University of Denver
COLORADO SEMINARY

DENVER RESEARCH INSTITUTE UNIVERSITY PARK, DENVER, COLORADO 80210

N65-32034
(ACCESSION NUMBER) (THRU) 1
(PAGES) 9 (CODE) 26
(NASA CR OR TMX OR AD NUMBER) CR 64581 (CATEGORY)
FACILITY FORM 602

30 June 1965

GPO PRICE $

CFSTI PRICE(S) $

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

National Aeronautics and Space Administration
1520 H Street, N. W.
Washington 25, D. C.

Attention: Office of Grants and Research Contracts, Code SC

Gentlemen:

This letter is a report of progress on Research Grant NsG-365, entitled "Theoretical Studies on the Relationships between the Thermionic Work Function of Refractory Intermetallic Compounds and their Electronic and Crystal Structures for the period 1 January to 30 June 1965.

1.0 Introduction

The group VI-A metals, chromium, molybdenum, and tungsten combine with rhenium to form intermediate phases of interest. A single σ -phase is present in all of the group VI-A-Re systems. The Mo-Re and W-Re systems also contain an additional intermediate phase having the α-Mn structure. The objective of the study is to measure the thermionic work functions of the five intermediate phases to discover what relationships may exist between the work functions and the electronic and crystal structures.

At the time of the last report, considerable difficulties were being encountered in the fabrication of the diodes shown in Figure 1. The major problem at that time was in the design of a spring which would keep the diode filament concentric with the collector elements from ambient temperature to 2000°C. This problem was surmounted during the report period just passed, and the diodes presently being produced appear to be satisfactory. All of the diodes received previously have been returned to the manufacturer for replacement of the springs with those of the latest design.

