Controlled-Porosity Dispenser (CPD) Cathodes for High.Resolution CRTS

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INTRODUCTION

Driven by the demand for higher resolution CRT's for high definition television (HDTV), automotive displays, computer graphic displays, projection television, and avionics applications, the CRT designer has had to consider the employment of cathodes capable of producing higher current densities than those presently obtainable from the triple carbonate oxide cathode.

In other than short pulse applications, the triple carbonate oxide cathode system, which has been the industry standard for decades, produces emission densities of less than 1 amp/cm2, and therefore cannot be used in applications where the higher densities are required.

A cathode system which will meet the demand for higher resolution must be capable of achieving two design criteria. First, a smaller diameter electron beam bundle which produces a smaller spot size at the viewing surface is required. This smaller electron beam is produced by using smaller apertures in the beam forming region (BFR) of the electron gun. Second, because brightness levels for these higher resolution applications must be maintained, the currents of these smaller diameter electron beams must be the same as those of the conventional larger beam diameter systems. To achieve this goal, a cathode system must operate at a higher current density.

OXIDE CATHODES

The characteristic behavior of an oxide cathode is related to the fact that it is essentially a dielectric material and will “charge-up”. As mentioned before, it can only achieve high current densities in short pulse length applications.

Oxide cathodes are also susceptible to poisoning, requiring exacting and lengthy tube processing to obtain the best performance characteristics.(1) The life of oxide cathodes in CRT guns is relatively short, particularly in applications where the current density is in excess of a few hundred milliameters per square centimeter. Because the dielectric nature of an oxide cathode limits the current density, a metal emitter as used in dispenser cathodes must be considered for CRT's.(2)

DISPENSER CATHODES

The impregnated dispenser cathode, (3) whose most typical use is in microwave tubes, is made from porous tungsten which is impregnated with barium compounds. When heated, the barium compounds react with the tungsten matrix allowing the barium to migrate to the surface of the cathode. Throughout its use, the cathode surface is constantly covered with barium, and the emitter surface work function drops from 4.5 electron volts to as low as 2.0 electron volts.

While the impregnated dispenser cathode is capable of producing higher current density and long lifetime, it must be operated at about 2000C higher than the oxide cathode. In addition to requiring a higher operating temperature to produce the higher current density, this cathode also requires a longer activation cycle. These two performance characteristics result in excessive evaporation of the barium which can cause unwanted grid emission and high voltage instability. Because of this, and because the conventional impregnated dispenser cathode is more expensive to manufacture than the oxide cathode, the reservoir dispenser cathode was considered superior for use in CRT applications.

The reservoir cathode was the original type of dispenser cathode. With this design, barium compounds are held in a cavity, or reservoir, behind a porous disk. When heated, the compounds decompose or react with a reducing agent. The barium is then dispensed through the porous disk to the surface.

The first dispenser cathode was developed in the 1940's by the Philips Company in the Netherlands. (4) This was the L-type cathode. This cathode consisted of a porous tungsten disk over a reservoir of barium carbonate. Because of processing difficulties with the L-type, the Philips Company developed the impregnated cathode. This cathode also used a porous tungsten disk, but instead of it being placed over a reservoir of barium carbonate, it had its pores impregnated with barium aluminate. The first model, called the A type cathode(5), was impregnated with a barium oxide and aluminum oxide compound. The B type cathode was developed when calcium oxide was added to the impregnant. Semicon Associates in 1954 introduced the S type cathode which used a different impregnant and fabrication process. In the late 1960's, the N type cathode(6) was developed which was either the B or S type cathode coated with a thin film of Osmium Ruthenium. In the 1970's, the mixed metal matrix cathode(7) was developed which added an enhancing metal (osmium, rhenium, iridium) to the tungsten matrix of the impregnated cathode

CPD Cathode

A unique controlled porosity reservoir cathode has been developed which will produce the higher current densities and brightness levels that are required in high-resolution CRT guns.

Development of the CPD cathode (8,9) began in the late 1970's and was refined and perfected to its present state by the late 1980's. This cathode took the original dispenser cathode concept, incorporated modern laser technology into its fabrication, and utilized the optimum alloy enhancement to produce a lower work function, constant and uniformly emitting, long life device.

Instead of using a porous tungsten disk for the emitter, a refractory alloy metal sheet is substituted. The porosity of the metal sheet is not random, as it is with the porous tungsten disk. A laser is used to drill a precise array of holes in a refractory alloy emitter directly behind the Gl aperture of the beam forming region of the electron gun. The size and spacing of the holes determine the dispensation rate of the barium from the reservoir, thus evaporation rate is controlled. Because of a low work function, the cathode operates at a lower temperature, lifetime is increased, and the higher current densities are made possible.

