THE EFFECT OF MAGNETIC FIELD ON THE SECONDARY ELECTRON YIELD IN THE ULTRA-HIGH VACUUM ENVIRONMENT*

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Abstract

A secondary electron emission measurement system has been designed and used to study the secondary electron emission (SEE) of different materials with an independently adjustable energy of 50 eV to 5 keV at National Synchrotron Radiation Laboratory. Here, we obtained the characteristics of the SEE yield from Pd film coatings, under the condition of magnetic field and without magnetic field. Then it was analysed that the effect of magnetic field on the secondary electron yield in the ultra-high vacuum environment. The results show that magnetic field shielding is critical to avoid the influence of magnetic field during secondary electron yield (SEY) measurements.

INTRODUCTION

Synchrotron radiation or ionization of residual gas particles in the vacuum chamber and so on, will induce the increase of the number of free electrons in an accelerator vacuum chamber and form the electron cloud which considerably hinder the stability of the high-intensity particle beams. SEY has great influence on the process of free electrons building up. Therefore, high precision SEY measurements of accelerator vacuum chamber materials are important apparently. Many research institutions, such as NSRL [1], CERN [2], KEKB [3] etc., have done some research on secondary electron emission measurements.

However, the SEY test results shown in Fig. 1 illustrate that magnetic field can affect the results. For sample Pd film coating with silicon substrate, when the incident electrons dose per unit area was $2*10^{-8}$ C • mm^{-2}, the maximum SEY were 1.75 and 1.43, respectively, under the condition of without and with the magnetic field. In addition, when the incident electrons dose per unit area was $5*10^{-8}$ C • mm^{-2}, the maximum SEY were 1.72 and 1.36, respectively under the condition of without and with the magnetic field. Therefore, this results show that the existence of the magnetic field lead to lower SEY obviously. Therefore, it is necessary to study how the magnetic field affects the SEY measurements. In this article, CST software is used to simulate the effect of magnetic field on the trajectories of electrons.

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APPARATUS AND METHODS

SEY Measurement System

The SEY measurement system shown in Fig. 2, mainly consists of electron gun, residual gas analyser, test samples, test chamber, vacuum system, data acquisition and processing system. The electron gun scans over an energy spectrum of 50 eV to 5000 eV on the samples at Emission Current Control (ECC) mode. Also, portable helium mass spectrometer leak detector was installed in the vacuum chamber to test vacuum leak rates. It is mainly composed of mass spectrometer room, extraction system and electrical components. What is more, the mass spectrometry room contains a permanent magnet with 225 ~ 235 mT magnetic field, as shown in Fig. 3.

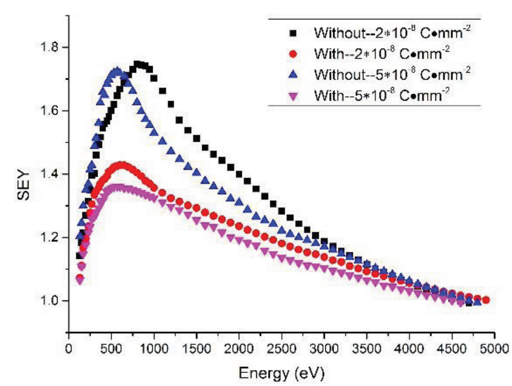

Figure 1. SEY test results for sample Pd film coating with silicon substrate.

Figure 2. SEY test device.

CST Model

CST EM STUDIO and PARTICLE STUDIO are used to simulate the effect of magnetic field on the trajectories

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of electrons. The relative position of Electron gun and permanent magnet are shown in Fig. 3. The influence of magnetic field on the electrons trajectories is related to the distance between the permanent magnet and electron gun. Therefore, we chose the horizontal distance of 10 mm, 50 mm and 100 mm, respectively.

