DESIGN AND RESEARCH OF SECONDARY ELECTRON EMISSION TEST EQUIPMENT WITH LOW ELECTRON ENERGY*

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Abstract

In particle accelerators, the secondary electrons resulting from the interaction between particles and vacuum chamber have a great impact on beam quality. Especially for positron, proton and heavy ion accelerators, massive electrons lead to electron cloud, which affects the stability, energy, emittance and beam life adversely. We have studied the secondary electron emission (SEE) of metal used for accelerators. A secondary electron emission measurement system with low electron energy has been designed and used to measure the SEE yield of metal and non-evaporable getter materials. With the equipment, we have obtained the characteristic of the SEE yield of stainless steel and oxygen free copper (OFC).

INTRODUCTION

The research of secondary electron emission has attracted great interest over the past many years [1-10]. In accelerator area, obtaining high quality beam is a main target. Under bombardment of massive particles, surface of vacuum chamber excites the secondary electrons, which affects beam quality, like stability, energy, emittance and beam life. For the reason above, measuring the secondary electron yield (SEY) of different materials is extremely critical and important. Finally, we intend to find low SEY materials used for accelerators.

Nowadays, most research institutes have measured SEY by reforming expensive SEM (scanning electron microscope) and AES (Auger Electron Spectroscopy) apparatus [2]. So we decided to design an independent secondary electron emission measurement equipment with low electron energy.

In this article, the basis for the design and some test of secondary electron emission measurement system with low electron energy was introduced.

TESTING PRINCIPLES

The secondary electron yield measurement principle is shown in Fig.1. I_p is the incident current, which causes the secondary electron emission from the surface material and I_s is the secondary electron current intensity. I_p and I_s are in opposite direction and I_t is the current flowing through the sample and is the sum of I_s and I_p. The secondary electron yield (σ) is the ratio of the secondary electron current and incident current. If I_p and I_t have been measured, we can obtain SEY value by the following formula:

$$\sigma = 1 - I_t / I_p \quad (1).$$

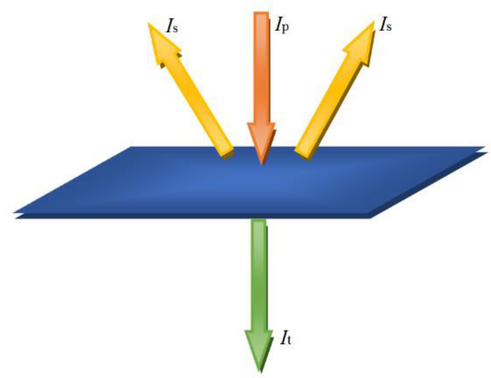

Figure 1: The SEY measurement principle.

There are two common methods of measurement: RP (Retarding Potential) method and ZR (Zero Retard) method. RP method can only measure vertical incident electron, because the electric field of sample bias in the case of oblique incidence will change the direction of the incident electron motion, so some incident electrons will not get to the sample surface. The sample is grounded with the method of ZR, and the bias voltage of the electron gun falls from zero to -300 V where the space charge effect appears, which is the main disadvantage of this method. In this mode, the incident current is changed with the increase of accelerating voltage, so both I_p and I_t need to be measured and recorded, then SEY value can be calculated by formula(1).

In further research, incident current I_p can be measured by a Faraday cup, which can reduce the irradiation time of the electron gun to the sample surface, so the charge accumulation of the sample surface will be less and the result accuracy will be improved. The schematic diagram of the Faraday cup is shown in Fig.2. Elastic scattering electrons from the surface will scatter to test indoor wall and produce secondary electrons, and these secondary electrons will cause a certain extent error to the measurement of I_s if reaching the sample surface. In order to eliminate this impact, some negative bias is applied on the samples.

