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Total electron emission yield measurement of insulator by a scanning small detector

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Due to the injection of primary electrons and the emission of secondary electrons in the surface layer of insulating materials, the target surface will be negatively or positively charged. A method by injecting a single pulse beam and using a small current detector for the total electron emission yield measurement of insulating material is proposed, which can avoid the influence from charged surface. Using the developed system, the total electron emission yield of 25 μm thick polyimide film has been studied, as induced by a single 50 μs pulse of primary electrons with energy up to 2500 eV. © *2011 American Institute of Physics*. [doi:10.1063/1.3647637]

The electron emission yields of conductors are relatively easy to measure, however, the yield measurement of insulating materials is more difficult because of the inside charging phenomenon. The accumulated charge can affect the secondary electron (SE) emission yields by altering incident energies of primary electrons (PEs) or by affecting the escape energies and numbers of SE and backscattered electrons (BSEs), or by recombination phenomena that might occur between the trapped holes and those electrons.

A great number of theoretical and experimental investigations have been published on secondary electron emission from insulators due to electron bombardment.[1–19] A short pulse irradiation method is proposed to reduce the influence of accumulated charge.[9] Willis and Skinner[10] used a beam current which was limited to 1 nA for a pulse duration of 1 μs over an area of 5 mm^2 at the target surface to avoid further charge effects. The test yield results will be influenced by the charge deposition in spite of low current density. Charge dissipation by target heating for thermally increasing the sample conductivity is also an effective method.[11] However, for the normal polymers, they cannot be heated to very high temperature, and they also show high resistivity even at high temperature, it will take a long time in charge dissipation. Charging neutralization by a low-energy electron flood gun for positively charged surface and by a variety of visible and ultraviolet light source for negatively charged surface was also used.[12,15,16] The problem is also focused on the trapped charge on the surface layer. The trapped holes in the surface layer are difficult recombine with the low energy flood electrons. There will be more electrons present on the surface. Kobayashi and Saito,[17] Miyake, *et al.*,[18] and Nitta *et al.*[19] changed the beam injecting position on the sample surface after each measurement to avoid the surface charging effect. The disadvantages are some emitted electrons from target surface will escape from the gap between collector and sample, and the secondary backscattered electrons will bombard the target surface again, that will lead to surface charging on the unmeasured position.

In this article, we introduce a method by injecting a single pulse beam and using a small current detector for the total electron emission yield (TEEY) measurement of insulating material. Using this technique, the real charging-free TEEY $\sigma(E_P)$ as a function of the primary electron energy E_P can be measured.

The small current detector design is as shown in Fig. 1, a narrow cup-like stainless steel collector in 6 mm diameter, in which the upper side includes a 1.5 mm hole, tightly touches the surface of target under test. The distance between two adjacent measurement spots is 10 mm without overlap region. The total electron emission yield is defined as the formula shown in Fig. 1.

The schematic diagram of the single pulse yield measurement system is shown in Fig. 2. This system is developed based on JEOL JAMP-10 SXII Auger Microscope. Measurements were conducted in an ultra high vacuum system at a pressure of 7×10^{-5} Pa. The target sample is 25 μm thick polyimide film (Kapton-100H Tenjin DuPonts). Yield measurements were made using a dynamic single pulse scanning method. The samples were metallized on the back-face with a $\sim$ 100 nm Au coating and cleaned using ethyl alcohol before introduction into the vacuum chamber. The electron beam current was $\sim$10–100 nA on a spot area of $\sim$1–1.5 mm^2 with a short duration time 50 μs. Because the LaB_6 electron gun worked based on thermally electron emission mechanism, the

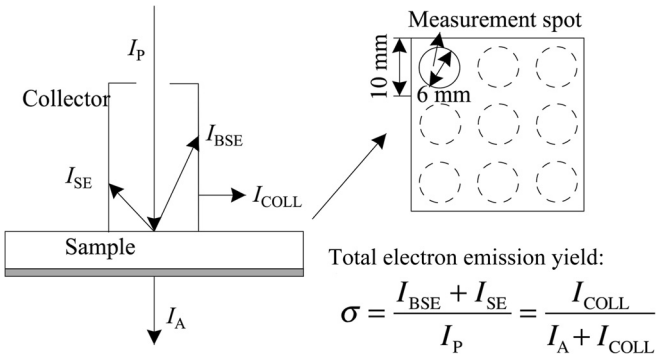

FIG. 1. Proposed small current detector.

