The Secondary Electron Yield for High-Energy Proton Bombardment on Aluminum Target

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The phenomenon of secondary electron emission was discovered in the beginning of the 20th century.[1] It is well known that there are two mechanisms contributing to the secondary electron emission,[1] potential emission and kinetic emission. The former may proceed in front of the surface either by Auger neutralization or by resonance neutralization following Auger deexcitation when the potential energy of the projectile is two times larger than that of the work function. The latter is more important than the former in the MeV range of projectile energies. It is dominant in many ion-beam analyses since they are usually performed with MeV ion beams.

Secondary electron emission is the dominant surface yield when MeV-energy protons enter metallic targets, with the yields of sputtered ions or reflected protons being insignificant.[2] The source of these electrons is the Coulomb interaction of the fast protons with electrons within about 100 Å of the surface of the target. In the experiment described here, the secondary-electron emission coefficient is measured for 33, 39 and 42 MeV protons from the cyclotron accelerator passing through aluminum surfaces.

When we measure the beam current, it is hard to get exact incident beam current because of excessive evaluation by reason of secondary electron. We try to get down it using negative electron voltage, it is very hard to get down because secondary electron energy is very high in case of high energy incident beam. So we need exact data for these but that is poor, and we can't correct its present situation. In this study, we try to measure this secondary electron using cyclotron accelerator it is many used for isotope production.[3,4]

Experimental

To measure the emission yield of secondary electrons, we manufactured a concentric spherical analyzer (CSA),[5,6] as shown in Figure 1. Projectile ion was introduced into the analyzer through an aperture with a diameter of 10 mm. A negative bias voltage of 150 V was applied to the aperture to prevent convoy electrons from entering the CSA with projectile ions and the secondary electron from escaping the CSA through the ion entrance hole. The surface of a high-purity (4 N) aluminum target (5 mm diameter, 10 mm length) was highly cleaned and mounted at the center of the CSA in a direction normal to the incident beam. They were electrically isolated from other parts of the analyzer. Secondary electrons from the target surface were collected by using a brass spherical collector with a diameter of 90 mm, which had two holes for evacuating the analyzer.

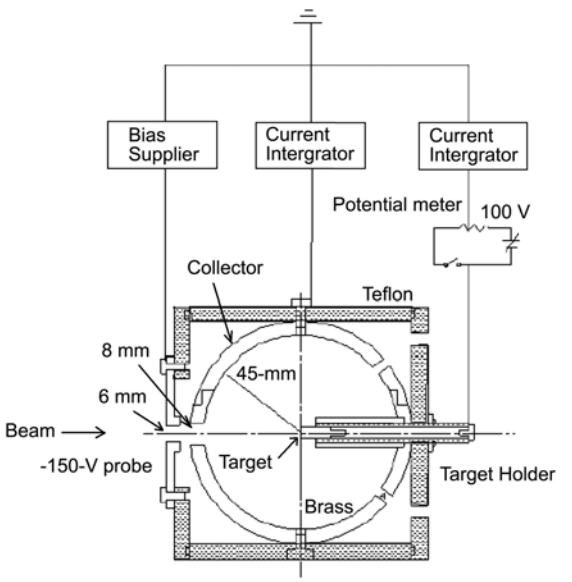

Figure 1. Schematic diagram and circuit of the concentric spherical analyzer.

The whole target-collector assembly was surrounded by a teflon shield to minimize the electric noise and was set in a vacuum chamber. As positive voltage was applied to the target, the target-collector assembly was operated as a CSA by using the retarding field method (RFM). Therefore, the energy distributions of the secondary electrons could also be determined.

The proton projectile ion was generated by using hydrogen ion source. This ion was accelerated by a 50-MV cyclotron accelerator. The typical pressure in the beam line of 2×10^{-4} Torr was not low enough to neglect the charge-exchange reactions of the fast ions in the residual gas, so the saturation point was obtained to compensate for the insufficient vacuum state.

Especially, in this work, the beam current was fixed at 20 nA to remove the influence of the beam current. Experi-

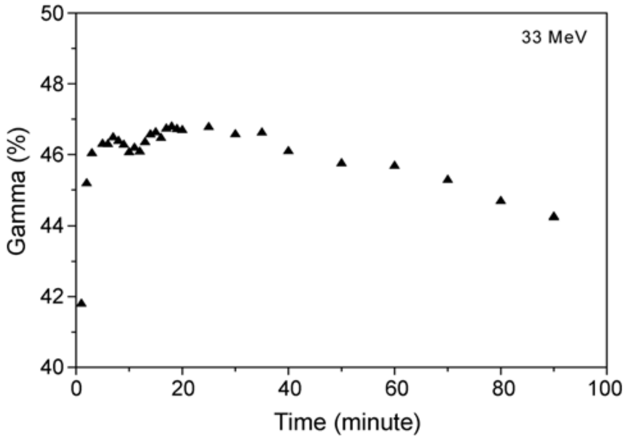

Figure 2. The secondary electron yields, at 33 MeV proton energy on Al surface.

mentally, secondary electron yield γ can be expressed as

$$\gamma = Z\frac{I_{collector}}{I_{target} + I_{collector}} \tag{1}$$

where Z is the charge state of the incident particles, and $I_{collector}$ and I_{target} are the integrated charges of the secondary electrons at the collector and those of projectile particles at the target, respectively. The deviation of γ is denoted as

$$\frac{d\gamma}{\gamma} = \frac{Z+\gamma}{\gamma}\left(\frac{dQ_{target}}{Q_{target}} + \frac{dI_{collector}}{I_{collector}}\right) \tag{2}$$

where $dQ_{collector}$, and dQ_{target} are the statistical deviations of $I_{collector}$ and I_{target}, respectively. We think that these deviations are related to back scattering, sputtering, tertiary electrons, and the roughness of the target surface.

