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Measurement of Ion-induced Secondary Electron Emission Yield of MgO Films by Pulsed Ion Beam Method

Sang Kook Lee[a], Jae Hong Kim[b], Ji Hwa Lee[b*], and Ki Woong Whang[a*]

Abstract

Measurement of the ion-induced secondary electron emission coefficient (γ_i) for insulating films is hampered by an unavoidable charging problem. Here, we demonstrate that a pulsed ion beam technique is a viable solution to the problem, allowing for accurate measurement of γ_i for insulating materials. To test the feasibility of the pulsed ion beam method, the secondary electron emission coefficient from n-Si(100) is measured and compared with the result from the conventional continuous beam method. It is found that the γ_i from n-Si(100) by the ion pulsed beam measured to be 0.34, which is the same as that obtained by continuous ion beam. However, for the 1000 Å SiO_2 films thermally deposited on Si substrate, the measurement of γ_i could be carred out by the pulsed ion method, even though the continuous beam method faced charging problem. Thus, the pulsed ion beam is regarded to be one of the most suitable methods for measuring secondary electron coefficient for the surface of insulator materials without experiencing charging problem. In this report, the dependence of γ_i on the kinetic energy of He^+ is presented for 1000 Å SiO_2 films. And the secondary electron emission coefficient of 1000 Å MgO e-beam-evaporated on SiO_2 / Si is obtained using the pulsing method for He^+ and Ar^+ with energy ranging from 50 to 200 eV, and then compared with those from the conventional continuous method.

Keywords : secondary electron emission coefficient, surface charging, pulsed ionbeam method

1. Introduction

Plasma display panel (PDP)[1,2] has gained greater attention as one of the most promising candidates for flat panel display due to its excellent advantages large display area, high brightness, simple structure, fast response and brood view, etc. In ac plasma display panels, the electrodes of a PDP cell are covered with a dielectric layer (~ a few tens of μm) and a thin insulating film is again deposited on the top of the dielectric which must be protected from erosion by plasma ion bombardment. Currently, a thin film of MgO (5000 Å) is widely used as the protective layer, which known for its long lifespan and maintenance of stable operation of PDPs. The high ion-induced secondary electron emission coefficient of MgO also makes itself dominant as a protecting layer because the firing as well as the sustain voltage of PDP is known to be greatly attected by the γ_i of the protecting layer.[3,4]

Moon et al., using a continuous beam (dc beam method)[5] have previously reported on the γ_i values for MgO films, which were e-beam evaporated on stainless steel substrate. In this report, we demonstrate that a pulsed ion beam technique can be successfully applied to measure the secondary electron ejection yield of the insulating films by comparing this method to the conventional dc beam method. The dependence of γ_i of 1000 Å SiO_2 films is measured with the focused mass selected beam of He^+. Finally, the secondary electron

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* Member, KIDS.
Corresponding Author : Sang Kook Lee
a. Division of Electrical Engineering. Seoul National University San 56-1, Shillim-dong Kwanak-gu, Seoul 151-742, Korea.
b. Division of Chemical Engineering, Seoul National University San 56-1, Shillim-dong, Kwanak-gu, Seoul 151-742, Korea.
E-mail : q30527@snu.ac.kr **Tel** : +2 880-8349 **Fax** : +2 880-1604

