Secondary Emission of Electrons from Sodium Films Contaminated by Gas*

Nelson[1] has given results showing rapid variation of secondary electron emission from thin oxidized films bombarded with primaries of low energy. This occurs as the secondary emission coefficient changes from less than to greater than unity, and he has suggested a reasonable explanation in terms of the charging of the surface. In this connection graphs presented by the writer[2] at Indianapolis may be of interest, since they show a similar phenomenon for high primary energies.

The logarithms of the secondary to primary ratios are shown in Fig. 1. The data shown in curve 2 were obtained after the following treatment. Upon a tantalum base, giving the secondary emission indicated by curve 1 of the figure, a thin film of sodium was condensed. This deposit was allowed to stand in the vacuum produced by the pumps for approximately one hour. A fresh deposit of sodium was then distilled over to the target, and immediately thereafter the secondary emission data shown in curve 2 were obtained. It will be seen that the secondary emission remains at a high value, about 2.5 secondaries per primary, until a primary energy of 2000 electron volts is attained, and then it decreases very rapidly to a value of less than 0.4 for primary energies of about 4000 electron volts. From the first it was evident that this peculiar behavior (which was not common to other data obtained in the investigation) was due to the chemical combination of the sodium in the first film with gas. Nelson's hypothesis suggests a suitable mechanism for its explanation. Throughout the high emission region the outermost layers of the surface film have a positive charge which assists the secondaries in escaping. At a critical primary energy, this positive charge rapidly disappears and is replaced by a negative charge in the outermost layers; hence the rapid decrease of the secondary emission. It is of interest to notice that the total secondary emission is about 2.5 secondaries per primary when the critical value is reached. This would seem to indicate that a large proportion of the secondaries originate at considerable depths in the surface, and, even though many escape, enough are trapped in the surface layers to account for the rapid change of the surface

FIG. 1. Secondary electron emission from sodium on tantalum.

charge necessary to explain this curve on this basis. At the end of the secondary emission observations, a microtitration of the sodium in the film revealed that it contained about 6 micrograms of sodium per square centimeter of surface area.

It is interesting to notice that rapid changes in secondary emission for primaries of high energy do not necessarily involve a transit through unit secondary emission ratio (or through zero on the semi-logarithmic plot). Curve 3 of the graph was obtained with a target formed by a single condensation of sodium under conditions such that considerable gas was present. The decrease of the secondary emission in the range from 200 to 1000 volts primary energy is so similar to that in curve 2 that the same cause is naturally suggested, but in this case the secondary emission coefficient remains greater than unity. The results shown in curve 4 give a dip whose slope is similar to that of curves 2 and 3, as shown by the dotted line extension of the trend, but in this case the secondary emission drops only a small amount before it again increases.

The total secondary emission is the integrated result of secondary excitation at various depths within the surface. Where the primary energy is high there is evidence[3] that conditions at considerable depths in the target influence the results. In the high energy region, therefore, certain layers might acquire a positive charge at the same time that other layers acquire a negative charge. If the results shown in Fig. 1 are to be explained on the basis of Nelson's hypothesis, this probably does occur in a target containing compounds of sodium bombarded with primaries of high energy. It would, of course, be interesting to measure the potential at various layers in such a surface, or, failing in that, to measure at least the potential of the outermost layer together with the resulting secondary emission as one check on Nelson's hypothesis. Related work on surface films is being continued in this laboratory.

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[1] H. Nelson, Phys. Rev. 55, 958 (1939).
[2] P. L. Copeland, Phys. Rev. 53, 328 (1938).
[3] P. L. Copeland, Phys. Rev. 48, 96 (1935).

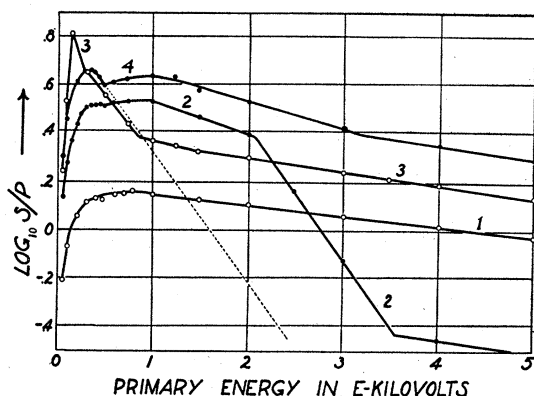## The Possible Use of Superconductivity for Radiometric Purposes

The limitations of radiometry, particularly in the infrared region, are given by the magnitude of the thermal indeterminacy of the produced effect itself and that of the indicating device caused by $\frac{1}{2}nkT$ for the n degrees of freedom of the system at the temperature level at which the radiation is received and indicated. The obvious way of decreasing this indeterminacy is to lower the temperature for the receiver of the radiation. In general this fails, however, for most indicative phenomena decrease at a rate comparable to the gain of thermal determinacy (e.g., thermal e.m.f., temperature coefficient of conductivity, thermal dilatation, etc.). Although some improvement may