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Design of the illumination system in the field emission Scanning Electron Microscope (SEM)

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Abstract

The main goal of This Work is to survey the field emission scanning electron microscope (SEM) to obtain on the optimal design for illumination system. The SEM optical column contains of illumination system that form a focused beam by electrons are released and animated to incident on the specimen surface, this backscattered electrons from the specimen surfaces, finally forming an image. mainly the optical column include a field emission source as the beam source, illumination system, electron control unit, and unit the vacuum. use of a finite element analyses in the design process of the SEM ingredient to be optimally determined. By the analysis we can predict the beam emission characteristics and relevant trajectories were predicted from the analysis of the present work from which a systematic design of the electron optical system is enabled.

Keywords: *illumination system, field emission gun, scanning electron microscope, optical column.*

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تصميم منظومة الاضاءة في المجهر الالكتروني الماسح ذو الانبعاث المجالي

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الملخص

يهدف هذا العمل الى دراسة تصميم منظومة الاضاءة في المجهر الالكتروني الماسح ذو الانبعاث المجالي . يتالف العمود البصري للمجهر الالكتروني الماسح من منظومة الاضاءة التي تنبعث خلالها الالكترونات لتشكل حزمة مبئرة تسقط على سطح العينة ثم تنعكس تلك الالكترونات من سطح العينة لتشكل الصورة . يتالف العمود البصري بصورة اساسية من قاذف الانبعاث المجالي كمصدر للحزمة ، منظومة العدسات ، وحدة السيطرة علي الالكترونات ، وحدة التفريغ. يستعمل تحليل العناصر المحددة في تصميم مكونات المجهر الالكتروني الماسح للحصول على تصميم مثالي ، خلال التحليل خصائص مسار الحزمة المنبعثة متوقع من خلال التصميم التخطيطي لمنظومة الاضاءة الالكترونية .

الكلمات المفتاحية: منظومة الاضاءة، قاذف الانبعاث المجالي، المجهر الالكتروني الماسح، العمود البصري.

1. Introduction

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When we decide, Electron microscope was used to study a specimen. The main goal of this study must be evaluated to properly choose the right path to obtain that aim. where the scanning electron microscope would be the instrument of choice for Some applications for example: studies involving the exterior morphology of the sample, the localization of large (20-30 nm) colloidal gold markers on the surface of the sample, the localization of boundaries between regions of differing atomic number composition, and the qualitative and quantitative identification of the elemental content of the specimen. Each of these applications requires that the instrument be operated properly so as to maximize the excitation and collection of the desired signal. in recent years are the requirement increases for high resolution electron microscope in aspects of development and manufacture for both two fields, microelectronics and optical electronics for calculates of the optical properties to the micro structures. for the measure and test of the micro / nano structures Consider the scanning electron microscope popular instrument by employ an electron source with wavelength of less than 1 nm [1]. All electron microscopes are high-vacuum equipment to prohibit electrical discharge in the electron source assembly and to let the electrons to drive within the instrument unimpeded. Because any contaminants in the vacuum can be fall out upon the surface of the specimen as carbon. Cleaner vacuums will minimize this artifact.

2. The field emission SEM column

Design the field emission SEM as consist of an electron optical system, chamber, stage, vacuum unit and a control unit. mainly The optical system consist of lens system in which emits an electrons that moves to form a collimated beam. For this reason, the optical system includes an electron beam source, apertures, magnetic lenses, detector and a deflection coils. Figure (1). Shows a design of SEM column. There are two classes of emission sources according to electron emission sources and different vacuum levels, thermionic emitters and field emitters. By using a field

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emission we could obtain on a highest resolution SEM [2-4]. Field emission SEM requires extremely high vacuums in the range of 10^{-10} Torr in which to operate.