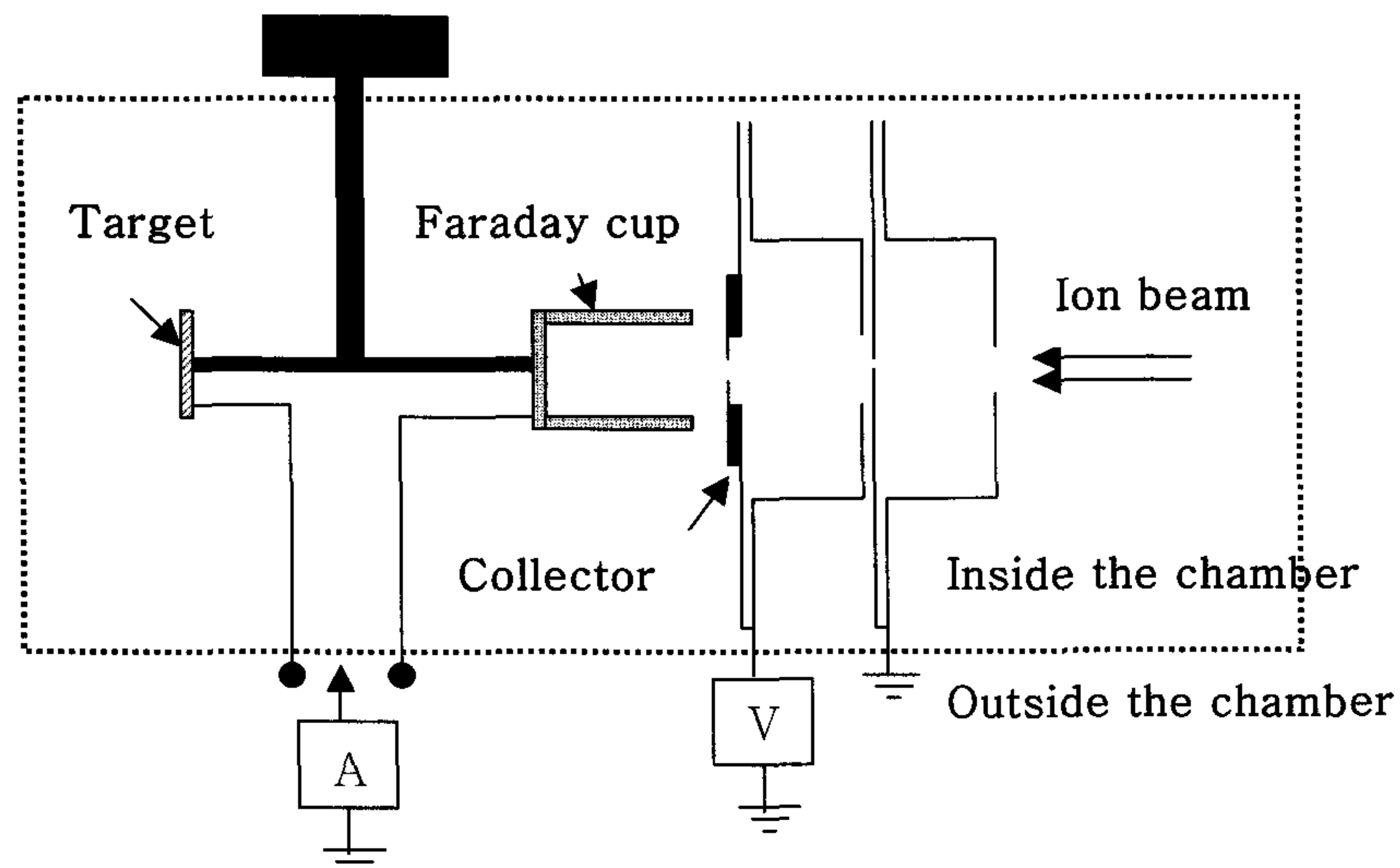

Fig. 1. Schematic diagram of the current measurement system.

emission yields from MgO films with 1000 Å thickness with the ion pulsed beam technique is compared with those from the conventional dc beam method.