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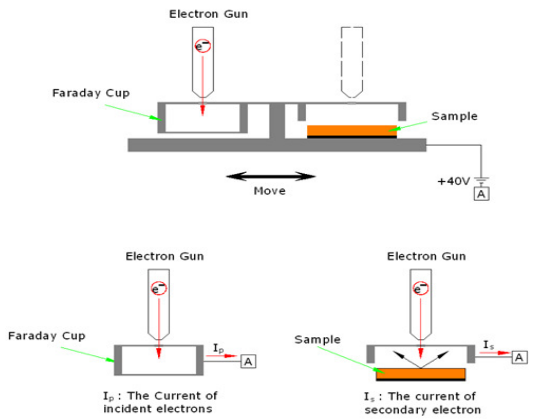


Figure 2: Schematic diagram of the Faraday cup.

TESTING APPARATUS

We have designed the testing apparatus on the basis of SEY testing principle. The measurement system mainly consists of vacuum chamber, ion pump, molecular pump, electron gun, sample holder and galvanometer. The vacuum chamber is used to provide the hermetic test environment. The ion pump and the molecular pump are used to pump air and finally get the ultrahigh vacuum environment (10^{-7} Pa). The electron gun is used to irradiate the electron in order to excite the secondary electron. The galvanometer is used to measure the values of I_P and I_t. The picture of the testing apparatus is showed in Fig.3.

During the measurement, bombardment of a large number of electrons will have a great influence on the sample surface, especially insulator sample, and surface charge accumulation will appear, which will obviously affect the measurement precision and accuracy. Thus it is required that emission current should be low and pulse be narrow. In this study, EGL-2022B electron gun of KIMBALL has been used, and the electron beam energy ranges from 50 eV to 5 keV, the emission current ranges from 1nA to 100μA. Standard working distance of the electron gun is 20 mm, and the beam spot radius is 1 mm to 5 mm.

Figure 3: Testing apparatus.

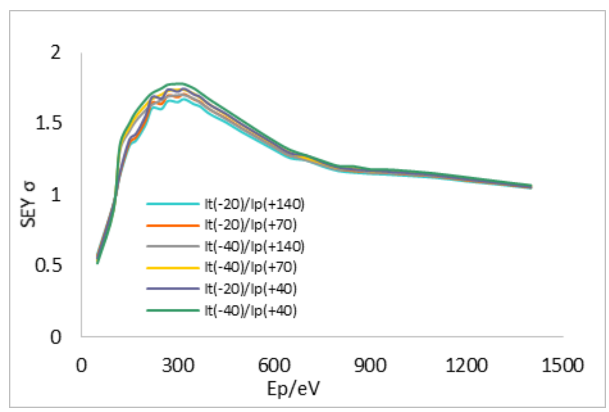
SEY MEASUREMENT RESULTS

We has tested SEY of stainless steel and OFC under different conditions. These parameters of the electron gun are as follow;

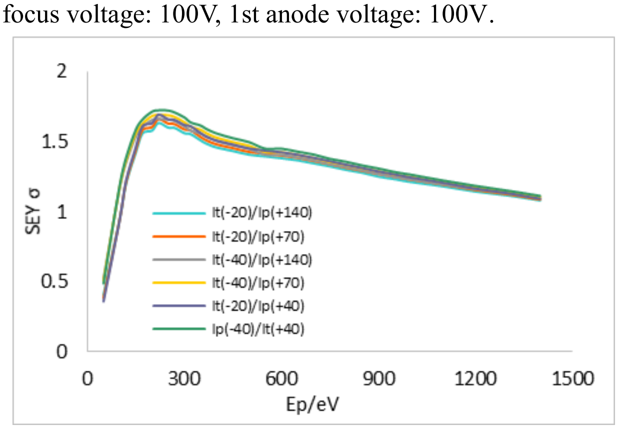
- incident electron energy (E_p): 50~1500eV
- emission current: 1μA 0.2μA
- working distance: 20mm
- gird voltage: 5V 9V
- focus voltage: 50V 100V
- 1st anode voltage: 50V 100V

In order to get accurate data, we have added different bias (+140V, +70V, +40V for I_p and -20V, -40V for I_t) to the samples and recorded the values of I_p and I_t. And we calculated SEY by formula (1). The results are showed in Fig.4 below.

