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Thermionic Emission Constants of Iridium*

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The thermionic constants of polycrystalline iridium have been measured with reasonable care, using thin ribbons of iridium as the emitting specimens. The values obtained for the quantities A and ϕ, both considered as constant in the equation $i_s = AT^2\exp(-\phi e/kT)$, are $A=170$ amp cm^{-2} deg C^{-2}, $\phi=5.40$ v.

The relationship between true and brightness temperature at the pyrometer wavelength of 0.65 μ was likewise determined. From the latter data, it was computed that the spectral emissivity ϵ_λ of iridium is 0.33 at that wavelength.

Data taken on fresh specimens yielded values of the Schottky slope higher than expected, and values of A orders of magnitude above the theoretical value. (This experience parallels that of workers who have studied the thermionic properties of platinum.) The values reported were obtained after prolonged and rigorous thermal cleaning of the iridium.

I. INTRODUCTION

A FAIRLY thorough search of the literature has revealed no previously published values of the thermionic emission constants A and ϕ for iridium. These parameters were measured here in experiments conducted some two years ago. The techniques of measurement are well known, and will only be outlined in this paper.

II. EXPERIMENTAL DETAILS

Since we could not at the time obtain suitable iridium wire, ribbons were cut from sheet material and mounted in guard-ring diodes. Direct-current measurements of emission were made, with the filament continuously heated by alternating current flow. The value of zero-field emission at a given temperature was obtained by Schottky extrapolation.

Temperature was measured with an optical pyrometer. A correction curve (Fig. 1) from observed to true temperature was prepared in the following manner: A strip of iridium was bent to have the cross section shown in the insert of Fig. 1, with its long dimension perpendicular to the cross section shown. When the angle of opening is made sufficiently small, the radiation from the opening approximates blackbody radiation, and the optical temperature observed through the opening may be taken as true temperature. The brightness temperature is that observed on the outer surface. From the data of Fig. 1, the spectral emissivity of iridium (at the pyrometer wavelength of 0.65 μ) was found to be $\epsilon_\lambda = 0.33$; the solid line of the figure is actually computed for this value of emissivity.

The unavoidable use of a ribbon form of filament gave rise to a geometry in which the field at the cathode surface is not uniform. A map of the field in the plane perpendicular to the long axis of the filament was constructed with an analog field plotter. (The field is substantially independent of position along the long axis.) From this map, the field strength at the surface as a function of position across the width of the cathode was obtained. If this function be denoted by $V_{\text{appl}}f(x)$, then the saturated emission current, i, at a given applied voltage will be

$$i = i_s l \int_{x=0}^{x=d} \exp\{4.403[V_{\text{appl}}f(x)]^{\frac{1}{2}}T^{-1}\}dx,$$

where d is the width of the cathode, T is the absolute temperature in degrees, i_s is the field-free current density at temperature T, and l is the length of the emitting area. The Schottky slope $\Delta\log i/\Delta(V^{\frac{1}{2}})$ could then be computed by numerical evaluation of the integral.

III. RESULTS

The behavior during emission measurements parallels the experience reported by other investigators[1,2] who have studied the thermionic emission of platinum. Values of i_s and true temperature were plotted on the conventional Richardson coordinates (Fig. 2). Values of the parameters A and ϕ in the emission equation are obtained by fitting the equation to the data.[3] Data

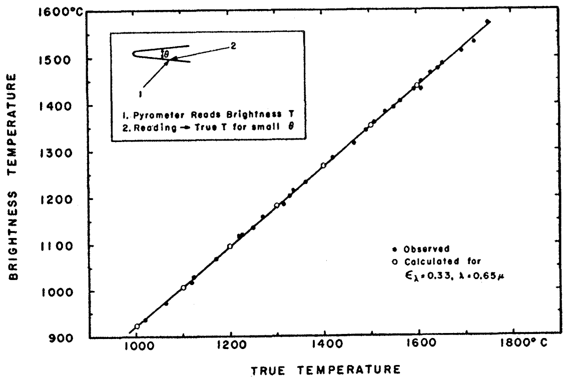

Fig. 1. Temperature correction curve for iridium.

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[1] H. L. Van Velzer, Phys. Rev. 44, 831 (1933).

[2] L. V. Whitney, Phys. Rev. **50**, 1154 (1936).

[3] When the values of A and ϕ are derived in this manner, they should actually be regarded as empirical parameters, since no account has been taken of the reflection coefficient or of the

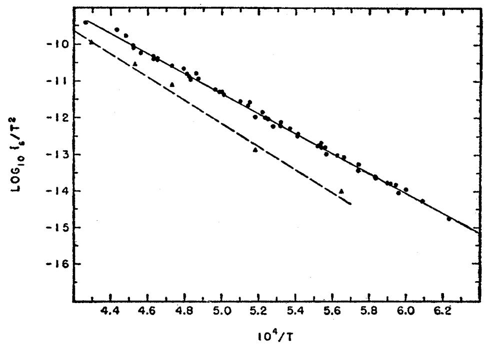

FIG. 2. Thermionic emission from iridium. The solid line is for the final, clean condition, and the data represent four experimental tubes. The dashed line is for a typical run on a partially cleaned specimen. The value of A indicated by the latter data is about 4000. The temperature T is in °K.

taken early in the processing of the iridium filament are characterized by very high values of the emission constant A. Also, the slope of the individual Schottky plots from which the values of i_s were derived, was much higher than the expected value in the early stages of processing.

Cleaning of the iridium at high temperatures resulted in a decrease of the value of A and of the Schottky slope. After prolonged heating at 2250°K, the data of Fig. 2 were obtained.

From the data of Fig. 2, the thermionic emission constants for iridium may be calculated:

$$A = 170 \text{ amp cm}^{-2} \text{ deg C}^{-2},$$

$$\phi = 5.40 \text{ v}.$$

It is to be noted that for the final state of the iridium filament, the value derived for A is not far from the value of 120 given by theory. Also, for the final state, the Schottky slopes were in agreement with the calculated values. Additional heat treatment after the data of Fig. 2 were taken caused no further change in the thermionic behavior of the iridium. For these reasons, it seems that the data taken early in the processing of the iridium were affected by the presence of contaminants, and that the values cited above, which were obtained after rigorous thermal cleaning of the filament, are the appropriate emission parameters for clean, polycrystalline iridium.[4]

IV. ACKNOWLEDGMENTS

This investigation arose from studies made by Mr. O. A. Weinreich[5] of the behavior of thoria-coated iridium. We are happy to acknowledge his interest in the work. We also wish to acknowledge the help of Mr. F. B. Thiess who made many of the measurements.

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temperature dependence of the work function. Nonetheless, all the evidence indicates that the empirically derived value of A should be of the order of magnitude of the theoretical value of 120 amp cm^{-2} deg C^{-2}, when one is dealing with clean metal emitters. An empirical value of A orders of magnitude different from this value is strongly suggestive of contamination of the surface.

[4] Platinum and iridium are known to be very similar in their chemical and physical properties. They are crystallographically identical with regard to structure, with the lattice constants differing by less than 3%. It is interesting to note that the data reported by Van Velzer on platinum for what he believed to be the cleanest state he obtained, are almost identical with the data obtained by us for iridium. Whitney's results for platinum are not quite identical with Van Velzer's; nevertheless the value of ϕ he cites as most reliable for platinum differs by only about 1% from our value of ϕ for iridium.

[5] Now with the Electron Tube Division, Tung-Sol Electric, Inc., Bloomfield, New Jersey.