2. Experimental

The ion source system (Colutron Inc. model G-2-D) is used to deliver a focused mass-selected beam of ions with the energy ranges from a few tens of eV to 10keV and with a beam current of 10-700 nA. The mass-filtered ion beam is chopped to a pulsed ion beam (duration = 2.5 μs) by combining of the pulse generator (Sanford Research System Inc.) and the high voltage generator (AVTECH). A thin film of 1000 Å SiO_2 is thermally-grown on n-type Si substrate and then, 1000 Å MgO layer is e-beam evaporated onto the SiO_2/Si. The thickness is measured by ellipsometer and α-step, respectively. The crystal orientation is confirmed with X-ray diffraction patterns. The sample is mounted on a rotatable X–Y–Z manipulator in a high vacuum ($P \sim 4\times10^{-8}$ Torr.) chamber together with a Faraday cage and a thin tungsten wire for measuring the primary ion beam current and the beam profile, respectively. The sample can be heated radiatively to 700 °C by a tungsten filament to relax the surface charging, which is usually formed on MgO surface by incident ion beam during each measurement. The temperature is monitored with a K–type thermocouple spot-welded to the substrates. The pulsed ion beam emerging from the decelerator of the ion source reaches the sample 4 cm downstream and the beam spot size is nearly 2.5 mm in diameter. The secondary electrons are completely collected by a half-closed cylinder, which is biased to a few positive volts. Fig.1 shows the schematic diagram of the current measurement system. In the continuous beam (dc) measurement, the target current (I_T) or the collector current (I_C) and the faraday current (I_F) are measured while scanning with respect to the sample ground. In the case of conventional continuous method, the currents (as a current mode itself) of the I_F, I_C and I_T are measured at the same time while the collector bias (V_C) is scanned. The secondary electron emission coefficient is defined as the ratio of the current of (I_T- I_F) to that of I_F or the ratio of the current of the I_C to that of I_F. Both ways always give the same ratio. For the pulsed beam method, the pulsed ions and secondary electros are measured by an internal capacitor of which output voltages are proportional to the current. Both current measurements are synchronized at the condition that V_C is fixed to a constant voltage to attract the electrons emitted from the sample. The secondary electron yields is defined in the same way as used in the continuous method.

3. Results and Discussion

The values of γ_i for n-Si(100) for 200 eV He^+ ions obtained by both (a) the dc beam and (b) the pulsed ion

