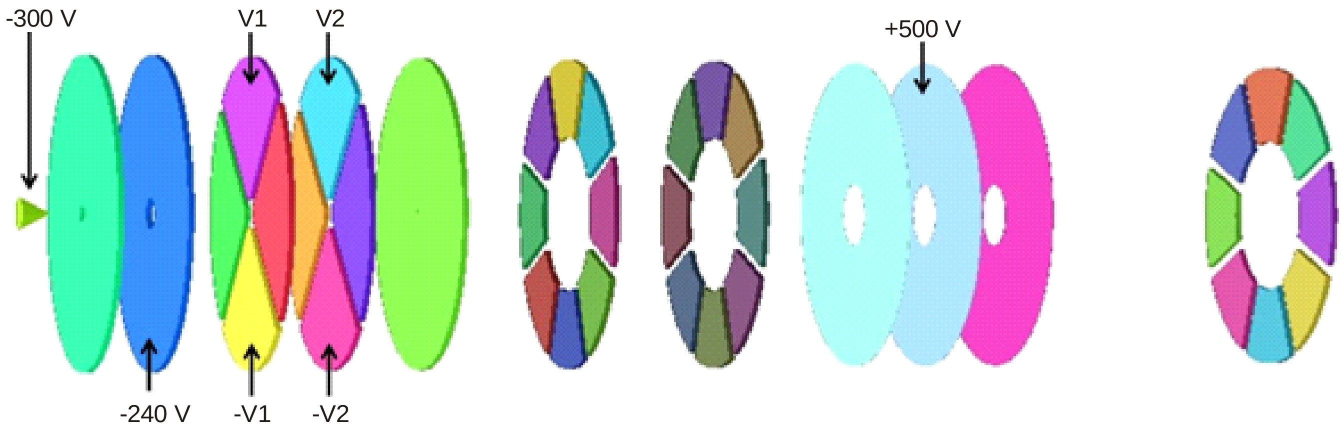

Fig. 4. Microcolumn simulation model with assigned bias voltage

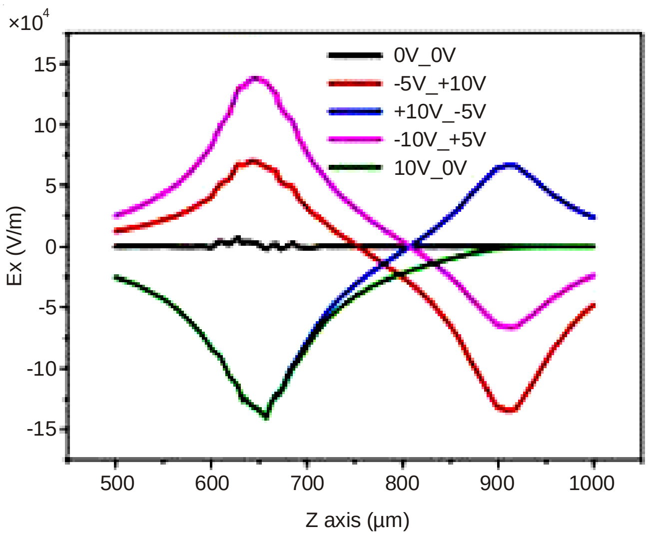

Fig. 5. Electric field distribution of x-direction

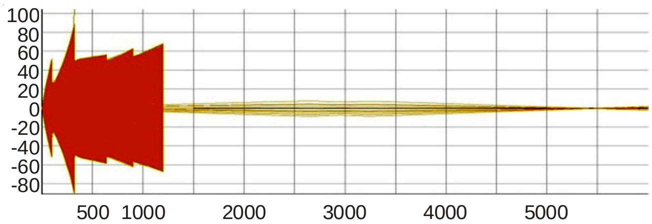

Fig. 6. Electron beam trajectories for the exactly aligned micro column

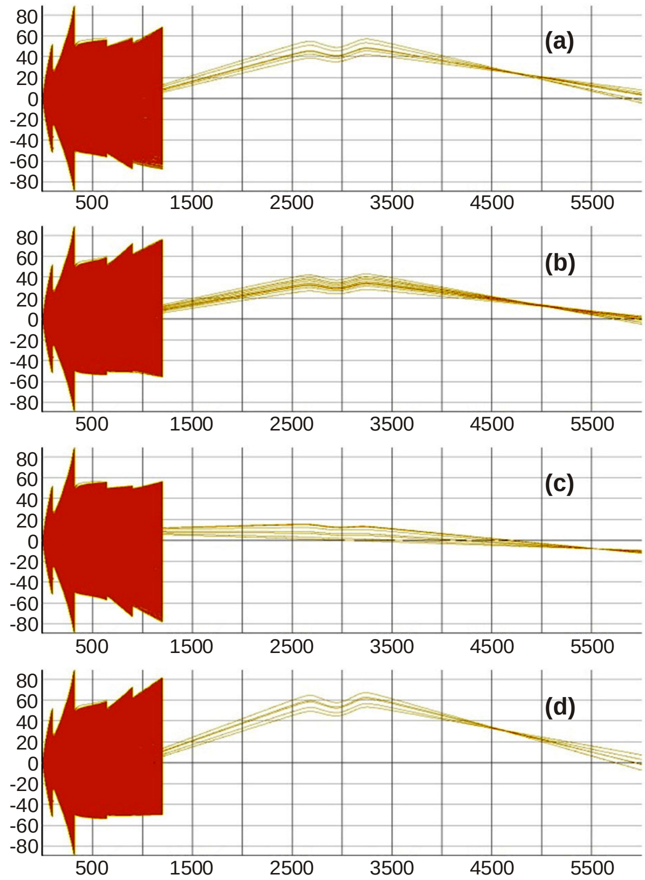

Fig. 7. Electron beam trajectories with (a) V1=-5V, V2=+10V(b) V1=+10V, V2=-5V (c) V1=-10V, V2=+5V(d) V1=+10V, V2=0V