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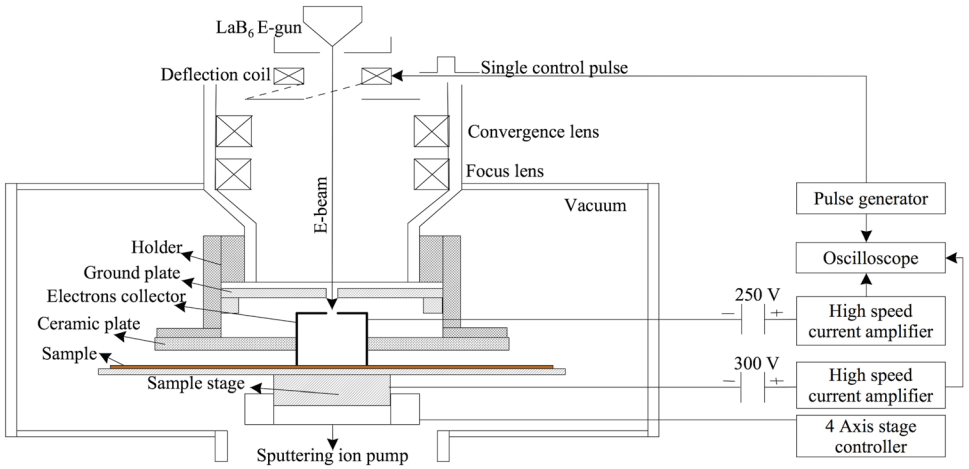

FIG. 2. (Color online) Schematic diagram of TEEY test system.

e-beam with low energy below 300 eV is difficult to emit. The low energy electron beam can be obtained by biasing the sample stage with −300 V respected to ground. Two electrolytic capacitors were charged and used to supply bias voltage, which have no noises due to power sources and have fast response time. The chemical cell battery was not suggested for pulse test considering to low response time. The high-speed current amplifier with fast response time (1.6 μs) and low-noise (10^7 V/A, 60 fA noise current) was used. After each measurement, the detecting position was moved to the adjacent spot without overlap area.

The experimental result is compared with references, and they are summarized in Fig. 3. The total yield curve is characterized in terms of the following four parameters: (1) and (2) the first and second crossover energies E_1 and E_2, which occur when the total yield is equal to 1; and (3) and (4) the peak yield σ_{max} at beam energy E_{max}. Our obtained parameters are $E_1 < 50$ eV, $E_2 \approx 650$ eV, $E_{max} \approx 150$ eV, and $\sigma_{max} \approx 1.8$. For Willis *et al.*,[10] they are $E_1 = 30$ eV, $E_2 = 500$ eV, $E_{max} \approx 150$ eV, and $\sigma_{max} \approx 2.1$. For Dennison *et al.*,[15] they are $E_1 \approx (30 \pm 10)$ eV, $E_2 \approx (962 \pm 25)$ eV, $E_{max} \approx (195 \pm 10)$ eV, and $\sigma_{max} \approx (2.4 \pm 0.1)$. For Nitta *et al.*,[19] $E_2 = 650$ eV, E_1, E_{max}, σ_{max} was not obtained due to the limitation from E-gun. Based on Burke's semi-empirical model which deduced from Matskevich, Willis *et al.*'s experimental data, they are $E_1 = 44$ eV, $E_2 = 698$ eV, $E_{max} = 189$ eV, and $\sigma_{max} = 1.96$.[3] Our result can make a approximate approach below E_2, and a good fit above E_2 with the prediction of the Burke's theory.