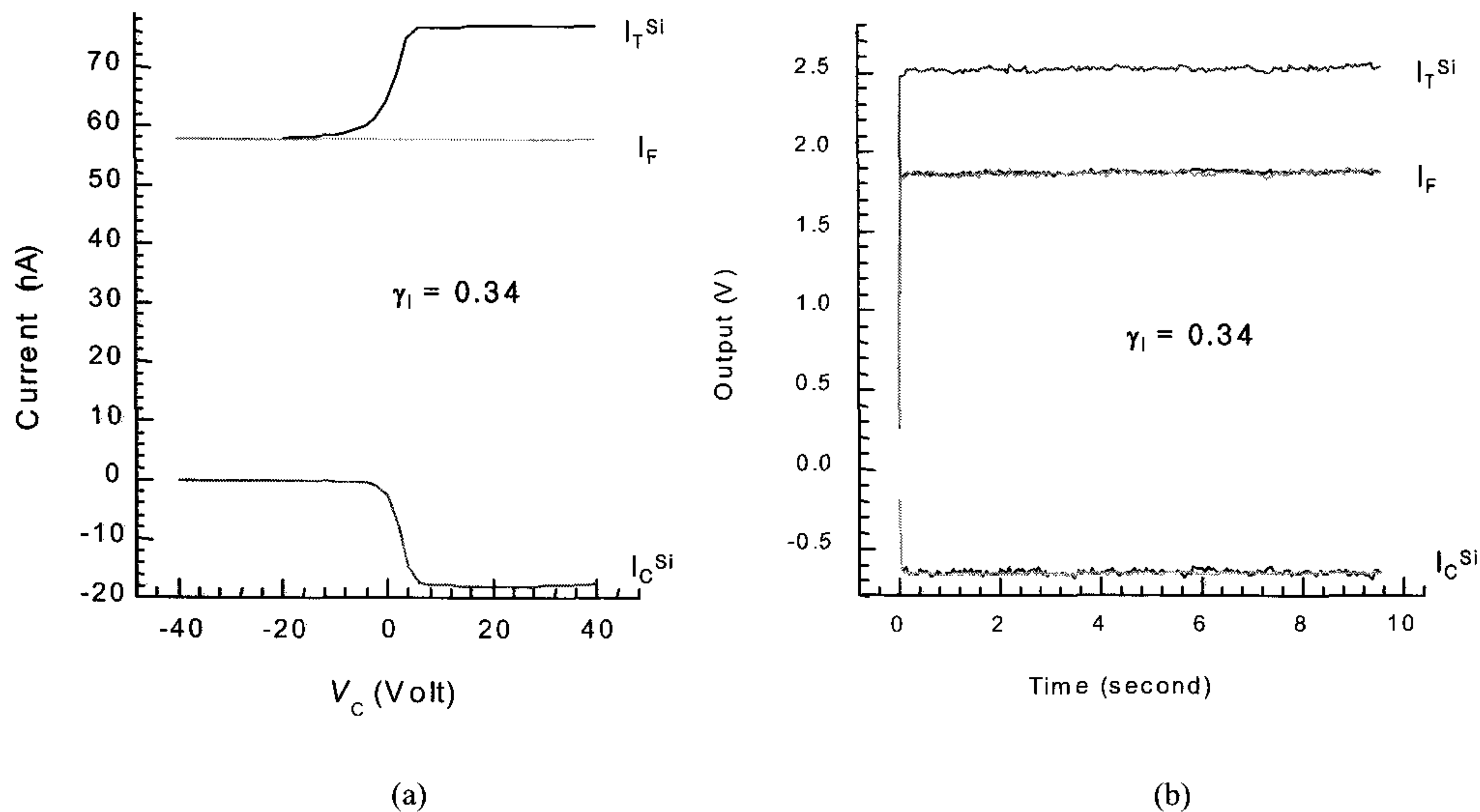

Fig. 2. Measurement of secondary electron emission coefficient of Si with the dc beam (a) and the pulsed ion beam (b).

