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PROGRESS REPORT NO. 30

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REA

I. SURFACE STUDIES

A. SURFACE CHARACTERIZATION CHAMBER

No work was performed on this task during this reporting period.

B. ADJUSTABLE CESIUM PRESSURE ACTIVATION CHAMBER

As described last month, the Adjustable Cesium Pressure Activation Chamber (ACPAC) is an apparatus for characterizing electrode materials in an equilibrium vapor pressure of cesium. Assembly of the device, as well as the oven necessary for heating the system, has been completed. A sample of RCA sprayed barium oxide, a material with a well-characterized work function, has been installed. Cesium will be introduced from a cesium channel which yields approximately 20 milligrams when expended entirely.

II. PLASMA STUDIES

A. CONVERTER THEORY

Comparison of the calculated output characteristics using the present computer model of a thermionic diode with the experimental data in Figure 1 has been made. Experimental current-voltage (I-V) data are shown in Figure 1 for the following operating conditions: $T_E = 1600$ K, $T_C = 900$ K, $d = 0.125$ mm and variable T_R . The calculated I-V curves are compared with experimental curves in Figure 2. The Thermo Electron computer model gives good agreement above the knee of the I-V curve. Characteristics for currents below the knee were generated using a retarding emitter sheath. Although this procedure results in the correct shape of the I-V curves, the calculated curves in this region are displaced by 0.1 to 0.2 volts in output voltage relative to the measured data. Loshkarev's* theory provides a slightly better prediction of the knee's location. The calculated densities of charged particles as a function of spacing for several output current densities are plotted in Figure 3. It is interesting to note that the maxima of the distributions shift toward the collector as the current density is reduced. The distribution of electron temperatures is shown in Figure 4. The electron temperature changes almost linearly for currents above the knee. For the currents below the knee, the electron temperature is higher for the region near the collector. The computer model indicates that most of the ions are produced near the emitter for the upper part of the I-V curve and near the collector for the lower part of the I-V curve. Comparison of the motive diagram is shown in Figure 5. For illustrative purposes, the sheath regions in the family of motive diagrams are drawn on an expanded scale. From these curves, one observes the following phenomena along the I-V curve:

*Loshkarev, A. I., "Non-monotonic Potential Distribution in the Electrode Region, "Sov. Phys. Tech. Phys. Vol. 19, No. 10 April 1977, p. 1308.

Figure 1. Experimental I-V Curve

Figure 2. Comparison of Observed and Calculated I-V Curves

Figure 3. Density Distribution as a Function of Current

Figure 4. Distribution of Electron Temperature

Figure 5. Motive Diagram

- 1) In the region above the knee, most of the arc drop is due to the difference in sheath height.
- 2) In the region below the knee, plasma potential difference is the main contributor to the arc drop.
- 3) The retarding sheath is formed when most of the ions are produced near the collector. There are not enough ions to compensate for the space charges near the emitter.
- 4) The simple double sheath theory does not give an accurate prediction of the knee.

B. EXPERIMENTAL PLASMA ANALYSES

Electron temperature profiles were obtained for steady-state operation of Converter No. 178 (tungsten emitter - tungsten oxide collector) across a 1-mm interelectrode gap with measurements made at intervals of 0.25 mm. The converter operating conditions were: $T_E = 1417$ K, $T_C = 745$ K, $T_R = 556$ K and $I = 5$ A. The results, based on the relative intensities of the continuum radiation caused by recombinant transitions to the 6^2P CsI level, indicated that the temperature between emitter and collector remains nearly constant at an average value of 2708 K.

Reduction of atomic-line intensity data for steady-state operation of the diode showed that the upper excited atomic levels are underpopulated with respect to the lower states and can be characterized by a temperature below that of the free electrons. However, in pulsed operation population inversions are created. Such inversions were observed for the $6P_{1/2} - nS_{1/2}$, $6P_{3/2} - nS_{1/2}$ and $5D_{5/2} - nF_{5/2, 7/2}$ series in recombinant plasmas produced by $5\mu s$ -long discharges.

III. CONVERTER DEVELOPMENT

A. LOW TEMPERATURE CONVERSION EXPERIMENTS

1. Inconel 671 Emitter, Nickel Collector (Converter No. 186)

If a single material can be found to act as both the emitter and the hot shell, it reduces the complexity and cost of constructing flame-heated thermionic converters. The purpose of this converter is to evaluate Inconel 671, (a high temperature alloy composed of 51.6% nickel, 48% chromium, 0.35% titanium and 0.05% carbon) as an emitter. The construction of this converter is complete and outgassing has begun.

B. HIGH EFFICIENCY CONVERSION EXPERIMENTS

1. Tungsten Emitter, Nickel Collector (Heat Flux Converter No. 175)

Heat flux measurements were made at interelectrode spacings of 0.05, 0.5 and 2 mm. The converter current was varied between 1 and 5 A. Figure 6 is a plot of the heat flux into the collector converter current. A least squares fit was used to determine the straight line slope. This slope appears at least 0.2 eV higher than expected from a summation of $\phi_C + 2 kT_e$ (ϕ_C is the collector work function, k is the Boltzmann constant and T_e is the electron temperature). Furthermore, there is very little change in the slope with variations in converter spacing. Currently these experiments are being extended to current densities above 10 A/cm^2 where Ritz and Bohdansky* noted a change in slope at low spacing.