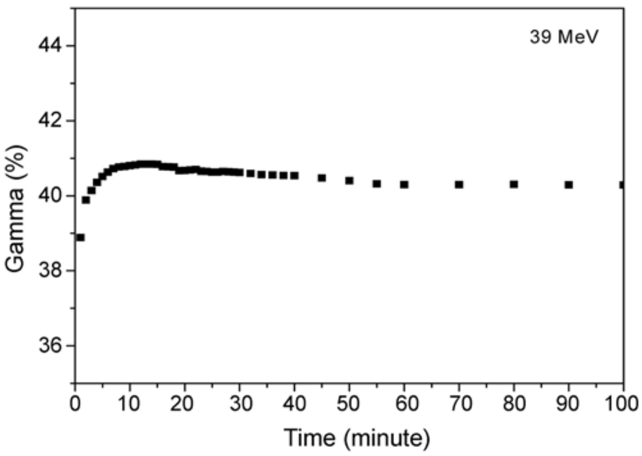

Figure 3. The secondary electron yields, at 39 MeV proton energy on Al surface.

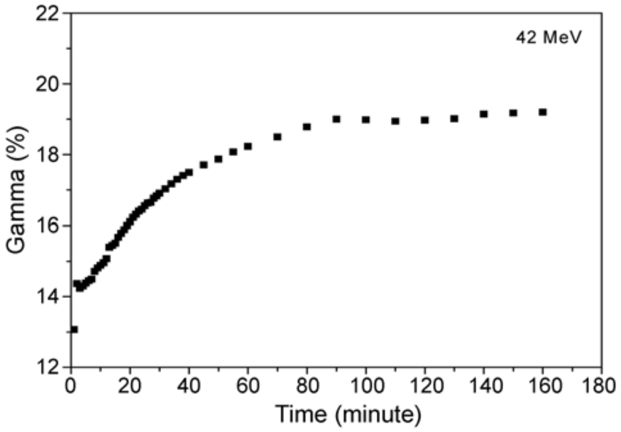

Figure 4. The secondary electron yields, at 42 MeV proton energy on Al surface.

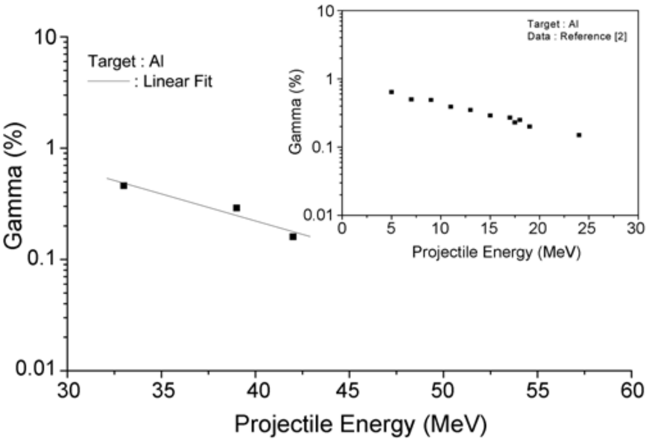

Figure 5. Total electron yields, from a clean Al surface as function of the projectile energy.

Results and Discussion

Figure 2, Figure 3, and Figure 4 are the secondary electron yields, γ, at 33 MeV, 39 MeV and 42 MeV projectile energies, respectively. In each figure, the secondary electron yields is changing for collision time of proton to target. Generally, if an hour is passed, the secondary electron yields are constant. Namely, we can know the exact beam current reached in target just after an hour. Going to the low energy of incident particle, the secondary electron yields are more higher, but stabilized time of the secondary electron yields is a little different according to the energy of incident particle. This is very important factor when we evaluate the beam current.

For the proton projectiles in Figure 5, as the incident particle energy increases, the secondary electron yield also decreases. In the Sternglass theory for the energy transport mechanism,[7] the material coefficient for proton projectile particles depends only on the projectile energy and the mass number of the particle. Our data were found to be in a good agreement with this theory and Borovsky's data.[2]

Conclusions

The secondary electron yields of various high energy proton projectiles were evaluated for a Al target. It was proven that the electron yield strongly depended on the type of incident energy. Since the transferred energy frees the electrons in the target atoms, the total energy loss is very important for the ionization of target atoms.

Also, we can know the yields of secondary electron are increasing as the energy of incident protons. This result is for high energy, but it was very similar with Borovsky's data for low energy. So we can think the yields of secondary electron is in inversely proportional to the energy of incident protons.

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