Comparison of the Secondary Electron Emission Due to H_2^+ and D_2^+ Ions

Results of experiments on the secondary electron emission due to bombardment of a hot Ni target by H_2^+ ions have been previously reported.[1] The values obtained ranged from four percent to 22 percent for ions having energies from 300 to 1500 ev.

The same method has now been used to compare the relative emission due to H_2^+ and D_2^+ ions of about the same energy range. The secondary emission, as shown in the accompanying graph, (Fig. 1) is markedly less for D_2^+ than for H_2^+ ions. To obtain these results a Ni target was again used, but after six weeks of continuous heating of the target, when the emission due to H_2^+ had been reduced nearly to the values formerly obtained, the fore pump of the vacuum system suddenly failed to produce the necessary fore vacuum, so that a small amount of air was admitted to the hot target. It was not thereafter possible to reduce the emission to the previous low value. However, reproducible values were obtained and the comparison of the emission due to two ions having so great a relative difference in mass is significant, especially in view of the fact that hydrogen always contaminates a Ni surface and makes impossible the determination of absolute values of emission from a clean Ni surface.

The emission varied approximately linearly from 13.1 percent to 44.7 percent for H_2^+ ions and from 12.2 percent to 35.7 percent for D_2^+ ions over the range of energies used. To be sure that the difference in the effect of the two isotopes was real, the emission for H_2^+ was measured again after the data for D_2^+ were taken and it was found to repeat as closely as before. All points on the curve are averages of a good many values. The deviations in the middle of the curve were not more than two percent. The values at the highest and lowest voltages are the least reliable on account of difficulties in obtaining a large steady positive ion beam at these voltages. The heavier ion is found to produce fewer electrons than the lighter one. This change in emission with mass of the bombarding particle is in the opposite direction to that found by Hill, Buechner, Clark and Fisk[2] for fast ions. The apparent flattening of the D_2^+ curve at higher energies is in agreement with the results of many measurements on secondary emission due to primary electrons. It is also in agreement with the work of Jackson[3] who used alkali ions as bombarding particles. It is not in agreement with any results found by the author for H_2^+ ions. Oliphant[4] found two such changes in slope in the energy range from 80 to 1000 ev for He^+ ions impinging on a Mo target.

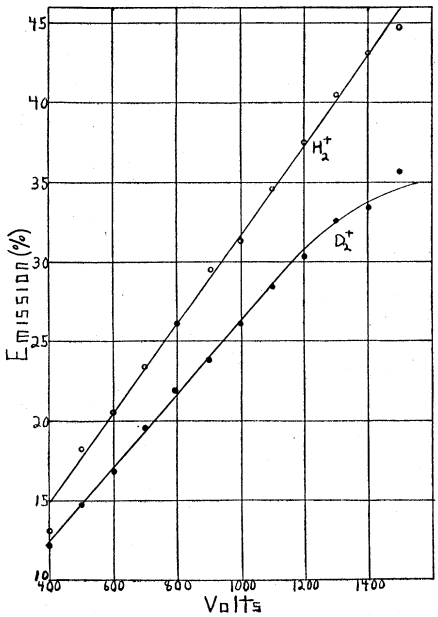

FIG. 1. Relation to energy of secondary electron emission due to H_2^+ and D_2^+ ions.

The increase in the emission over that obtained before, for a Ni surface that is as clean as possible in a hydrogen atmosphere, may be due either to a thin NiO film on the surface or to roughnesses produced by unusual heating of the target in an effort to clean it after its contamination. Güntherschulze and his co-workers[5] report such an increased emission from oxide surfaces over that for pure metals for various metals and gases. Their conclusions were drawn from calorimetric measurements made on the cathode of an anomalous glow discharge.

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Interaction of Fast Neutrons with Protons

The interaction of neutrons with protons, as shown by the scattering by protons of neutrons of not too inhomogeneous velocities, has been confined hitherto to neutrons of three Mev or less. We have measured the neutron-carbon and neutron-proton cross sections for higher energies and present here the results of measurements with neutrons of about 15 Mev.

The neutrons from a lithium target bombarded by 0.9-Mev deuterons were all of energies less than 16 Mev (calculated from the mass data of Allison[1]); the threshold of copper, the detector used, is, according to Sagane,[2] between 12 and 13 Mev. Experiments on the angular distribution of the neutrons from the target lead us to believe that the activity of the copper (10.3-minute period) was due predominantly to the neutrons in the higher portions of the 12–16-Mev range.