Figure 1 is a three dimension drawing showing the thermally efficient CPD cathode design utilizing a lanced tab suspension of the cathode heater assembly(lO)

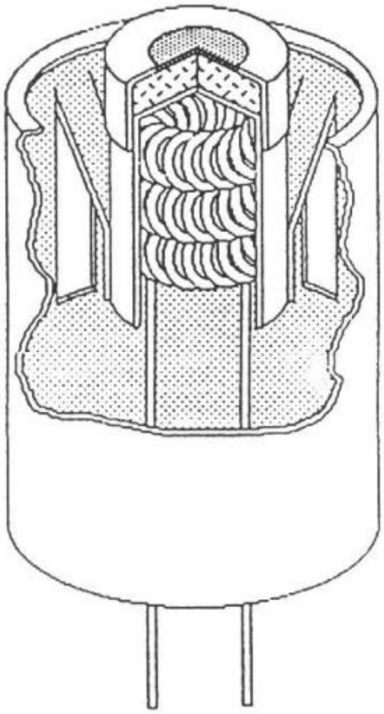

Figure 1. Schematic Representation of Low Power CPD Cathode Design

A thermally efficient structure has been designed which requires very low heater input power (less than 1.3 watts) to achieve current densities in excess of 3 amps/cm2 The inner cathode subassembly consists of a tungsten-rhenium alloy cap which is laser seam-welded to a molybdenum heater cup. This weld insures excellent heat transfer from the heater cup to the electron emissive surface. A pellet containing barium compounds is captured between the cap and the heater cup to provide a long-life supply of barium to the cathode surface. The molybdenum heater cup allows good heat transfer from the heater coils within, while providing a moderately low thermal emissivity to reduce outside surface radiation losses.

Further radiation loss reduction is accomplished by limiting the total outside surface area of the subassembly. The cathode outside diameter has been reduced to .060 inch diameter and the heater cup volume has been held to a minimum. The heater is a coiled-coil design which incorporates a maximum amount of wire mass in the provided cup volume. The outside of the tungsten-rhenium heater coils are A1203 coated1 with a second thinner outer layer of a small particle size tungsten powder, or 1'dark" coating, to increase the thermal emissivity of the coil surface.

The outer support structure utilizes a three-point suspension of the inner cathode assembly by attachment to tabs which are lanced from the seamless tantalum tubing. The tabs are resistance spot-welded to the molybdenum heater cup and then subsequently laser spot-welded to insure a secure bond. The tantalum provides a moderately poor thermal conductor which reduces the power loss to the support structure.

The inverted tab structure provides a rigid mechanical support for the inner cathode assembly and thermally isolates the inner assembly from the outer support. The heat transfer from the tabs is in a direction of higher temperature, which is due to the close proximity of the outer support cylinder, and thus can reduce the tab thermal loss. At the same time the outer support cylinder acts as a reflective heat shield to "blanket" the inner assembly. Another advantage of the inverted tab is to offset the linear thermal expansion inherently produced at cathode operating temperature, by expanding in a direction opposite to the inner cathode assembly, thereby reducing the cathode/Gl spacing changes which can otherwise occur.

RESULTS

Figure 2 is data of classic Schottky plots (current density versus square root of voltage). As the data shows, at llOO0CBr, J0 is almost 50 amperes per square centimeter.

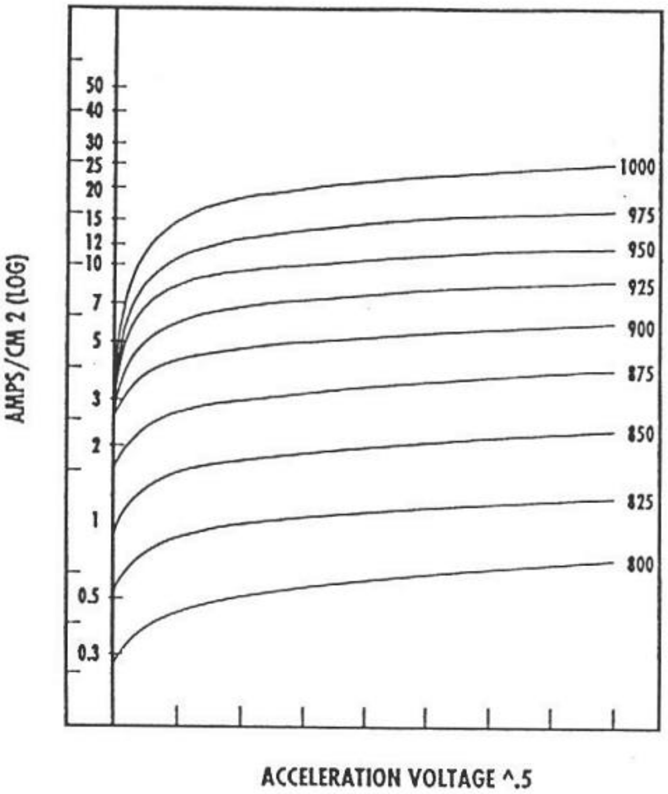

Figure 2. Schottky plots. Current Density Versus Square Root of Voltage.

Figure 3. Heater power characteristics of the efficient low power design compared to a conventional single cylinder support design.

