ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Catania

INFN/BE-74/5
22 Maggio 1974

G. Foti, R. Potenza and A. Triglia: SECONDARY ELECTRON EMISSION FROM VARIOUS MATERIALS BOMBARDED WITH PROTONS AT $E_p < 2.5$ MeV.

196

Reparto Tipografico
dei Laboratori Nazionali di Frascati

Istituto Nazionale di Fisica Nucleare
Sezione di Catania

INFN/BE-74/5
22 Maggio 1974

G. Foti, R. Potenza and A. Triglia: SECONDARY ELECTRON EMISSION FROM VARIOUS MATERIALS BOMBARDED WITH PROTONS AT $E_p < 2.5$ MeV[(x)]

The yield of secondary electrons emitted from a target under light ion bombardment is connected[(1, 2, 3)] to the ionization cross section of the target material. As is known[(4, 5, 6, 7)] this cross section is just one of the terms which describe the stopping cross section of the incident particle in the target, the other term being given, at intermediate energies, by the excitation cross section. This last term can be measured, for example, by X-ray yield under ion bombardment[(8)].

Object of the present paper is experimental investigation on the connection between electron emission and stopping cross section.

We measured the secondary electron yield from targets of Al, Si, Cu e Ge bombarded with protons.

The particles were accelerated by the 2.5 MeV Van de Graaff machine of the C. S. F. N. and S. M. laboratory in Catania. The incident energies ranged from 0.3 MeV to 2.5 MeV.

The metallic targets were obtained by evaporation on thick aluminum supports. Their thickness was measured by the helium backscattering tecnique and resulted about 0.5 μ. The Si and Ge targets were thick wafers. The targets were all mounted inside a standard scattering chamber and maintened at room temperature. Around them there was a guard ring (G) to which a variable potential V was applied (see Fig. 1). The geometric configuration was such to insure total suppression of electrons at high negative values of V.

(x) - Work supported in part by G. N. S. M., I. N. F. N., C. R. R. N. and C. S. F. N. S. M.

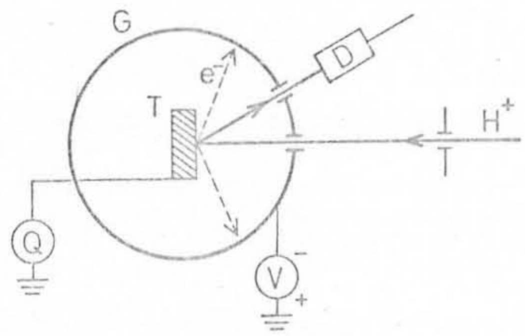

FIG. 1 - Experimental set up: G = guard ring, T = target, D = proton detector, Q = charge integrator, V = power supply for the guard ring.

The backscattered light ions were detected by means of a surface barrier detector supplied by ORTEC connected to a standard amplification chain. The pulses were counted by a scaler.

The total charge collected at the target was measured by means of a current integrator (Q) supplied by WELEX Electronics.

The runs were done at constant collected charge and the number of backscattered particles was measured as a function of the potential applied to the guard ring.

The yield was defined as:

$$Y = \frac{N_{max} - N_{min}}{N_{min}} \qquad \text{(el/ion)}$$

where N_{min} was the number counted at $V > 0$, while N_{max} was the number counted at the plateau for $V < -100$ Volt.

The values of the yield obtained for copper are reported in Fig. 2 vs. incident energy. The present data extend the energy range in which other authors performed measurements[9]. The data of these authors are also reported in Fig. 2.

As is known the secondary electron yield is described by a theory that takes into account: i) for the mechanism of electron production, a reasonable interplay between excitation and ionization cross section[1, 2]; ii) for the escape mechanism, a diffusive model[1, 2, 10, 11].

The interplay sub i) can be described by the single parameter $\bar{\varepsilon}_0$, that is the mean energy for the production of one free electron. Due to the excitation processes, it is clearly greater than the mean ionization energy.

We computed the curves of Fig. 2 using the expression given in ref. (1) where was placed $\bar{\varepsilon}_0 = 25$ eV, which corresponds to an excitation cross section of about 1/4 of the total stopping cross section at the used energies. Furthermore we used the experimental values[12] of the stopping cross section for the full curve of Fig. 2 and the Bohr-Bethe theo

