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DIMINOIDE THERMIONIC CONVERSION
WITH 111-IRIDIUM ELECTRODES

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SUMMARY

This report presents preliminary data indicating thermionic-conversion potentialities for a 111-iridium emitter and collector spaced 0.2 mm apart. These results comprise output densities of current and of power as functions of voltage for three sets of emitter, collector, and reservoir temperatures: 1553, 944, 561 K; 1605, 898, 553 K; and 1656, 1028, 586 K. For the 1605 K evaluation, estimates produced work-function values of 2.22 eV for the emitter and 1.63 eV for the collector with a 2.0-eV barrier index (collector work function plus interelectrode voltage drop) corresponding to the maximum output of 5.5 W/cm² at 0.24 volt. The current, voltage curve for the 1656 K 111-iridium diminiode yields a 6.2 W/cm² maximum at 0.25 volt and is comparable with the 1700 K envelope for a diode with an etched-rhenium emitter and a 0.025-mm electrode gap made by TECO and evaluated by NASA.

INTRODUCTION

This report presents preliminary thermionic-conversion results for a diminiode (ref. 1) with 111-iridium electrodes separated by 0.2 mm. Making both the emitter and collector of the same bulk material counteracts converter vaporization, deposition effects (ref. 2). The choice of 111-iridium derives from "the fact that higher work function (metallic) surfaces are known to provide a lower work function value in the presence of a specified Cs pressure and substrate temperature" (refs. 3 to 5): The bare work function of 111-iridium is 5.76 eV; of 0001 rhenium, 5.34 eV; of 110 tungsten, 5.25 eV; and of 110 molybdenum, 4.92 eV (ref. 3). So of the potential metallic electrodes, 111-iridium promises the lowest cesiated work functions, which means greater current densities from the emitter and greater output voltages from the collector. In addition the vapor pressure of iridium is similar to that of molybdenum, losing less than 10⁻⁴ mm a year at 1700 K in vacuum (fig. 1). Thus, 111-iridium is an excellent prospect among possible metallic electrodes for cesium thermionic converters.

STAR category 75
This preliminary report is the product of initial testing of a variable-gap
diminioide with 111-iridium electrodes: A malfunction terminated the evalu-
ation. And subsequent examination revealed irreparable damage as well as a
capillary opening covered by liquid cesium in the end of the reservoir. No
other indication of a leak had been apparent. While a replacement diminioide
is in process, the present results can serve to indicate the thermionic-
conversion potentialities of 111-iridium electrodes. To that end these data
represent observed maximum performances corresponding to three sets of
emitter, collector, and reservoir temperatures: 1553, 994, 561 K; 1605,
898, 553 K; and 1656, 1028, and 586 K.

As a background reference 6 cites references 7 to 10 on cesium diodes
with iridium emitters. References 7 and 8 report 5.5 W/cm² for a 1703 K
emitter and a 0.76 mm electrode gap. Reference 9 reveals that a 1643 K
polycrystalline-iridium emitter 0.23 mm from a stainless-steel collector
produced 5.8 W/cm² at 0.3 volt and a maximum of 7.2 W/cm² at 0.16 volt
with about 2 torr of cesium vapor. Adding 60 torr of xenon increased those
performances to 7.4 W/cm² at 0.3 volt and a maximum of 8.4 W/cm² at 0.2
volt. "As before, high cesium pressure with close spacing yields better high-
current output at lower voltages, and low cesium pressure with wider spacing
yields higher output at higher voltages" (ref. 9). Incidentally reference 10
discusses effects of pulsed discharges of the reference 9 diode.