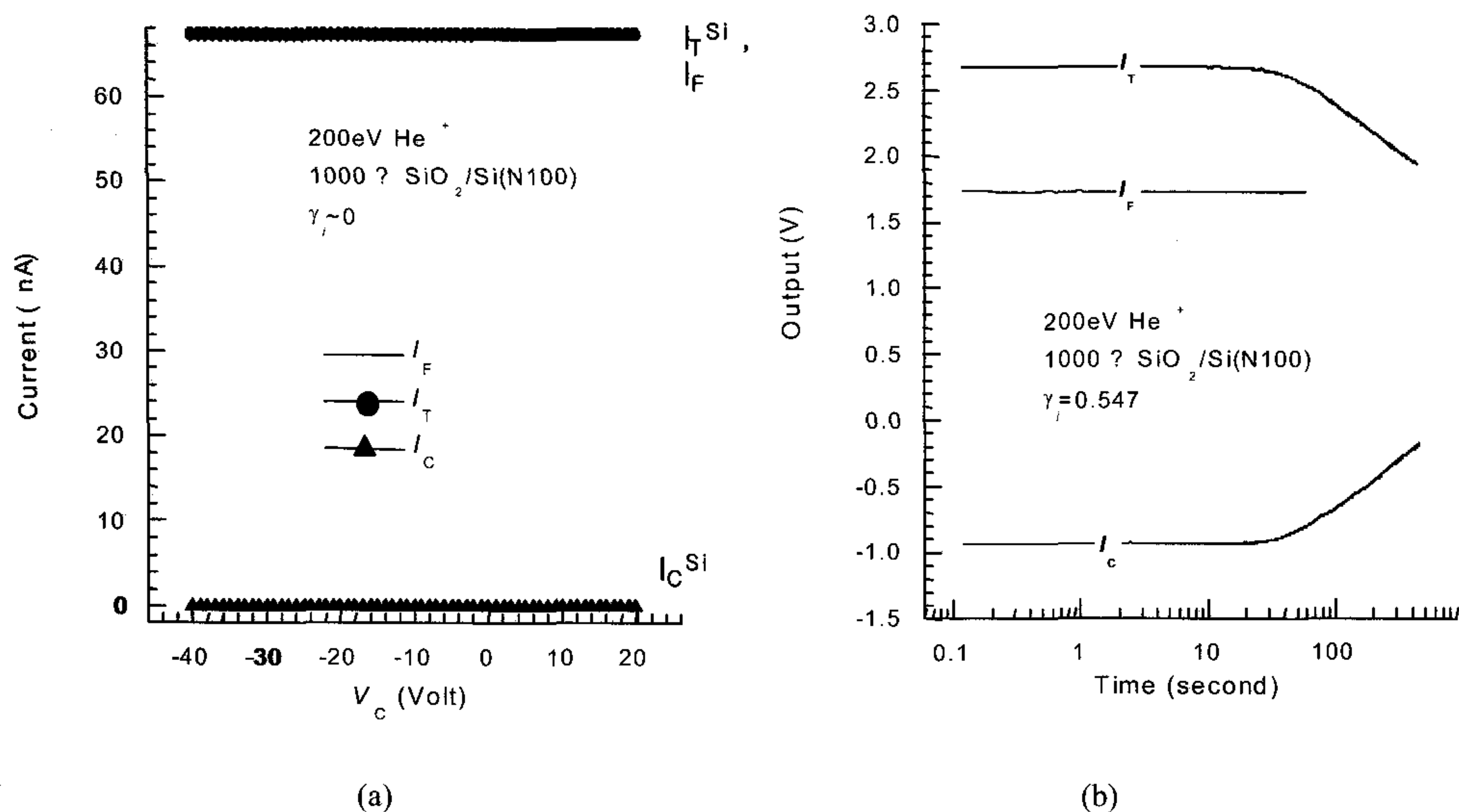

Fig. 3. Secondary electron emission coefficient of SiO_2 measured with the dc beam (left) and the pulsed ion beam (right).

beam are presented in Fig. 2. As shown in Fig. 2 (a), in the dc beam method, a constant He^+ ion beam incidents to the sample while collector bias (V_C) is scanned from –40 to +40 V. In the negative bias of V_C, secondary electrons are completely suppressed by the negative collector bias, indicating the collector current is nearly zero. Therefore, the target current measured on the sample (I_T, sum of incident ion current and secondary electron current) is equal to the current measured on the faraday cage (I_F). However, when the collector bias changed from negative to positive, secondary electrons are completely attracted by the collector. From the definition of γ_i, the ratio of the emitted electrons to the incident ions, γ_i is estimated to be 0.34.

In contrast, in the pulsed ion beam method, V_C is fixed to +6 V, which is large enough to collect secondary electrons. If the collector voltage is too large, compared with the kinetic energy of ions, there is some possibility that the ion beam can be affected by the collector bias, and an undesirable deformed beam trajectory arises, especially, in the lower kinetic energy range (less than 30 eV), which leads to an inaccurate measurement. As can

be seen in Fig. 2 (b), the same value of $\gamma_i = 0.34$ for n-Si is obtained from both the methods, indicating that the definition of γ_i on both methods are identical.

Both methods are also applied for measuring γ_i of 1000 Å SiO_2 films (see Fig. 3). From the dc beam method, the secondary emission current can not be successfully measured because of surface charging, which builds up when the primary beam incidents on the SiO_2 films. Unlikely the dc method, ac method is able to determine γ_i = 0.547 for 1000 SiO_2 Å films with He^+ of 200 eV. The reason why the dc beam method is able to measure γ_i from Si is due not to suffer from the serious surface charging problem. However, in the case of SiO_2 films, incident ions make the surface of SiO_2 films immediately charged due to the ejection of secondary electrons, which usually leaves positive charges on the surface. Fortunately, the surface charging time can be delayed up to ~ a few tens of seconds in the pulsed ion beam technique in which pulsed ion beam delivers low flux of ions, causing the surface charging, which in turn enables us to measure the true secondary electron emission coefficient of insulator.