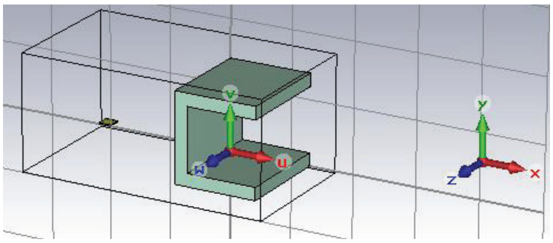
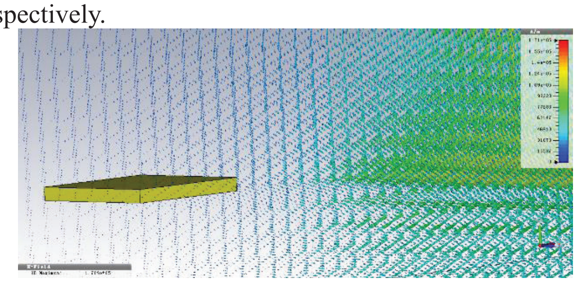


Figure 3: The relative position of Electron gun and permanent magnet in CST model.

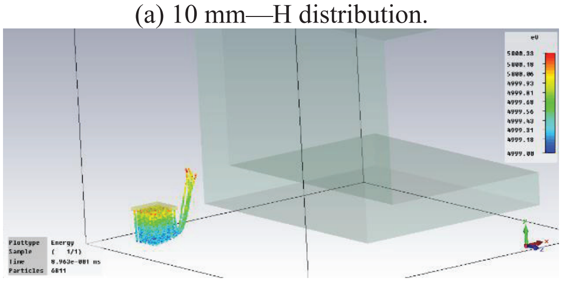
CST SIMULATIONS

Distance-10 mm

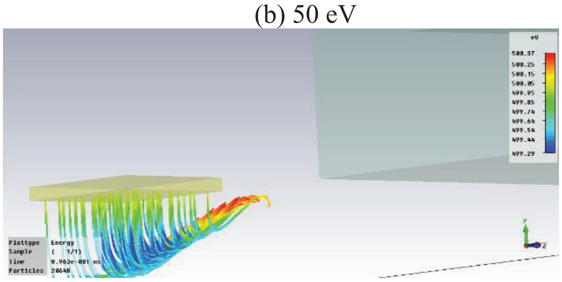
When the horizontal distance between electron gun and permanent magnet is 10 mm, the magnetic field strength H distribution is shown in Fig. 4(a). The trajectories of electrons with 50 eV and 5000 eV primary energy under the magnetic field, are shown in Fig. 4(b) and 4(c), respectively.



(a) 10 mm—H distribution.



(b) 50 eV

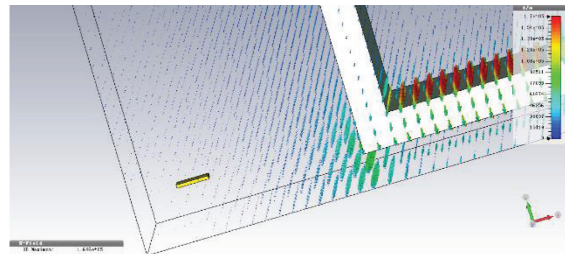


(c) 5000 eV

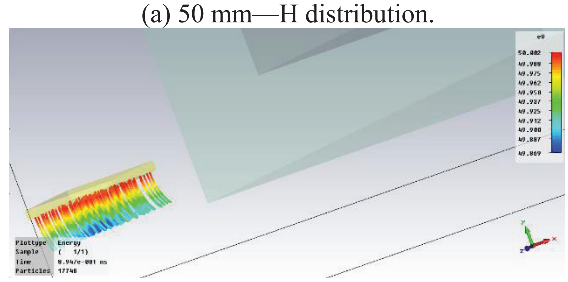
Figure 4: When the horizontal distance between electron gun and permanent magnet is 10 mm, (a) is the magnetic field strength H distribution; (b) and (c) are the trajectories of electrons with 50 eV and 5000 eV primary energy, respectively, under the magnetic field.

Distance-50 mm

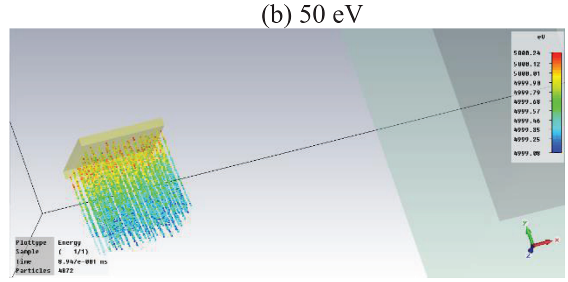
When the horizontal distance between electron gun and permanent magnet is 50 mm, the magnetic field strength H distribution is shown in Fig. 5(a). The trajectories of electrons with 50 eV and 5000 eV primary energy under the magnetic field, are shown in Fig. 5(b) and 5(c), respectively.