Enlightened consensus indicates that the usually higher performances
found in early thermionic-converter studies probably involved oxygenation
effects unrecognized at that time. The same sophisticated opinions propose
that additives used in those early studies, particularly inert-gas additions,
generally contained oxygen as an impurity. And "the presence of minute
quantities of oxygen (10⁻⁸ to 10⁻⁶ torr) in a cesium thermionic converter re-
sults in improved performance characteristics" (ref. 11). In fact, such observ-
ations received support en masse as more effective quality control in diode
processing led to lower and lower thermionic-conversion outputs. These find-
ings contributed to the initiation of a program that presently explores oxygen-
ation of cesiated electrodes (ref. 12). And today a practical demonstration of
this effect is the increased performance of the TECO cesium, oxygen, tungsten
diode over that of the standard nonoxygenated version.

Thus the high power densities of the reference 9 diode undoubtedly re-
dounded at least partially from undefined prductive oxygen effects. The re-
results from the 111-iridium diminioide may also involve some unspecified
oxygenation. But the absence of leakage symptoms and the presence of performance levels substantially below those of reference 9, indicate probably negligible additive influences in this diminiode study.

W. E. Frey and R. D. Schaal developed and performed special procedures and conducted research tests necessary to fabricate this diminiode.

EQUIPMENT AND PROCEDURES

Reference 1 provides detailed descriptions of all equipment and procedures used in the experiments treated in this report.

RESULTS

Figures 2 to 4 show selected data representing maximum performances observed in limited initial testing of a diminiode with 111-iridium electrodes spaced 0.2 mm apart. These results comprise output densities of current and power as functions of voltage for three sets of emitter, collector, and reservoir temperatures: 1553, 944, 561 K; 1605, 888, 553 K; and 1656, 1028, 586 K.

Because insufficient data exist to form constant-emitter-temperature envelopes, the present exemplary curves serve only to imply potentialities for thermionic converters with both electrodes made of 111-iridium. For example, outputs reach at least 2.9 W/cm$^2$ at 0.14 volt for a 1553 K emitter, 5.5 W/cm$^2$ at 0.24 volt for 1605 K, and 6.2 W/cm$^2$ at 0.25 volt for 1656 K.

Work function estimates for the 1605 K test are 2.22 eV for the emitter and 1.63 eV for the collector. These values compare with 2.38 and 1.54 eV for cesiated rhenium at appropriate electrode-to-reservoir temperature ratios of 2.9 and 1.6 (ref. 13). The work functions for this 1605 K 111-iridium diminiode indicate a barrier index (collector work function plus interelectrode voltage drop) of 2.0 eV corresponding to the 5.5 - W/cm$^2$ maximum.

Figure 5 reveals that the 1656 K current, voltage curve is similar to the better 1700 K envelope for diodes with etched-rhenium emitters and 0.25-mm electrode gaps made by TECO and evaluated by NASA (ref. 14).

Such results merit further investigation: Another 111-iridium diminiode is now in the fabrication process.
REFERENCES


12. NASA Contracts with Thermo Electron Corporation (TECO): NAS7-508, NAS3-14413, and NAS3-19866


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VAPORIZATION OF PURE METALS AND LANTHANUM HEXABORIDE

FIGURE 1

VAPORIZATION RATE, CM/YR

VAPORIZATION RATE, MIL/YR

TEMPERATURE, K

CS-76160
OUTPUT VOLTAGE, VOLTS

FIGURE 2

DIMETHOXY OUTPUTS FOR 111-IRIDIUM ELECTRODES 0.2 MM APART
(1573K EMITTER, 944K COLLECTOR, 561K CESIUM RESERVOIR)
Figure 3. Dimenode Outputs for 111-iridium Electrodes 0.2mm apart (160°C Emitter, 89°C Collector, 55°C Cesium Reservoir)
FIGURE 4. DIODE OUTPUTS FOR 111-IRIDIUM ELECTRODES 0.2MM APART (165K EMITTER, 1028K COLLECTOR, 596K CESIUM RESERVOIR)
FIGURE 5: A COMPARISON OF 1700K-EMITTER (0.25MM-GAP) ENVELOPES (REF. 14) WITH DIODE OUTPUTS FOR 311-IRIDIUM ELECTRODES 0.2MM APART (1656K EMITTER, 898K COLLECTOR, 553K RESERVOIR).