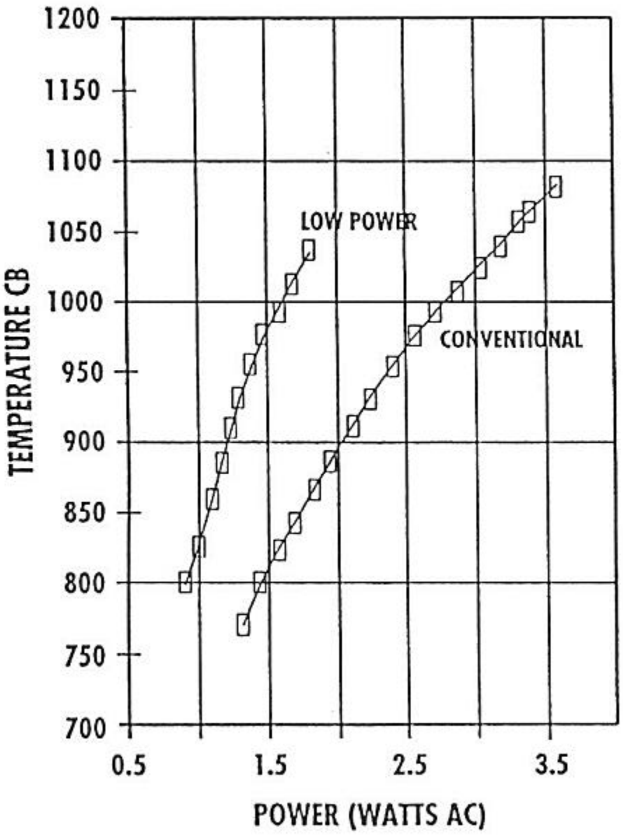

Fig.3

Figure3. Heater Power Characteristics Low Power And Conventional Shank Designs

Figure 4 is data from close-spaced diode testing showing current density versus temperature at various acceleration voltages.

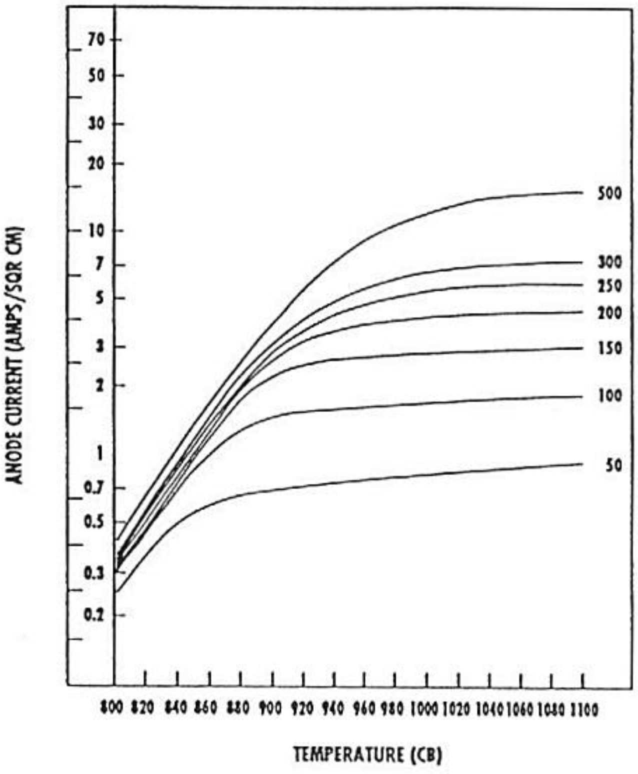

Figure 4 Current Density Versus Temperature At Various Acceleration Voltages.

Figure 5 shows work function versus temperature data measured at the U.S. Naval Research Laboratory in Washington, D.C. by Dr. J.W. Gibson.

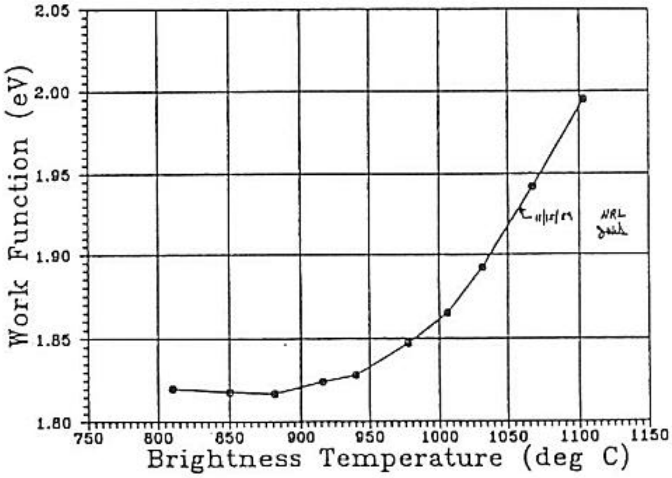

Figure 5

Figure 5 NRL Data. Work Function Versus Temperature.

CONCLUSION

The CPD cathode permits almost direct substitution of an oxide cathode in most CRT guns. The advantage of high current density (up to 10 A/Cm2 and higher) and long life offer the opportunity for the design of many high resolution high brightness CRT applications.

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