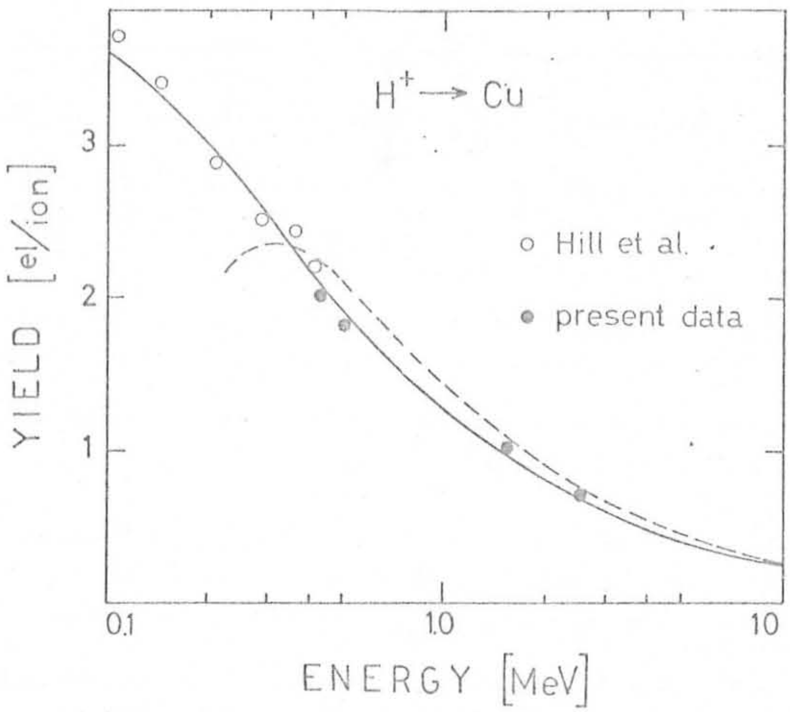

FIG. 2 - Yield of secondary electrons from Cu. Full line: theoretical yield computed using experimental stopping cross section. Dashed line: as full line, but using the Bohr-Bethe approximation for the stopping cross section.

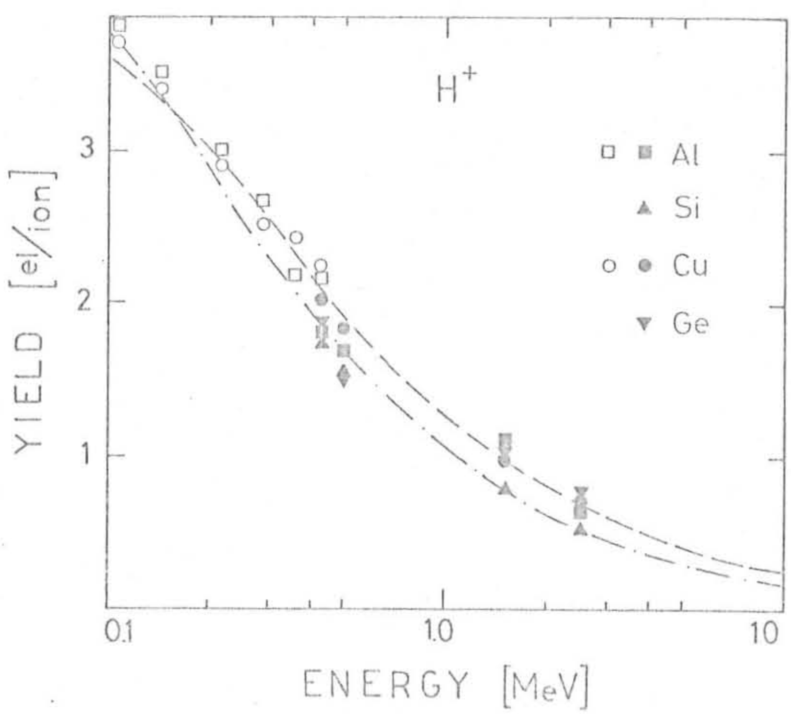

FIG. 3 - Yield of secondary electrons from various materials. Black symbols refer to present data. White symbols to data of other authors. See text for the curves.

retical values for the dashed curve. As is seen the agreement is good for the full curve, as expected.

The values of the yield obtained for various materials are reported together in Fig. 3. In the same figure are reported the data obtained at other energies by other authors[9].

As is seen, the yield does not depend appreciably on the atomic number of the target material. The physical explanation of this result lays on the opposite dependence on the atomic number of the production and escape contributions to the yield[1].

The curves reported in Fig. 3 are computed using the experimental values of the stopping cross section for Al (point-line curve) and for Cu (line-line curve). As is seen, the agreement is again good.

So we can conclude that the connection between stopping cross section and secondary electron yield, given by theory, is well confirmed by the experimental data with protons. However it is necessary to investigate better the connection between $\bar{\varepsilon}_0$ and the excitation cross section for the electrons.

REFERENCES. -

(1) - E. J. Sternglass, Phys. Rev. 108, 1 (1957).
(2) - S. N. Ghosh and S. P. Khare, Phys. Rev. 126, 1254 (1962).
(3) - G. Carter and J. S. Colligon, Ion Bombardment of Solids (Heinemann Educational Books, Ltd., London, 1968).
(4) - N. Bohr, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 18, n. 8 (1948).
(5) - J. Lindhard, M. Scharff and H. E. Schiøtt, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 33, n. 14 (1963).
(6) - R. S. Nelson, The Observation of Atomic Collisions in Crystalline Solids (North-Holland, Amsterdam, 1970).
(7) - A. Dalgarno and W. G. Griffing, Proc. Roy. Soc. (London) A232, 423 (1955).
(8) - J. A. Cairns, A. D. Marwick and I. V. Mitchell, Thin Solids Films 19, 91 (1973).
(9) - A. G. Hill, W. W. Buechner, J. S. Clark and J. B. Fisk, Phys. Rev. 55, 463 (1939).
(10) - A. J. Dekker, Solid State Physics 6, 251 (1958).
(11) - H. Bruining, Physics and Application of Secondary Electron Emission (Pergamon Press, London, 1954).
(12) - W. Whaling, Hand. der Phys., Vol. XXXIV (Springer, Berlin, 1958).