The Secondary Emission of Electrons by High Energy Electrons

J. G. TRUMP AND R. J. VAN DE GRAAFF
Massachusetts Institute of Technology, Cambridge, Massachusetts
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The secondary emission of electrons from tungsten, steel, aluminum, and graphite was studied as a function of the energy of the bombarding primary electrons in the range from 30 kilovolts to 340 kilovolts. The ratio of secondary to primary electrons was found to diminish with increasing primary energy and to increase with the atomic number of the target material. Thus, with aluminum the ratio diminished from 0.25 at 50 kilovolts to 0.17 at 200 kilovolts, while with tungsten it diminished from 0.73 to 0.62 in the same voltage range. Study of the energy distribution of the secondary electrons showed a percentage with energies less than 20 volts. Most of the remainder had energies greater than the available 800-volt repressor potential and resulted mainly from elastic nuclear scattering, particularly in the case of targets of high atomic number.

INTRODUCTION

IN the course of experiments directed primarily at investigating the mechanisms of voltage breakdown in high vacuum,[1] the opportunity arose to measure the emission of electrons from a number of materials under impact by steady streams of high energy electrons. Constant voltages up to 700 kilovolts developed by an air-insulated electrostatic generator were brought into an 18-inch diameter vacuum chamber through an evacuated porcelain bushing. By means of a corona loading device, the voltage could be held steady to about one percent at any value in this range. The vacuum chamber was constructed mostly of polished stainless steel parts and was maintained at pressures of 10^{-5} mm Hg or better by means of a mercury diffusion pump with a liquid air trap in series.

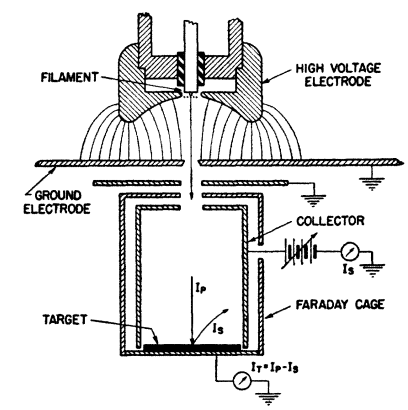

FIG. 1. Electrode arrangement for measuring secondary electron emission.

The electrode arrangement for measuring the secondary electron emission under high energy electron bombardment is shown in Fig. 1. The accelerating voltage was applied between the upper electrode and the steel ground plane, their geometry being such that the electrons from the 7-mil tungsten filament passed through the axial hole in the ground plane and on toward the Faraday cage beneath. A grounded intermediate diaphragm with slightly larger aperture was used to collect scattered electrons and further shield the target system. Within the Faraday cage, an insulated collector of steel was positioned to receive most of the secondaries emitted from the target. The potential of this collector relative to ground could be varied from +800 to −800 volts. Targets in the form of tungsten, steel, aluminum, and graphite disks were successively placed at the bottom of the Faraday cage. In these experiments, the energy of the bombarding electrons was varied over the range from about 30 kilovolts to 340 kilovolts. The targets were smooth and chemically cleaned, and their emission characteristics became stable after a short period of electron bombardment. The emission measurements were made with primary electron currents of about 10 microamperes; no changes caused by the heating of the target were noted.[2]

The curves in Fig. 2 show the ratio of secondary to primary electrons for tungsten, steel, aluminum, and graphite as a function of primary

[1] J. G. Trump and R. J. Van de Graaff, "The insulation of high voltages in vacuum," J. App. Phys. **18**, 327–332 (1946).

[2] Treolar and Landun, Proc. Phys. Soc. **50**, 625 (1938).

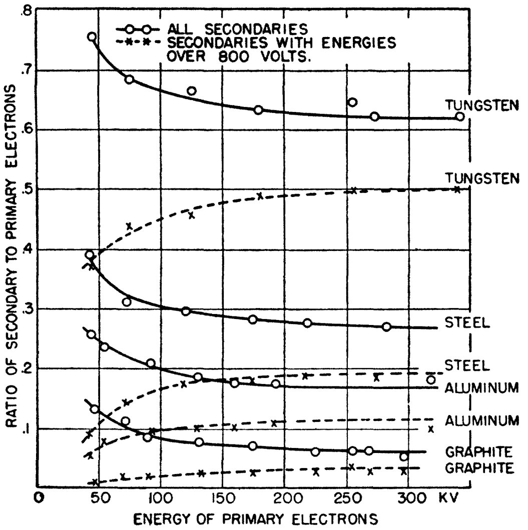

FIG. 2. Secondary emission of electrons by electrons with energies up to 340 kv.

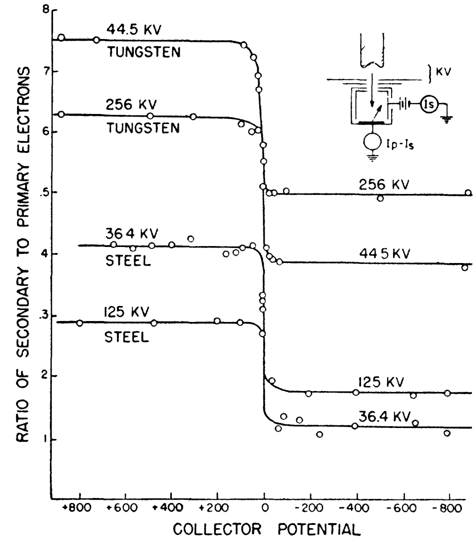

FIG. 3. Variation of secondary emission with collector potential.

energies from 30 kilovolts to 340 kilovolts. The descending curves include all of the secondaries, while the ascending curves include only those secondaries with energies in excess of 800 volts. The low energy secondaries actually lay almost entirely in the region of less than 20 volts, as can be seen from the variation of secondary emission with collector voltage given in Fig. 3. No adjustment was made in these curves for secondary electron emission from the walls of the collector by impact of secondaries from the target. It would be desirable in experiments of this kind to employ collectors of low atomic number such as beryllium or carbon in order to minimize these higher order effects.

These data show that the electron emission under high energy bombardment includes a considerable proportion of energetic electrons. These result mainly from elastic nuclear scattering rather than from electron-electron scattering or inelastic nuclear scattering.[3] This proportion increases with the energy of the bombarding primaries and has the expected marked dependence on atomic number. Low energy secondaries account for nearly 50 percent of the emission from tungsten and 90 percent of the emission from graphite at primary energy of 50 kilovolts, but the percentage of the low energy secondaries diminishes with increase in primary energy. Above 200 kilovolts all of the curves become substantially constant. In all cases, the ratio of the total secondary to primary electrons was well under unity and decreased with increasing bombarding energy. These results do not appear to be inconsistent with the emission peaks and values found by other investigators at lower energies.[4]

This work was performed some years ago as part of the experimental study of vacuum insulation, particularly the mechanisms for the emission of electrons, positive ions, and photons from electrodes subjected simultaneously to high voltages and high electric fields. The authors take pleasure in acknowledging the assistance of J. R. Maull in making some of the measurements.

[3] R. J. Van de Graaff, W. W. Buechner, and H. Feshbach, "Experiments on the elastic single scattering of electrons by nuclei," Phys. Rev. **69**, 452–459 (1946).

[4] Bruining and DeBoer, Physica **5**, 17 and 901 (1938).