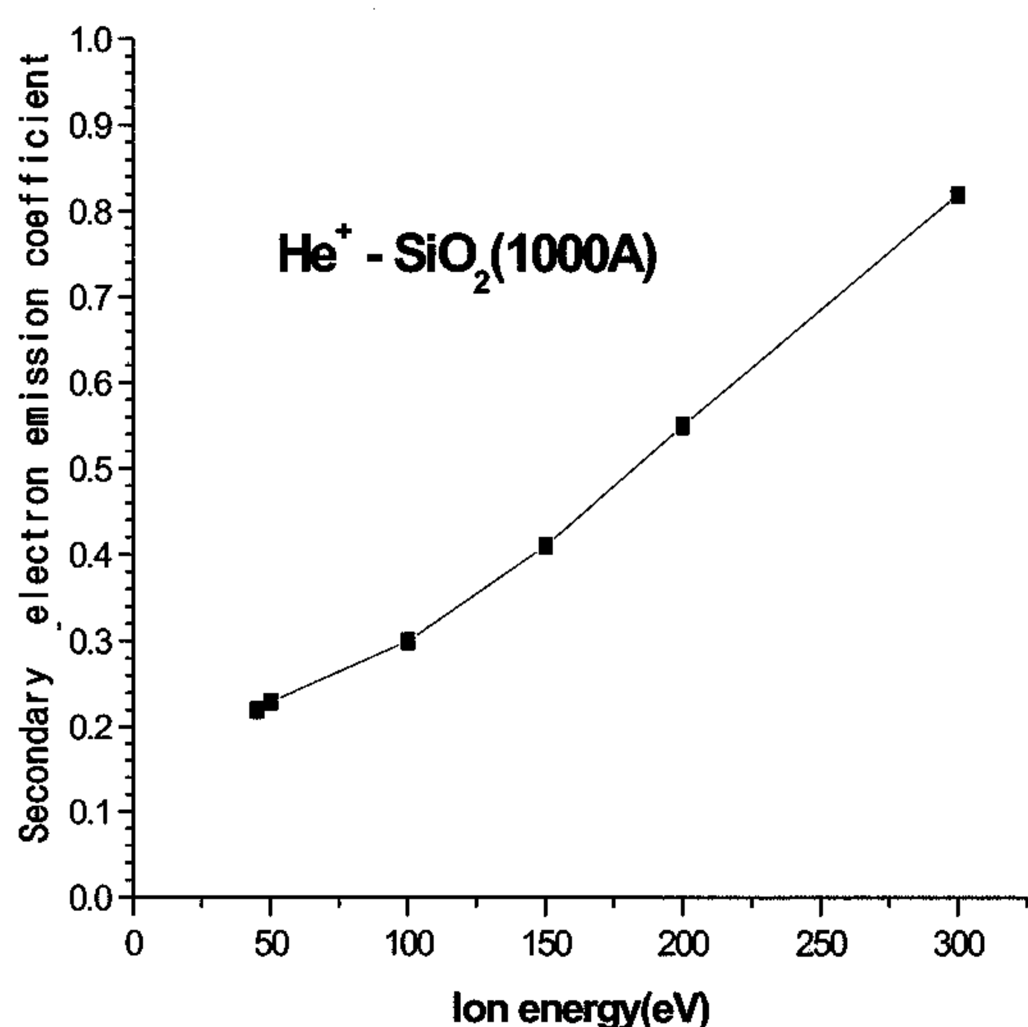

Fig. 4. Energy dependency of γ_i of 1000 Å SiO_2 for He^+.

The measurement is made with 1000 Å SiO_2 films deposited on n-Si(100) substrate using He^+ of kinetic energy varying from 45 to 300 eV. In Fig. 4, the dependence of γ_i of SiO_2 films on kinetic energy of incident ions is clearly seen with γ_i decreasing from 0.85 at 300 eV to 0.21 at 45 eV. It is well known that secondary electron emission takes place by the combination of potential emission and kinetic emission, at least in the energy range used in our experiment.

