SECONDARY ELECTRON EMISSION FROM TUNGSTEN, COPPER AND GOLD

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Abstract

By a null method of high precision, previously described, the secondary electron emission from tungsten, copper and gold surfaces bombarded by an electron stream has been measured and the ratio I_1/I_2 of secondary current to primary current plotted as a function of the velocity of the primary electrons. The maximum values reached by the ratio I_1/I_2 were as follows: 1.45 for tungsten at 700 volts, 1.32 for copper at 240 volts, 1.14 for gold at 330 volts. Tungsten showed fairly satisfactory critical potentials at 11.0, 17.1, 25.2, 29.3, 40.5, 46.0, 89.5, and 271.5 volts. Copper showed breaks at 7.8, 12.6, 16.8, 19.5, 23.8, 39.0, 56.9 and 73.5 volts, the first two being marked by very definite minima. Gold indicated critical potentials at 15.5, 21.0, 23.2, 31.5 and 43.7 volts. Comparison of these potentials with soft x-ray levels does not lead to a definite conclusion as to the relation between the two.

In a previous paper[1] the method and the results of a study of the secondary electron emission from iron, nickel and molybdenum surfaces under bombardment by a stream of electrons have been described by the author. The results of a similar investigation of the secondary emission from tungsten, copper and gold are given in the present paper.

The method used is described in detail in the previous paper. Electrons from a hot filament were drawn through openings in a series of diaphragms by a field V_1 of 0–1500 volts. The stream of electrons thus formed struck a plate P of the metal which was being studied and any electrons reflected from P or emitted as secondary electrons were drawn by a small field V_2 to a nickel cylinder C which almost entirely surrounded P. The current I_1 to C and the total current I_2 striking the plate P were measured by two galvanometers; the ratio I_1/I_2 gives the number of secondary electrons emitted per primary electron striking the plate. This ratio was plotted as ordinate against the accelerating field V_1 in volts as abscissa. The curves obtained show breaks or places of rapid change of slope at fairly definite velocities of impact. The same precautions as in the earlier work were taken to secure high vacua, and to ensure target surfaces free from occluded gases.

Results

The results obtained were, in general, less satisfactory as to absolute values of I_1/I_2 than were those given in the earlier papers. These later

[1] R. L. Petry, Phys. Rev. **26**, 346 (1925).

runs were taken when somewhat larger leakage currents could not be avoided because of greater humidity.

Curve 1, Fig. 1, shows the variation of I_1/I_2 with velocity of impact up to 700 volts, for copper after heat treatment. Curve 2 gives similar data for tungsten up to 700 volts and curve 3 for gold up to 300 volts. Tungsten reached a maximum value of I_1/I_2 of 1.45 secondary electrons

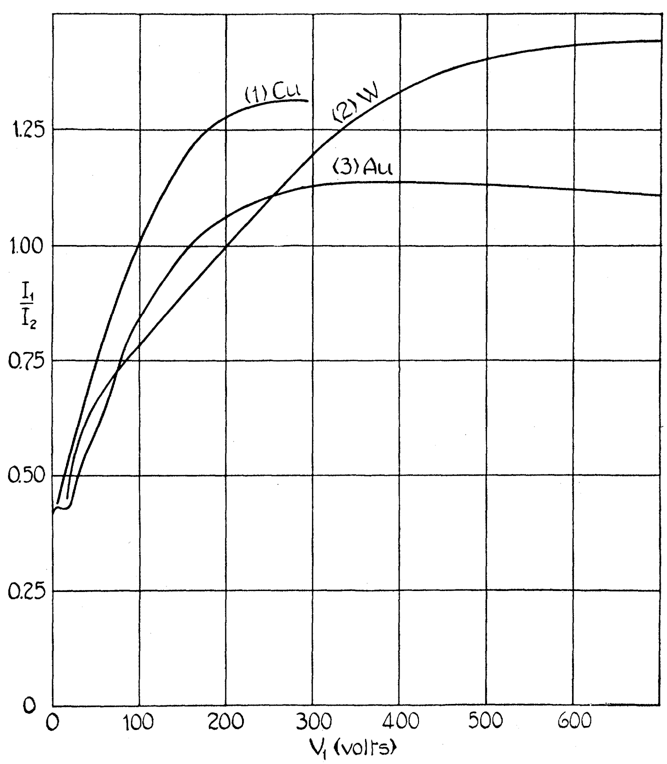

Fig. 1. Number of secondary electrons emitted per primary electron. 0-700 volts, after heat treatment. Curve 1, Cu; Curve 2, W; Curve 3, Au.

per primary electron at about 700 volts. Copper reached a maximum ratio of 1.32 at 240 volts while the maximum value for gold was 1.14 at 330 volts. Only a few runs for gold were taken and not as much weight can be attached to these results as to those for the other metals.

Curve 1, Fig. 2, shows the region 0–25 volts for copper; curve 2, the same region for tungsten; curve 3, results for gold in the same region. All the curves for tungsten up to 25 volts had the same form but showed only fair agreement as to critical voltages. Four very similar curves, of the form of curve 1, were obtained for copper but in later runs over the same region the maxima and minima practically disappeared. Farnsworth[2] has given curves for copper similar to curve 1 and has found that continued heating of the target near the melting point caused the maxima and minima to be smoothed out; this he attributes to a change in crystal structure.