*Ritz, K. and Bohdansky, J., "Collector Heat Dissipation in a Variable Spacing Diode", 1975 Thermionic Conversion Specialists Meeting Proceedings, Eindhoven, p. 221

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Figure 6. Heat Flux into Collector for a Spacing of 0.05 mm, 0.5, 2.0 mm.

IV. COMPONENT HARDWARE PROGRAM

A. CVD COMPONENT DEVELOPMENT

Eight leak-tight SiC/C/W composite hot shells were fabricated during this period and are described in Table I. Fabrication conditions were optimized further by means of a new RF coil having a higher turns concentration at the closed end (Region D) of the shell. During deposition, Region D was held at 1568 K, approximately 15 K hotter than the open end.

B. ALLOY HOT SHELL DEVELOPMENT

Simulated furnace testing continued at a furnace gas temperature of 1573 K. The inside of each shell is evacuated to 10^{-7} torr. Table 2 presents the status of these tests as of January 3, 1978.

TABLE 1
DEPOSITION THICKNESSES (inches/mm)

78I-20

SHELL	W DEPOSIT				SiC DEPOSIT			
	A	B	C	D	A	B	C	D
W9	0.254	0.305	0.381	0.406	0.787	0.787	0.635	0.127
	0.010	0.012	0.015	0.016	0.031	0.031	0.025	0.005
W10	0.229	0.254	0.356	0.406	0.584	0.635	0.359	0.178
	0.009	0.010	0.014	0.016	0.023	0.025	0.022	0.007
W11	0.254	0.305	0.381	0.432	0.559	0.483	0.483	0.356
	0.010	0.012	0.015	0.017	0.022	0.019	0.019	0.014
W12	0.279	0.330	0.406	0.406	0.381	0.406	0.483	0.152
	0.011	0.013	0.016	0.016	0.015	0.016	0.019	0.006
W13	0.229	0.305	0.356	0.432	0.432	0.432	0.533	0.381
	0.009	0.012	0.014	0.017	0.017	0.017	0.021	0.015
W14	0.203	0.229	0.305	0.254	0.406	0.432	0.457	0.356
	0.008	0.009	0.012	0.010	0.016	0.017	0.018	0.014
W15	0.229	0.305	0.330	0.305	0.457	0.533	0.737	0.432
	0.009	0.012	0.013	0.012	0.018	0.021	0.029	0.017
W16	0.229	0.254	0.330	0.279	0.330	0.483	0.711	0.381
	0.009	0.010	0.013	0.011	0.013	0.019	0.028	0.015

COMPOSITE
HOT SHELL

TABLE 2
SIMULATED FURNACE TESTS
(3 January 1978)

TEST PORT NO.	HOT SHELL	TEST HOURS	COMMENT	DATE OF TEST INITIATION
1	REACTION BONDED SILICON CARBIDE	15,466	LEAKTIGHT THIS HOT SHELL WAS BRAZED TO A MOLYB- DENUM SLEEVE WITH NICKEL-COPPER	9 April 75
2	KANTHAL A1	13,879	LEAKTIGHT	25 Aug. 75
3	446 CRES PLASMA ARC SPRAYED WITH NICHROME	1,253	LEAKTIGHT	31 Oct. 77
4	INCONEL 671	6,916	LEAKTIGHT	17 Nov. 76
5	446 CRES PLASMA ARC SPRAYED WITH Cr_2O_3	1,253	LEAKTIGHT	31 Oct. 77
6	-	-	-	-

V. COMBUSTION HEATED THERMIONIC DEVICE

A. MINIATURE FLAME-HEATED DEVICE (Converter No. 179)

Flame-heated testing of the miniature thermionic device described in last month's report was continued. Current-voltage characteristics were recorded periodically. Difficulty was encountered in measuring emitter temperature due to the deterioration of the thermocouple. Within this limitation, converter performance has been stable for a period of 117 hours. Additional testing of the miniature device is planned with electrical heating which should overcome the difficulties encountered in measuring emitter temperature during flame heating.

B. WORKHORSE DEVICE (Converter No. 188)

The design of the "workhorse device" is shown in Figure 7. The diameter of the hot end of this diode is approximately two inches. The effective electrode area is 18 cm^2 . The hot shell/emitter is fabricated from Inconel 671. The ceramic-to-metal seal is designed to provide variation of the emitter-collector spacing by means of spacer blocks. The outboard location of this seal provides ready access to the collector for instrumentation and cooling.

The workhorse device mounts flush in the chamber wall of the combustion facility described in Progress Report No. 29. A photograph of the unit installed in the combustion facility is shown in Figure 8. The static current-voltage characteristic of the workhorse device for an emitter temperature of 1500 K and an interelectrode spacing of 0.75 mm is shown in Figure 9. A power output of 7.3 watts is obtained at a current of 56 A and a load potential of 0.13 volts. The short circuit current is about 82 A.

Figure 7. Design of Workhorse Device

Figure 8. Photograph of Workhorse Device Installed in Combustion Facility

Figure 9. Current-Voltage Characteristic of Workhorse Device at a Spacing of 0.75 mm

The static current-voltage characteristic for an interelectrode spacing of approximately 0.4 mm at an emitter temperature of 1500 K is given in Figure 10. At this reduced spacing, the output power is increased to 18 watts (60 A at 0.3 volt), corresponding to a power density of 1.0 watt/cm^2 . The short circuit current is over 130 A. Testing of this device will continue.

Figure 10. Current-Voltage Characteristic of Workhorse Device at a Spacing of 0.4 mm