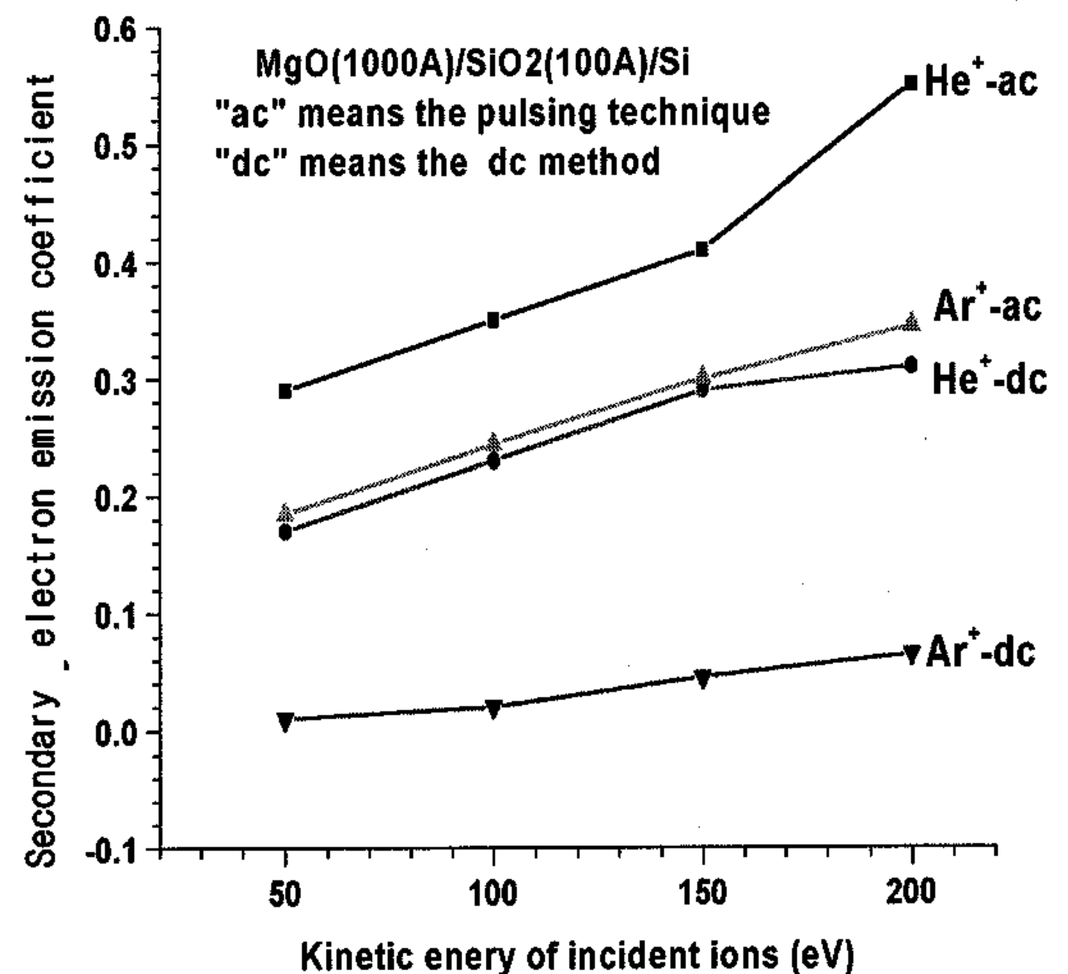

Fig. 5. Comparison of the pulsed ion beam technique and the conventional dc beam method in the secondary electron emission coefficient of MgO films.

Finally, the γ_i of 1000 Å MgO films on SiO_2 is measured for He^+ and Ar^+ with kinetic energy of 50 to 200 eV using the two different methods. Before each measurement, MgO films were heated to about 300 °C for 20 min to relax the possible remnant surface charging. In Fig. 5, the dependence of ion-induced electron emission coefficient of MgO films shows the same trend on both He^+ and Ar^+ ions. The emission coefficient decreases from 0.55 at 200 eV to 0.32 at 50 eV in case of He^+, similarly from 0.38 at 200 eV to 0.18 at 50 eV for Ar^+ ions. However, the smaller value from the dc method for the two ions in the kinetic energy range used in the measurement is believed to be due to the surface charging which can make the dc method inapplicable to the measurement of insulator. In contrast, the higher yields from the pulsed ion beam technique gives clear evidence that the measurement can be carried out before the charging affects the secondary electron emission.

4. Summary

The capability of the pulsed ion beam technique is demonstrated in the measurement of γ_i of insulating films. While the application of the dc beam method is limited to the γ_i measurement of insulator due to the surface

charging, the pulsed ion beam technique become possible to measure the secondary electron emission coefficient of insulator such as SiO_2 and MgO films. In the case of n-type Si, the γ_i measures to be 0.34 by both the dc beam and the pulsed ion beam methods. However, the ion beam technique is able to determine the γ_i of SiO_2 films while the dc beam method can not be used. Using the pulsed ion beam, the secondary electron emission coefficient γ_i of both SiO_2 formed on Si substrate and MgO films on SiO_2/Si show similar dependence on the kinetic energy of He^+ and Ar^+ ions in the kinetic energy range varying from 50 to 200 eV. From the comparison of the secondary electron emission coefficient of insulators such as SiO_2 and MgO used in the different methods, namely, the pulsed ion beam technique and the dc beam method, it is clearly demonstrated that the pulsed ion beam technique can determine the γ_i of insulators without experiencing surface charging problem.

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