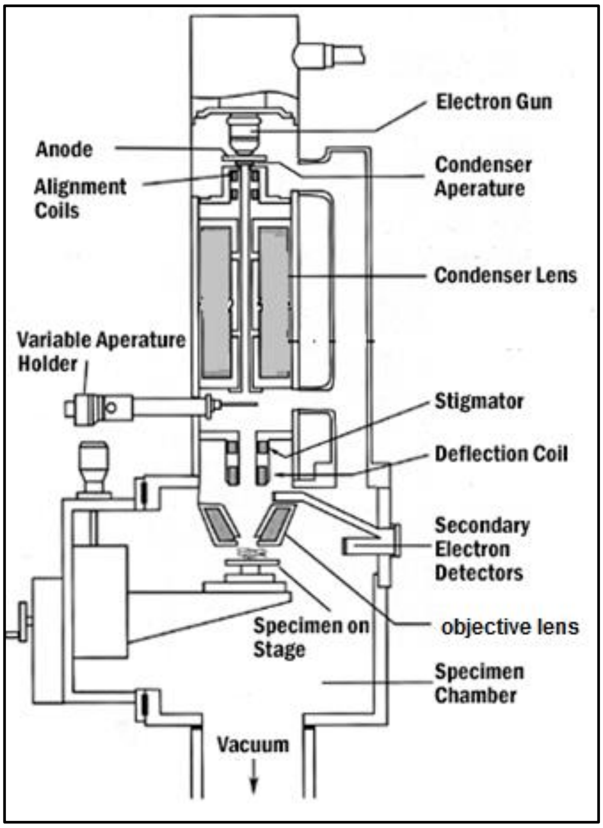

Figure (1). Shows a design of SEM column

Field emission gun use two anode plates sets down the source assembly. The first anode is extracts electrons from the filament tip. The extraction voltage is usually in the range of 3-5 kilovolts, another anode has the accelerating voltage connected with it use to accelerates an electrons through optical system. The two anodes doing as electrostatic lenses, collect the beam into a small initial crossover. Figure (2). Diagrammatic of electron source.

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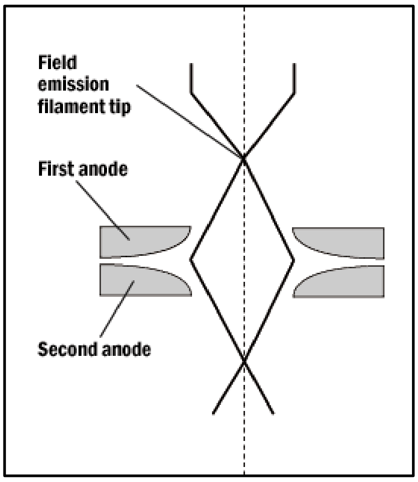

Figure (2). Diagrammatic of electron source

The filament that emits an electrons, that's being focused by magnetic lenses and accelerated by high voltage, [5], The magnetic flux which generated from an electric coil, into a small area by the current flow through a coil [6].an electron beam that reaches to the specimen has diameter about from (nanometer – micrometer) and carries current about (Pico ampere – micro ampere) depending on the type of the gun used, in the thermal gun dp=10 nm while in the field emission gun dp=1.2 nm [7],[8] . which ranges in diameter dG of (1-5) nm this type from guns use for high resolution. Minimum value for beam current which require to obtain on image from SEM instruments called critical current and equals 1 pA this value determined from detectors system and image display instrument in a SEM, Figure (3)shows the optical column in SEM.

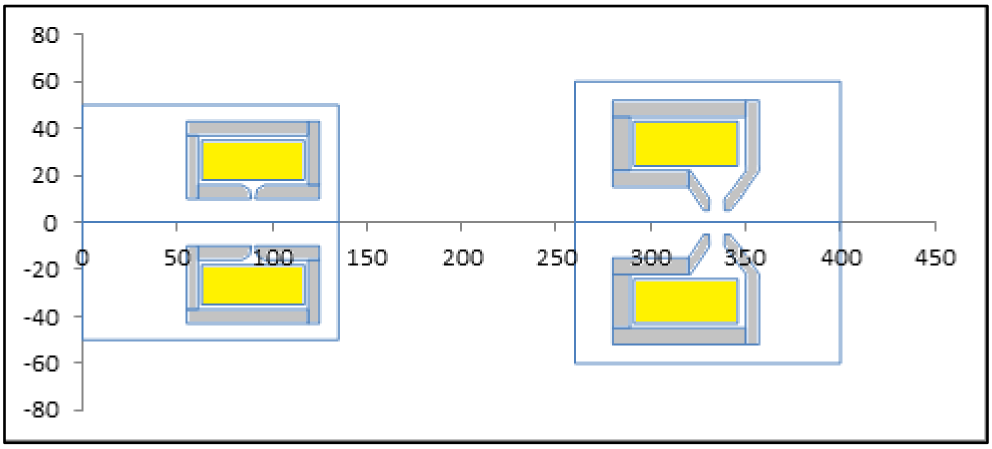

Figure (3)shows the optical column in SEM

In order to study the behavior of lenses and know of the optical performance to every part of it, important to find the magnetic flux lines density within. Flux software was used to draw the lines of magnetic flux path which represent points of equal flux density at every point of the lens points [9]. Figure (4) represents the magnetic flux lines density within illumination system.