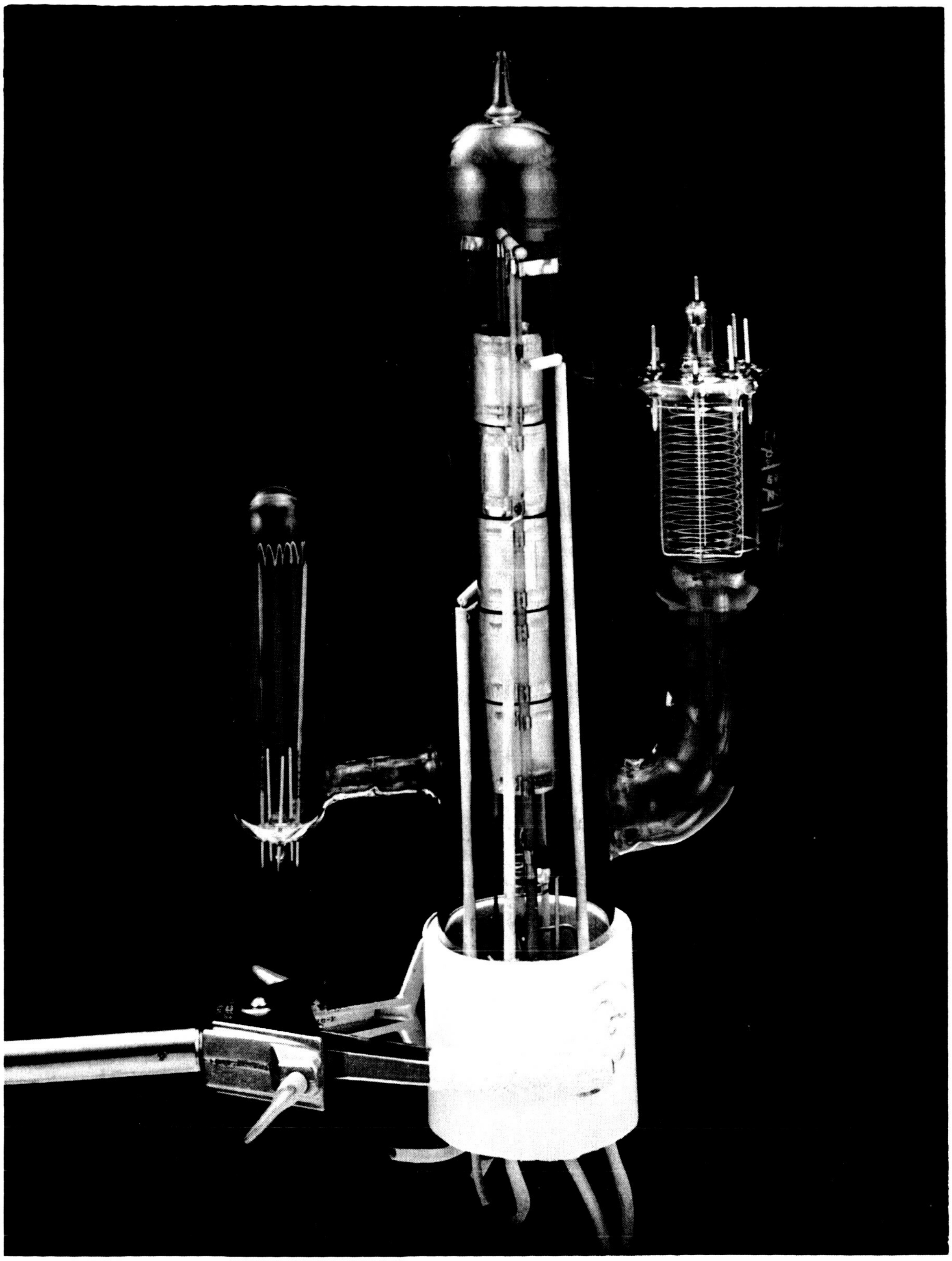

Figure 1. Thermionic Diode

2.0 Measurement of the Work Function

A major portion of the report period was devoted to measurement of the current-voltage characteristics for the various materials. As described in a previous report, the work function is given by the Richardson-Laue-Dushman equation:

$$j = A_o\,(1-\overline{r})\,T^2 \exp(-\phi/kT)$$

where j = current density
A_o = constant = 120 amp · cm^{-2} · deg^{-2}
$\overline{r}$ = reflection coefficient of the surface for electrons
T = absolute temperature
ϕ = work function
k = Boltzmann constant

If the work function is independent of temperature, a plot of $\log j/T^2$ vs. $1/T$ yields a straight line having a slope equal to $-\phi/2.303\ k$.

In the absence of an applied field, electrons emerging from the emitter surface are influenced by various retarding fields. In such cases, only a fraction of the emitted electrons reach the collector, and the current that would be measured is not the true emission current. Therefore, one commonly used method is to provide an applied field so as to overcome the retarding fields and cause all of the emitted electrons to travel to the collector. A diode operating in this condition is said to be saturated.

According to theSchottky theory, of which an excellent review is given by Herring and Nichols[1] the logarithm of current density in the saturated region varies linearly as the square root of the applied field. If this linear portion of the Schottky plot is extrapolated to zero applied field, the value obtained is taken to be the value that would be obtained in the absence of all electric fields. Figure 2 shows a typical Schottky plot constructed from current-voltage characteristics of a tungsten emitter at 1166C.

2.1 Measurement of the Work Function of the Tungsten Reference

A diode having a pure tungsten filament was prepared for the purpose of checking the equipment and procedures used in the determination

---

[1] C. Herring and M. H. Nichols, Rev. Mod. Phys. 21 (1949).