(a) 50 mm—H distribution.



(b) 50 eV



(c) 5000 eV

Figure 5: When the horizontal distance between electron gun and permanent magnet is 50 mm, (a) is the magnetic field strength H distribution; (b) and (c) are the trajectories of electrons with 50 eV and 5000 eV primary energy, respectively, under the magnetic field.

Distance-100 mm

When the horizontal distance between electron gun and permanent magnet is 100 mm, the magnetic field strength H distribution is shown in Fig. 6(a). The trajectories of electrons with 50 eV and 5000 eV primary energy under the magnetic field, are shown in Fig. 6(b) and 6(c), respectively.

When the primary energy of electrons is 50 eV, the influence of magnetic field on the electrons trajectories decrease obviously with the increase of the horizontal distance, which can be seen in Fig. 4(b), 5(b) and 6(b). It shows the same trend when the primary energy of electrons is 5000 eV. However, the difference is that the influence of magnetic field on the electrons trajectories decrease gradually with the increase of the primary energy, when the horizontal distance is the same, which can be seen in Fig. 4(b), 4(c), 5(b), 5(c), 6(b) and 6(c).

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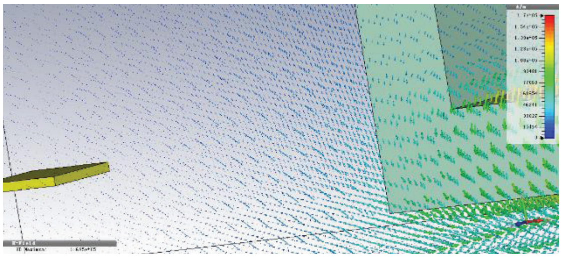
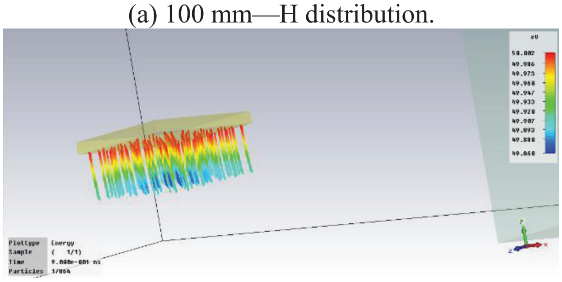
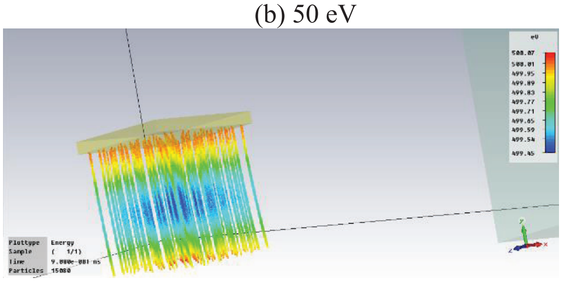


(a) 100 mm—H distribution.



(b) 50 eV



(c) 5000 eV

Figure 6: When the horizontal distance between electron gun and permanent magnet is 100 mm, (a) is the magnetic field strength H distribution; (b) and (c) are the trajectories of electrons with 50 eV and 5000 eV primary energy, respectively, under the magnetic field.

CONCLUSION

The effects of magnetic field on trajectories of electrons with 50 eV and 5000 eV primary energy, are simulated using CST software, when the horizontal distance between electron gun and permanent magnet are 10 mm, 50 mm and 100 mm, respectively. In addition, the results show that magnetic field can lead to that the maximum SEY decreased about 20% for the same sample, under the condition of 100 mm horizontal distance between electron gun and permanent magnet, when the test conditions and parameters are the same. Hence, in order to avoid the effect of magnetic field on the trajectories of electrons, it is better to remove the portable helium mass spectrometer leak detector.

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