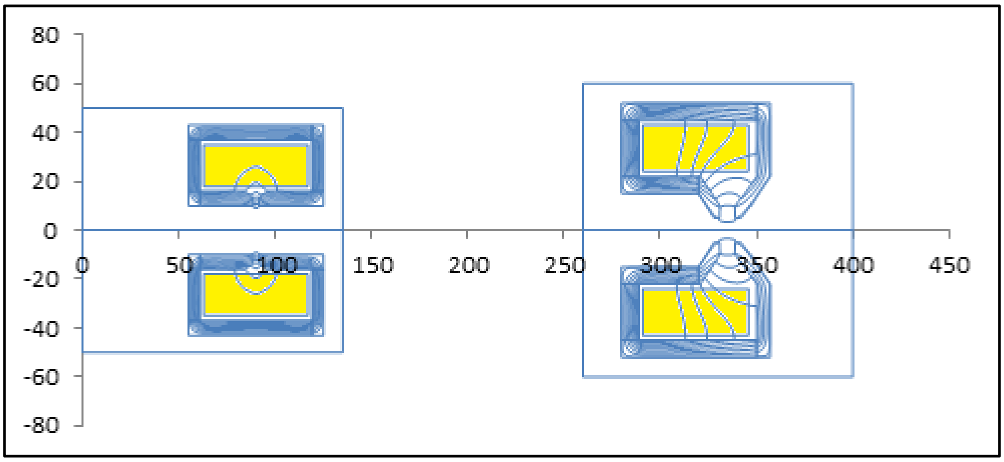

Figure (4) magnetic flux lines density within illumination system

3. Geometrical optics theory

The electron source size can be minimized to several stages during passage the electron beam within the optical column which consists of from condenser lens and objective lens to fall on the specimen surface to be examined. As shown in Figure (5).

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which shows the diagram for illumination system in SEM.

We assume that the effective diameter for electron source dG and the distance between the crossover and the center of the condenser lens is L1 and the distance between the centers of the condenser lens and objective lens L2 and these distances are always constants the instrument. The Geometrical diameter to electron probe the incident on the specimen surface d0 given in terms of the number of times demagnification of optical system (dM)t according to the following relationship:

$$d_0 = \frac{d_G}{(dM)_t} \qquad (1)$$

(dM) given by the following equation:

$$(dM)_t = dM_1 * dM_2 \qquad (2)$$

We can also express the number of times demagnification in the optical column in terms of the focal length of the optical system f1 and f2 and the constants of the instrument by the following equation:

$$(dM)_t = \frac{d_G}{d_o} = \frac{L_1 S_2}{f_1 f_2} - \frac{S_2}{f_2} - \frac{L_1}{f_1} + 1 \qquad (3)$$

The expression of geometrical diameter d0 obtained using the following equations:

$$dM_1 = \frac{d_G}{d_1} = \frac{L_1}{S_1} \qquad (4)$$

$$dM_2 = \frac{d_1}{d_2} = \frac{S_2}{S_3} \qquad (5)$$

As the S1 the distance from the first image to the condenser lens center and . Although S2 the distance from the first image to the objective lens, The S3 represents the distance from the second image to the objective lens Center.