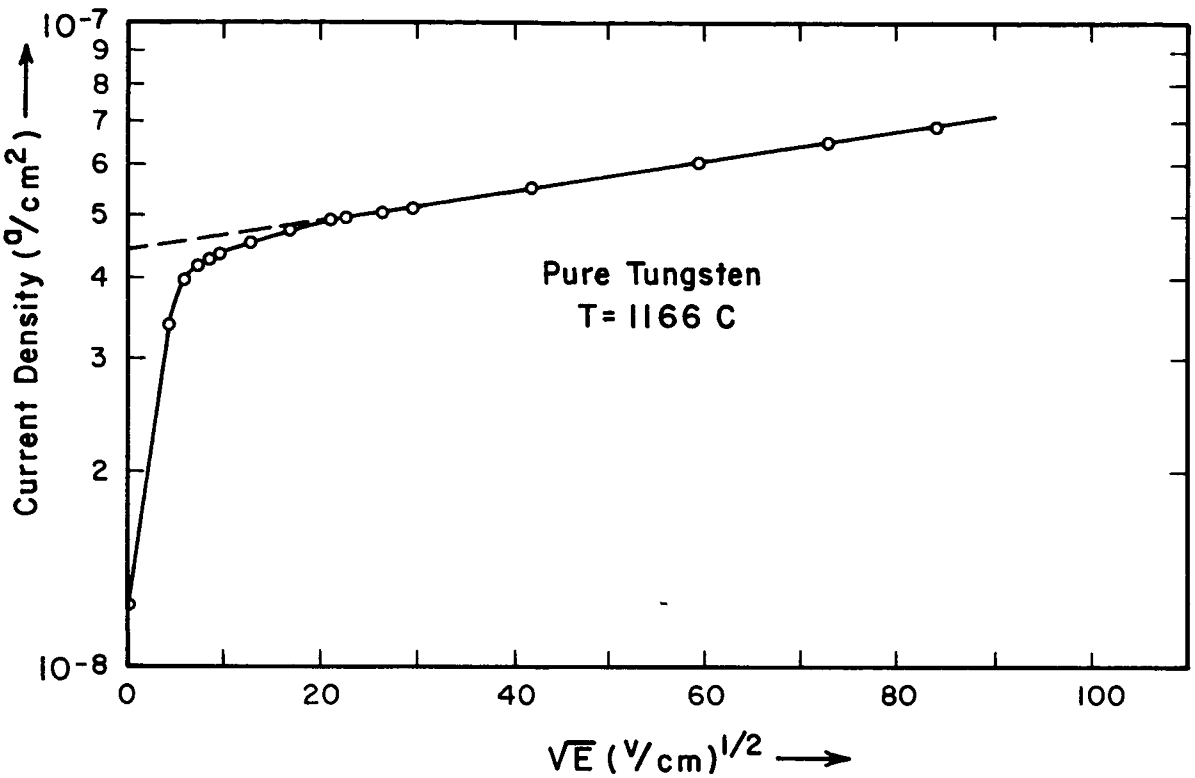

Figure 2. Extrapolation of Linear Portion of Schottky Plot to Obtain Zero-Field Current Density

of the work function. As originally supplied, the diode did not have a spring of the proper design, and some deflection of the filament was encountered at incandescent temperatures. Nevertheless, the current-voltage characteristics of the diode were measured at various temperatures between 1150 and 1600C, before returning the diode to the manufacturer for replacement of the spring.

The diode characteristics were determined by measuring the current as the electric field was increased by increments from 0 to 3700 V/cm. The voltage was supplied by a Lambda Model 1500M power supply, and the current was measured with a Keithley Model 414 micro-microammeter. The temperature of the emitter was measured with a micro-optical pyrometer and corrected for the emittance of the material and for the transmittance of the pyrex envelope. The zero-field current densities were determined by constructing a Schottky plot for each temperature at which the current-voltage measurements were made. As described in section 2.0, the zero-field values were used in a plot of log j_o/T^2 vs. $1/T$. The work function for tungsten determined in this way was 4.58 e.v. as shown in Figure 3. Published values[2] range from 4.25 to 4.69, depending on the crystal orientation of the emitting surface.

The work function will be measured again after the diode has been fitted with the correct spring. Only a minor change is anticipated, however, due to the cylindrical geometry of the diode, and because the deflection of the filament was small.

2.2 High Voltage Pulser System

The 15KV pulser system which is a substantial copy of the apparatus constructed by Haas of the U. S. Naval Research Laboratory is still not operating satisfactorily. A satisfactory voltage pulse is being generated; however, the current pulse is not obtained. Work to resolve this problem is still underway. The pulser system is shown in Figure 4.

2.3 Measurement of the Current-Voltage Characteristics of Intermediate Phases in the Mo-Re and W-Re Systems

Four diodes incorporating the new spring design have been received to date, of which one diode was returned because of an inadequate

[2] H. B. Michaelson, J. Appl. Phys. 21, 536 (1950).