In case of Willis's test, the previous remained positive charges in the same injecting spot will recombine with PEs, BSEs by PEs, or internal SEs, then reduce the TEEY and E_2 value. In case of Dennison's test, after neutralizing process, the negative charges will deposit on the surface layer of target sample, and it should be contributed to higher TEEY through the entire incident energy and increasing of the E_2 value. In case of Nitta's test, TEEY at high energy is higher than ours, which should be influenced by BSEs from inner side of collector. The reflecting BSEs can reach to other unmeasured position. Above E_2, negative charges will deposit, and it will contribute to high yield. In our case, the primary electron beam passed through the upper hole of small current detector in 6 mm diameter and reached to the sample surface, and the BSEs from sample surface and second BSEs from inner side of collector will be only restricted inside of collector and not escape into other unmeasured position.

The normalized yield curves are plotted in Fig. 4. The energy dependence of $\delta(E_p)/\delta_{max}$ can be well fitted experimentally by an approximately universal scaling function in Fig. 4.[8] The scaling factor s is obtained by fitting. For the direct interpretation of secondary electron emission yield

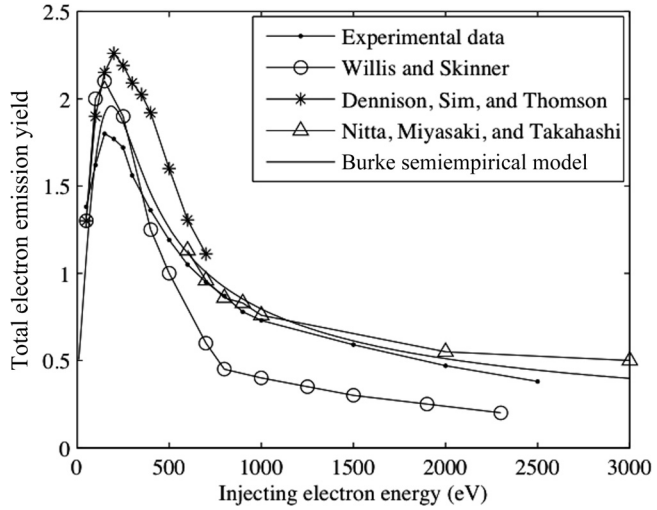

FIG. 3. TEEY curves of Kapton film.

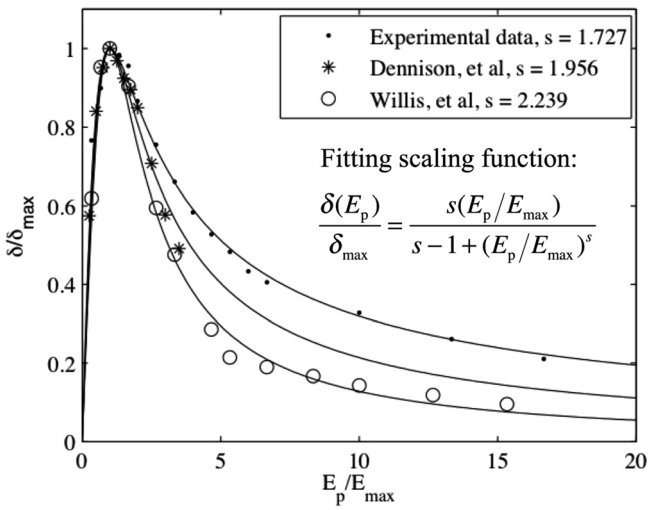

FIG. 4. Normalized TEEY curves of Kapton film.

data, the most frequent choice is s = 1.3, s = 1.35, or s = 1.4 for insulators and semiconductors.[6] According to our experimental data, $s = 1.727$, it is very close to $s = 1.725$ recommended by Burke.[3]

To conclude, using this technique by injecting a single pulse beam and using a small current detector, we obtained the different total electron emission yields of 25 μm thick Kapton polyimide film. E_2 is about 650 eV, $E_{max} \approx 150$ eV, and σ_{max} is about 1.8. This method can actually avoid the surface charging of insulating material during TEEY test, and then measure the TEEY of the real uncharged surface at each measurement.

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