An Analysis for the Performance of Condenser Lens in SEM
주사 전자 현미경의 집속 렌즈에 대한 성능 분석

*,#S. J. Lim[1], J. H. Kang[2]
*,#임선종(sjlim@kimm.re.kr)[1], 강재훈[2]
[1,2] 한국기계연구원, 나노융합・생산시스템본부

Key words : Condenser lens, Focal length, Thin lens, Principle plane

1. Introduction

The performance of lens means the finding out the focal length and principle planes. The focal length and the position of principle planes specify the electron-optical properties of the lens. These factors are required for considering the solution of the PRE(Paraxial Ray Equation). The purpose of the analysis is to find out these factors. These data are useful for understanding the behavior of the entire beam .

We show, in this paper, the properties analysis of condenser lens in our system. These results are utilized for designing the lens and developing the simulation software.

2. Electron path in magnetic lens

PRE is the equation for an electron path very close to the axis making very small angles with the axis. The PRE becomes[1-7]

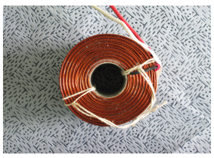
$$\frac{d^2r}{dz^2}+\frac{1}{2V}\frac{dV}{dz}\frac{dr}{dz}+\left(\frac{1}{4V}\frac{d^2V}{dz^2}+\frac{e}{8m_eV}B_z^2\right)r=0 \quad \ldots (1)$$

The PRE in the absence of electron fields, with V constant, then simplifies to Equation (2).

$$r''=-\frac{eB_z^2}{8m_eV}r \quad \ldots (2)$$

3. Application for condenser lens

Condenser lens and pole-piece used in this experiment is in Fig. 1. This lens has N=920, where N is the number of turns in the lens coil.


(a)


(b)

Fig. 1 Condenser lens and pole-piece

We consider first condenser lens from electron gun. This lens adjusts the range of spot size for each acceleration voltage. Fig. 2 (b) shows the pole-pieces including the pole-piece of second's condenser lens. These lenses have identical shape. The current through the lens is measured for calculating the properties of lens. The measured range of current is from maximum spot size to minimum spot size. Table 1 shows the measured current from 1 [kV] to 10 [kV]. 'OPT' means the value of capturing images.

Table 1 The current range through the lens

Acceleration voltage [kV]	The range of spot size	Current [A]
1	Max	0.075
	Opt	0.1125
	Min	0.375
3	Max	0.15
	Opt	0.1875
	Min	0.675
5	Max	0.2
	Opt	0.375
	Min	0.8875

Electron lenses are treated as 'thin' lenses, because of many practical considerations. Then, the focal length and the position of PP(Principle plane) are given by

$$\frac{1}{f}=\frac{\left(z\sqrt{\frac{eB_z^2}{8m_eV}}\right)\sin\left(z\sqrt{\frac{eB_z^2}{8m_eV}}\right)}{z} \quad \ldots (3)$$

$$PP=z\left(1-\frac{1-\cos\left(z\sqrt{\frac{eB_z^2}{8m_eV}}\right)}{z\sqrt{\frac{eB_z^2}{8m_eV}}\sin\left(z\sqrt{\frac{eB_z^2}{8m_eV}}\right)}\right) \quad \ldots (4)$$

In real lens, the path of electron beam is dealt with by sophisticated computer-aided methods because lens has various aberrations which cannot be easily calculated. But the simple numeric solution is useful to understanding the path. The calculated results for focal length and PP(principle plane) are in the table 2. Fig. 3 and Fig. 4 are presented as the figures for those tables.

4. Results

We analysis our condenser lens to find out the properties. The focal length is longer than the field of pole-piece in maximum spot size. That is shorter than the field of pole-piece in minimum spot size. The position of PP is the left of the center of the pole-piece because the gap of pole-piece is 2 [mm]. The above methods is not suit for understanding a real column. But such results in this experiment give us the opportunities to understand the behavior of the entire beam.

Table 2 The focal length and principle plane

Acceleration voltage [kV]	Focal length [M]	PP [M]
1	0.012473	0.000986
	0.005741	0.000968
	0.001099	0.000415
3	0.008707	0.000980
	0.006171	0.000970
	0.001104	0.000340
5	0.008880	0.000980
	0.002805	0.000925
	0.001111	0.000283

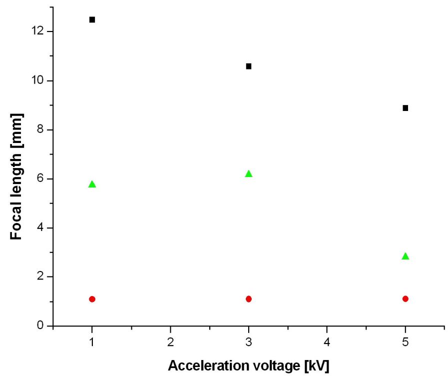


Fig. 2 The distribution of focus length

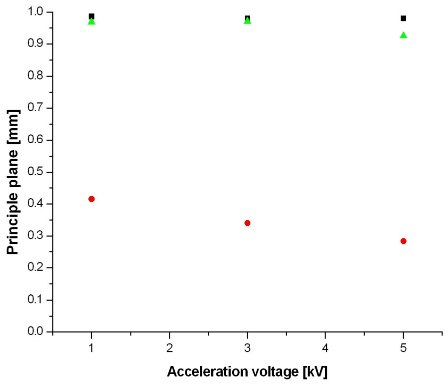


Fig. 3 The distribution of principle planes

REFERENCE

1. John, T. L. T., "Electron beam testing technology," Plenum Press, pp. 129-147, 1993.
2. Eugene, H., "Optics," Addision Wesley, pp. 149-170, 2002
3. Klemperer, O,. "Electron optics," Cambridge, pp. 20-131, 1971.
4. Ludwig, R., "Scanning electron microscopy," Springer, pp13-56, 1998.
5. Hawkes, P, W., "Principles of electron optics," Academic press, pp. 201-238, 1989.
6. Erich, P., "Electron-optical components for e-beam testing," Microelectronic Engineering, Vol. 12, pp. 189-204.
7. Hawker, P, W., "Computer-aided design in electron optics," Computer-aided design, Vol. 5, pp. 200-214, 1973.