$$d_0 = \frac{d_G}{\frac{L_1}{S_1} * \frac{S_2}{S_3}} \qquad (6)$$

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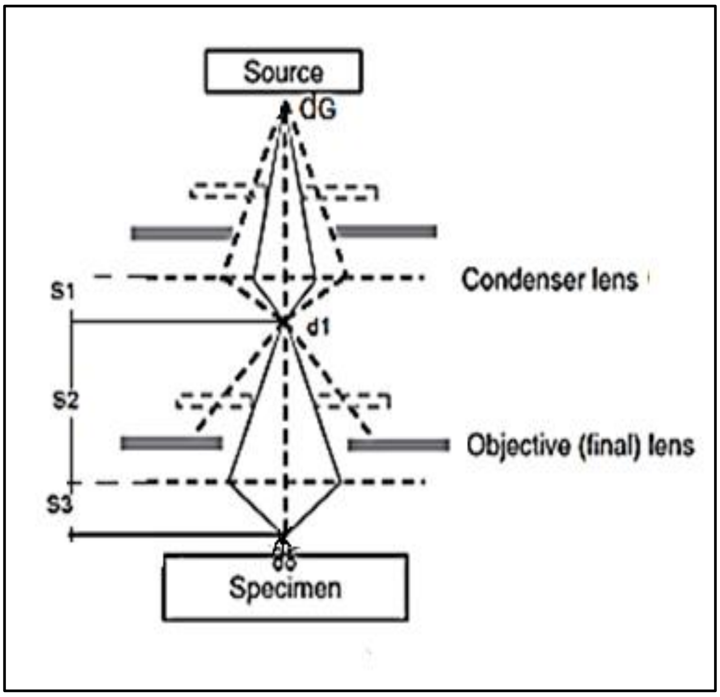

Figure (5). shows the diagram for illumination system in SEM

Distribution of the magnetic flux axial density Bz at excitation NI = 1000A.t for illumination system showed in figure (3) To investigate the characteristics of the focus of (focal length f, and image position Zi, and the number of times demagnification dM ... etc) We use a software AMAG [9] which is depends on the finite element method .figure(6) Describe the distribution of magnetic flux density Bz along the Z axis. table(1) shows the Acceleration voltage Vr(volt), Location of refraction beam, Focal length, Value of demagnification, beam diameter for the illumination system in the SEM at excitation NI=1000 A.t.

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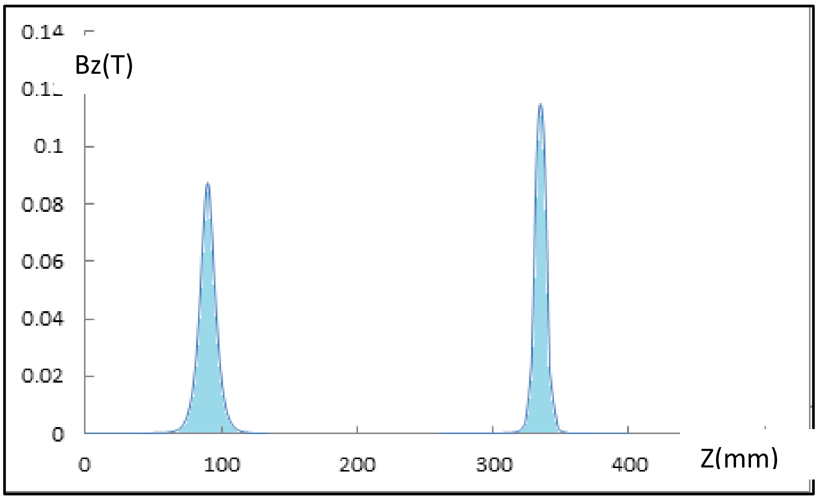

figure(6) Describe the maximum flux density Bz at excitation NI=1000 A.t

table (1) shows the Acceleration voltage Vr(volt), Location of refraction beam, Focal length, Value of demagnification, beam diameter at excitation NI=1000 A.t.

Acceleration voltage Vr(volt)	Location of refraction beam of CL Zp(mm)	Location of refraction beam of OL Zp(mm)	Focal length of CL f(mm)	Focal length of CL f(mm)	Value of demagnification of CL dM	Value of demagnification of OL dM	Beam diameter do(nm)
٨٠٠٠	٨٨.٢٦	٣٣٣.٦٧	8.12	5.73	7.30	9.80	0.0698
١٠٠٠٠	٨٨.٥٧	333.93	9.32	6.54	6.21	7.57	0.1063
١٢٠٠٠	88.80	334.12	10.54	7.36	5.37	6.50	0.1432

4. Calculations

We conclude from the current study that electron probe diameter increase with accelerating Voltage when excitation still constant in NI=1000 A.t when evidence of the specimen at the same level, so that we recommend increasing the specimen distance after an increase of accelerating voltage because the electron probe will be at the bottom of the specimen position.

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