The scattering was measured by the reduction in intensity of the neutron beam when it traversed paraffin and graphite, cut into truncated cones just large enough to intercept all the neutrons traveling from target to detector. The observed transmissions ranged from 40 to 80 percent, with paraffin 0.54 and 0.84 g/cm^2 and graphite 0.49 and

0.73 g/cm². The intensity of the neutron beam was calibrated each time by a copper monitor, whose activity was measured with a pressure ionization chamber; the activity of the detector was measured with a Geiger-Mueller counter. No noticeable scattering from the room could be detected.

The results of these measurements were: neutron-carbon cross section 1.13×10^{-24} cm², neutron-proton cross section 0.61×10^{-24} cm².

The theoretical neutron-proton cross section was then evaluated from the phase shifts, according to the theory of Faxen and Holtsmark,[3] with 2.17 Mev for the binding energy of the deuteron, a rectangular well and a range of 2.81×10^{-13} cm. The contribution of the antiparallel spin orientations was calculated with a depth of well 11.7 Mev, obtained by Breit (private communication) from the scattering of slow neutrons. The contribution of the parallel spins was calculated with 20.4 Mev for the depth of the well. The total calculated cross section came out to be 0.61×10^{-24} cm², in satisfactory agreement with the measured value.

The details of these and other measurements will be given later.

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Phenomenon of Secondary-Electron Emission

Recently published results on secondary-electron emission indicate that the high secondary-to-primary ratios, δ's, previously reported for electropositive metals are characteristic of contaminated rather than clean surfaces. Bruining and de Boer[1] report that for uncontaminated surfaces the maximum δ is very low while for oxidized surfaces it is very high. Thin oxidized films of Ba and Li on a metal base, for instance, give maximum values of δ of 4.8 and 4.2, respectively.[1]

It has occurred to the writer that the existence of a positive charge in surface films of this type may be an important factor influencing their secondary-electron emission characteristics. A positive charge produced in the insulating layer as a result of the primary-electron bombardment may give rise to an intense electric field through the film. Though the dielectric strength of this type of film is not great enough to support fields of sufficient intensity to give rise to thin-film field emission,[2] it may support fields strong enough to increase materially the probability of escape of the secondary electrons produced within the layer and in the base metal.

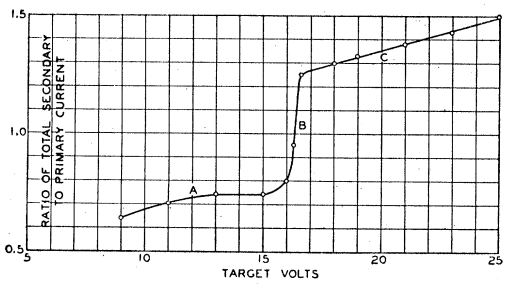

FIG. 1.

In accordance with the hypothesis advanced above, it is to be expected that a curve of δ as a function of primary-electron velocity for the type of surface under consideration should show a definite break in the region of low potentials corresponding to a transformation from negative to positive charge in the insulating film. The film should be negatively charged as long as the δ for its outermost layers remains less than unity and it should become positively charged when this δ becomes greater than unity as the velocity of the primary electrons is increased. When the δ becomes greater than unity, a sudden increase in the secondary emission should result.

An experiment, therefore, was performed to determine δ as a function of the velocity of the primary electrons in the region of low potentials for a film of MgO on Nichrome. The film (about 1000 angstroms thick) was evaporated onto the Nichrome surface in vacuum from a MgO-coated platinum filament. The total secondary emission (true secondaries plus reflected electrons) was determined as a function of the voltage of the MgO-Nichrome target, when the electric field drawing the secondaries from the surface was 100 volts per cm. The curve shows definitely three regions *A*, *B* and *C* corresponding, respectively, to conditions where the charge is negative, where the charge changes from negative to positive, and where the charge is positive and in a state of equilibrium. In regions *A* and *C* the secondary-electron emission remains substantially constant with time while in region *B* it increases with time when readings were taken from low to high potentials and decreases with time when readings were taken in the opposite sense. At the beginning of region *B*, a regenerative action evidently sets in. A positive charge is produced in the outermost layers of molecules which assists the escape of a greater fraction of the secondaries generated within the films, more positive charge is produced, and in turn more secondaries escape, and so on until an equilibrium condition is produced.

At higher voltages, δ varied normally with the potential. A maximum δ of 5.4 was reached at about 400 volts. Neither instability nor thin-film field effects were observed.

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