There are electron beam trajectories for several misalign corrector bias voltages (Fig. 7). For some applied voltages of (a) and (d), electrons are further away from the optical axis. However, Fig. 7(c) shows similar electron beam trajectories to the exactly aligned ones in Fig. 6. Thus, we found the possibility of fixing misalign defect by using correction electrode.

Now, let's check electron beam behaviour on the sample plane. In Fig. 8(a), electrons form a small point, *i.e.* small spot size. However, electron beam spot size is enlarged and distorted and far away from the origin for Fig. 8(b). In Fig. 8(c), we can find the electron beam almost recovered its shape and position, which means that the misalign corrector works well to fix the defects.

Fig. 9 is the current ratio to the misaligned case of 0V_0V, *i.e.* V1=V2=0V. As the figure, exactly aligned case has the largest sample current among them. This result comes from that electron beam emitted from a conventional emitter tip shows Gaussian distribution with the distance from the beam center. Thus, the exactly aligned column pushes electrons from a densely populated area to the limiting aperture. However, electrons coming from a thinly electron populated area will pass through the limiting aperture for the misaligned cases. Thus electrodes misalign causes defects, beam shape distortion, shift from center line and also lower electron current.

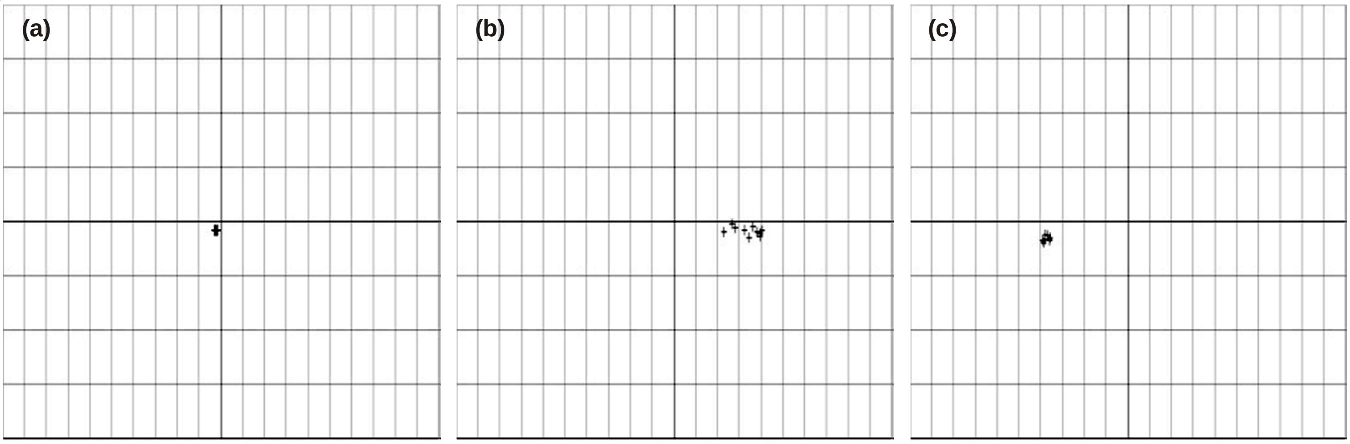

Fig. 8. Electron impact points on a sample plane for (a) exactly aligned (b) +10V_-5V (c) -10V_ +5V

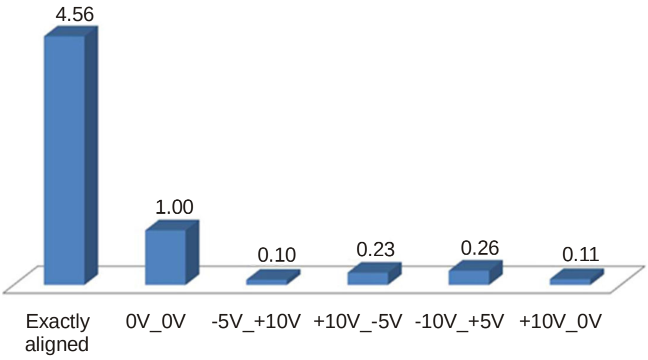

Fig. 9. Current ratio on the sample plane for the investigated models

Conclusion

In this study, we examined the possibility of misalign corrector for compensating misalign defect on electron beam properties. It is found that one can control electron beam with bias voltage applied on the corrector. Electron beam can be recovered its shape and returned back to the optical axis. However, electron beam current is still very low compared to the case of exactly aligned. Thus, when we use the beam misalign corrector, one should consider beam shape recovery as well as enhancement beam current.

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