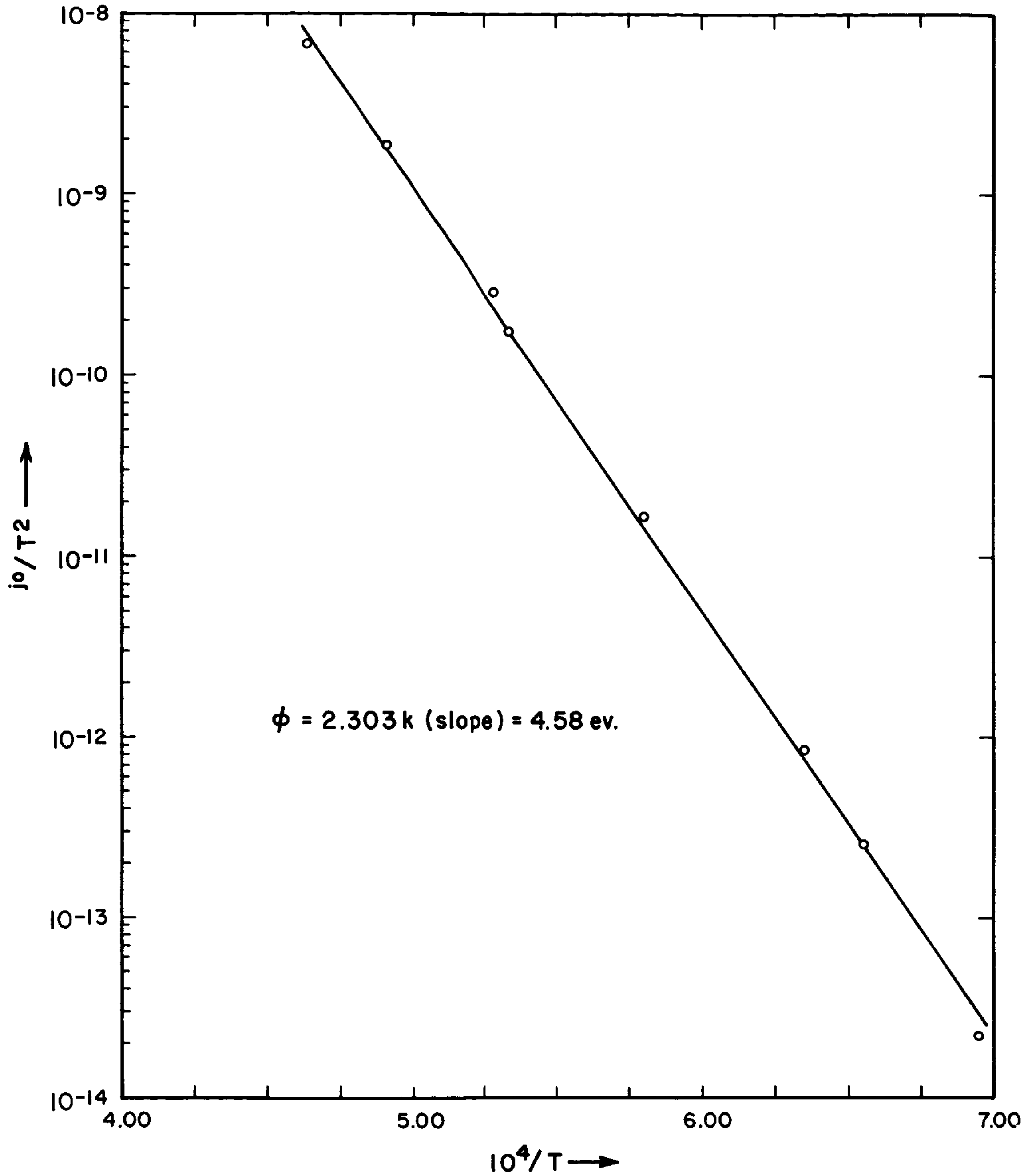

Figure 3. Richardson Plot for Determination of the Work Function of Tungsten

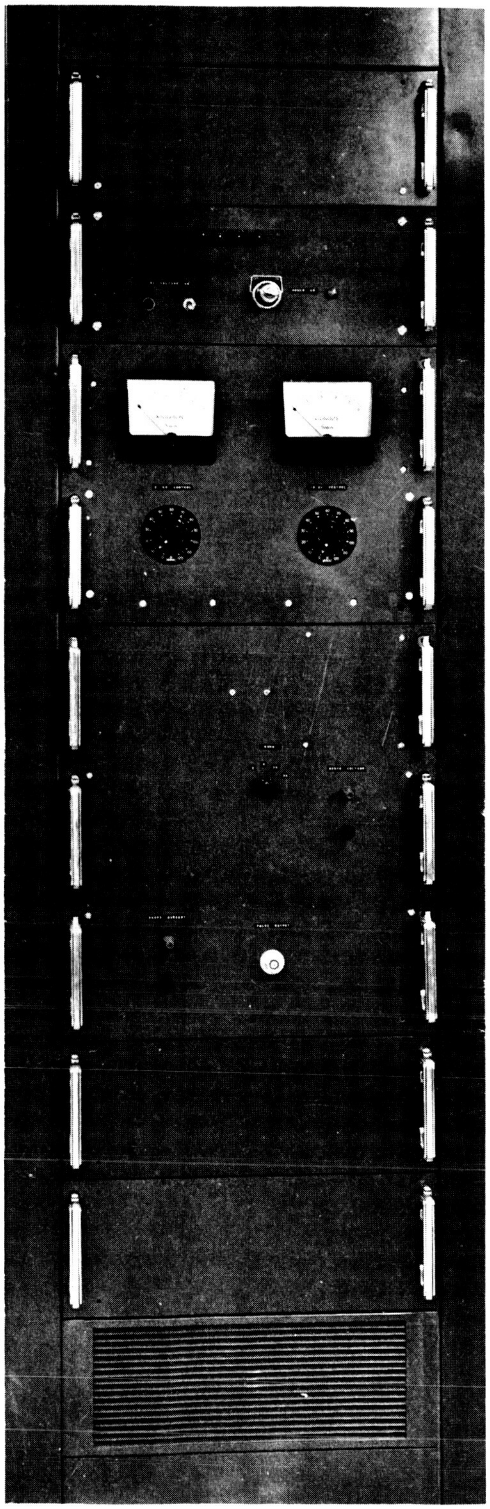

Figure 4. 15 KV Pulser System

vacuum. Measurement of the current-voltage characteristics of the three satisfactory diodes at various temperatures has been accomplished, and Schottky plots have been constructed to obtain the zero-field values shown in Table I. The values shown were obtained graphically from the original Schottky plots. A simple regression analysis program for the Burroughs B5500 computer has been adapted to find the best values, and these correct values will be included in the final report.

Table I. Zero Field Currents at Various Temperatures Obtained from Extrapolation of the Linear Portion of the Schottky Plots

Diode #1		Diode #2		Diode #4	
T(°C)	I_o(amp)	T(°C)	I_o(amp)	T(°C)	I_o(amp)
1297	2.7×10^{-9}	1096	2.35×10^{-11}	1154	2.2×10^{-10}
1335	9.25×10^{-9}	1157	1.83×10^{-10}	1196	4.15×10^{-10}
1390	4.25×10^{-8}	1198	6.30×10^{-10}	1256	2.05×10^{-9}
1440	1.17×10^{-7}	1245	3.95×10^{-9}	1303	1.20×10^{-8}
1490	3.68×10^{-7}	1295	1.12×10^{-8}	1356	7.60×10^{-8}
1540	2.35×10^{-6}	1341	7.22×10^{-8}	1432	5.05×10^{-7}
		1458	7.70×10^{-7}	1498	2.84×10^{-6}
		1501	2.23×10^{-6}	1534	6.05×10^{-6}
		1554	6.30×10^{-6}		

2.4 Emittance Measurements

Since temperature is measured with an optical pyrometer, it is necessary to correct the observed temperatures for the emittance of the material being observed. Such data are available for tungsten,[3] and the correct temperature could be obtained by solution of the Planck radiation equation. A tabulation of the solutions for various emittance values is available.[4]

For the materials of the present study, no such published data are available, but are presently being determined by the Worthing tube method, as discussed in the last report.

[3] Handbook of Thermophysical Properties of Solid Materials, Volume I - Elements.

[4] D. E. Poland, Green, J. W., and Margrave, J. L., Corrected Optical Pyrometer Readings, NBS Monograph 30.

3.0 Discussion of Future Work

In the two-month period from 1 July 1965 to 31 August 1965, measurement of the current-voltage characteristics for the remaining two materials should be completed, as well as the measurement of the emittances for all of the materials of interest. These data will permit calculation of all of the work functions, as well as the temperature dependence of the work functions.

Respectfully submitted,

C. Samuel Miller

C. Samuel Miller
Graduate Research Assistant

Jerry D. Plunkett S.M.

Jerry D. Plunkett
Project Supervisor