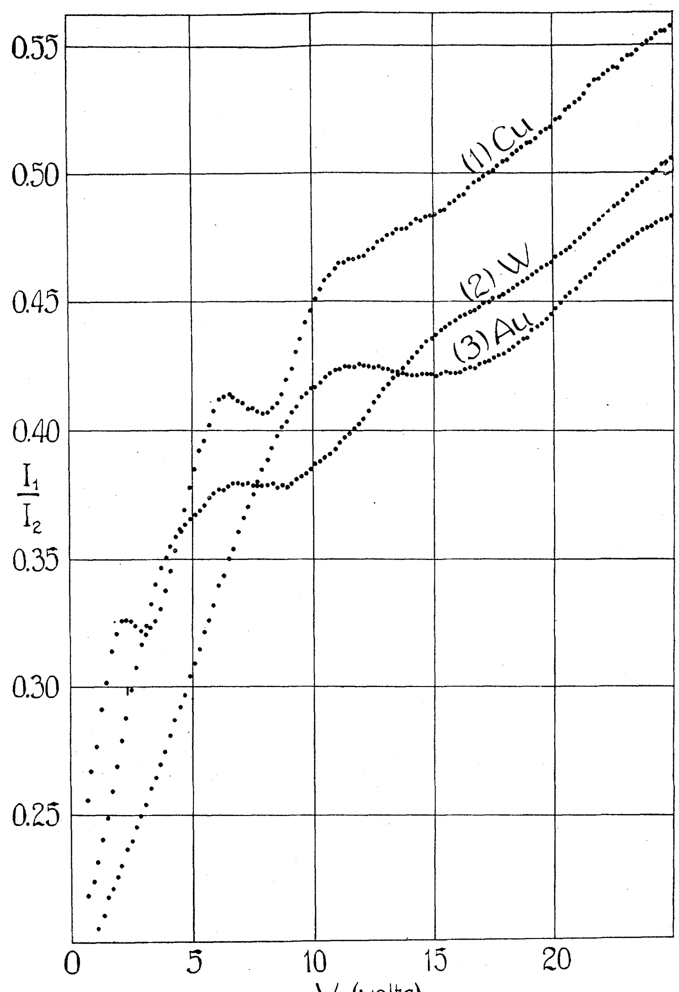

Fig. 2. Secondary emission curves, 0-25 volts. Curve 1, Cu; Curve 2, W; Curve 3, Au.

The first column of Table I gives the critical potentials for secondary emission from tungsten as indicated by the data obtained. The voltage correction to be added to V_1 because of initial velocity of emission of the

[2] H. E. Farnsworth, Phys. Rev. **25**, 41 (1925).

primary electrons and because of voltage drop across the filament has been determined experimentally to be 0.5 volt, while 4.5 volts have been

TABLE I

Critical primary potentials for tungsten

Critical potential (volts)	Weight factor	Sign	Soft x-ray levels (Richardson & Calklin)
11.0	2	−	
14.0	0	+	
17.1	2	+	
25.2	2	+	
29.3	2	+	
40.5	1	+	36.8
			40.3
46.0	2	−	44.9
			70.8
89.5	1	−	108.2
			(4 values omitted)
271.5	1	−	263.7
700—maximum value of I_1/I_2			

added for the work function and contact difference of potential, following the suggestion of Richardson and Calklin.[3] The second column gives an evaluation of the importance of the break based on intensity and on definiteness of location. The third column shows whether the break was due to an increase of slope (+) or a decrease (−). The fourth column gives results for soft x-ray levels for tungsten observed by Richardson and Calklin.[3]

Table II gives results for copper; 5.2 volts have been added to V_1 as the total correction. The fourth column gives results obtained by

TABLE II

Critical primary potentials for copper

Critical potential (volts)	Weight factor	Sign	Soft x-ray levels (Thomas)
7.8	5	+	10.3
12.6	4	+	12.3
			14.2
16.8	1	+	15.7
19.5	3	+	19.0
			20.7
23.8	0	+	23.8
			25.5?
			33.7
39.0	0	−	37.5
			40.0
			(4 values omitted)
56.9	1	+	53.8
			62.0, 64.5
73.5	1	−	74.0
240—maximum value of I_1/I_2			

[3] Richardson and Calklin, Proc. Roy. Soc. **A110**, 247 (1926).

Thomas[4] for soft x-ray critical potentials for copper. Table III gives results for gold; 5.4 volts have been added to V_1 as the total correction.

TABLE III

Critical primary potentials for gold

Critical potential (volts)	Weight factor	Sign
15.5	3	−
21.0	3	+
23.2	1	+
31.5	1	+
43.7	1	+
330—maximum value for I_1/I_2		

The agreement observed between curves in the present work is such as to suggest that breaks obtained, even at the higher voltages, represent true critical potentials in secondary emission. However, there is little evidence of a correspondence between these critical potentials and soft x-ray levels. From a study of secondary emission from iron with apparatus of three types Farnsworth[5] has concluded that breaks for iron above about 12 volts vary with several factors and consequently do not represent critical potentials for secondary emission.

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[4] C. H. Thomas, Phys. Rev. **26,** 739 (1925).
[5] H. E. Farnsworth, Phys. Rev. **27,** 419 (1926).