For stainless steel, σ_{max} ranged from 1.634~1.78 and for OFC, 1.843~1.943. Under different bias voltage, σ_{max} had a 6.3% difference. For Fig.4-a, σ_{max} is 1.78 at bias voltage of -40V/+40V and 1.674 at -20V/+140V, for Fig.4-b, σ_{max} is 1.724 at bias voltage of -40V/+40V and 1.634 at -20V/+140V, for Fig.4-c, σ_{max} is 1.909 at bias voltage of -40V/+70V and 1.843 at -20V/+140V, for Fig.4-d, σ_{max} is 1.943 at bias voltage of -20V/+50V and 1.906 at -40V/+70v.



a) Stainless steel, emission current: 1μA, gird voltage: 9V, focus voltage: 100V, 1st anode voltage: 100V.



b) Stainless steel, emission current: 0.2μA, gird voltage: 5v, focus voltage: 50V, 1st anode voltage: 50V.

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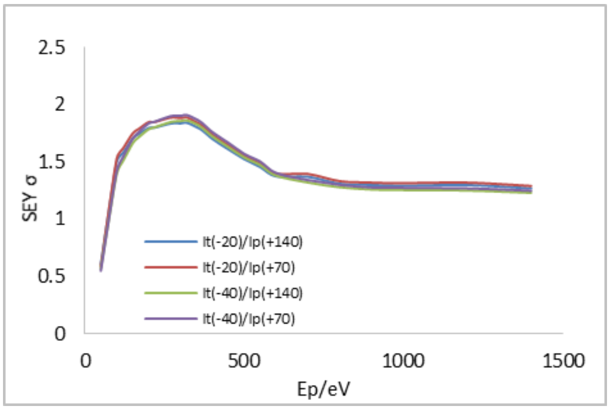
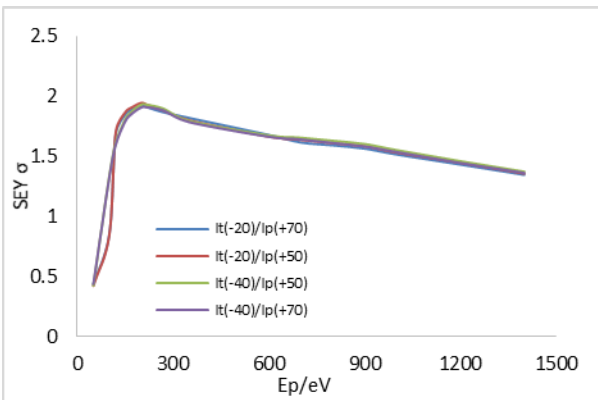


c) OFC, emission current: 1μA, gird voltage: 9V, focus voltage: 100V, 1st anode voltage: 100V.



d) OFC, emission current: 0.2μA, gird voltage: 5V, focus voltage: 50V, 1st anode voltage: 50V.

Figure 4: Measurement results of SEY on stainless steel and OFC.

CONCLUSION AND DISSCUSSION

In this article, the SEY testing apparatus was introduced and the results of SEY of stainless steel and OFC samples under different bias voltage were showed and analysed. According to the results, it's believed that our apparatus is credible compared with other results [3]. There are still some aspects which need to be improved in the measurement system, such as contamination on the surface of the sample and accuracy of measurement.

FUTURE PERSPECTIVES

We will make improvements on the system and make it more convenient and accurate. Besides the Faraday cup, we will add an Ar ion gun and a quadrupole mass spectrometer (QMS) to the measurement system in the future. During the production and delivery process, the contamination of sample surface is inevitable. Contaminated layer will seriously affect the measurement precision and accuracy. In order to improve the reliability of the test results, Ar ion gun is used to clean the sample surface. In addition, we will test the characteristic of the SEE yield of non-evaporable getter materials (NEG) thin film, insulation materials and semiconductor materials in the future.

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