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A Cavity Reservoir Dispenser Cathode for CRT's and Low-Cost Traveling-Wave Tube Applications

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Abstract-This paper describes the application of an old concept, the cavity reservoir dispenser cathode, to a new requirement of long-life high~urrent-density cathodes for CRT's and other vacuum devices. Fabrication techniques are described and data are presented showing emission current versus temperature. The data were obtained from tests conducted in actual CRT guns.

I. INTRODUCTION

DRIVEN by the demand for higher resolution CRT's or high-definition television (HDTV), automotive displays, computer graphic displays, projection television, and avionic applications, a unique dispenser cathode has been developed that will allow these demands to be met. In order to obtain higher resolution, the CRT designer is forced to consider use of cathodes capable of higher current densities. The cathode type currently used in CRT's is the triple (barium strontium calcium) carbonate coating that converts during tube processing to oxides. Although used very effectively in long-life applications, these cathodes are limited in other than short-pulse applications to less than 1 A/cm2. This places a restriction on the CRT electron gun design. The size of the Gi hole determines the size of the electron beam diameter. Higher resolution requires a smaller electron beam which starts with a smaller Gi hole. In order to achieve the proper brightness, the current in this smaller beam must be the same as in the larger beam, thereby increasing the current density at which the cathode must operate. Other options might involve improvements in electron optics design, but this appears to have been nearly fully exploited. It is preferred to utilize a cathode capable of higher current densities so that the G 1 hole and beam diameter can be reduced. There is also a demand for inexpensive traveling wave tubes (TWTS) for use in expendable ECM applications. The cathodes for these should not only be low cost but be capable of high current densities and fast turn on.

II. IMPREGNATED DISPENSER CATHODES

The characteristic behavior of an oxide cathode [1] is related to the fact that it is essentially a dielectric material and will "charge-up". This limits its high current performance to very short pulse length applications and therefore a metal surface cathode must be considered in CRT's. The most obvious choice is a relatively low work function activated metal surface cathode as opposed to a high work function metal emitter like tungsten or tantalum. The activated metal surface cathode commonly used in microwave tube high current density applications for the past 25 years or so has been the B-type impregnated dispenser cathode originally developed by Levi [2]. An improvement on this cathode is the M-type cathode developed by Zalm and Van Stratum [31 in the late 1960's. This cathode has come into very popular usage during the past 10 years. It is the same as the B-type impregnated cathode developed by Levi but over coated with an osmium ruthenium alloy that significantly lowers the work function. Other metals and alloy coatings have been used such as pure osmium and iridium and combinations with ruthenium and rhenium. To overcome the possible effects of reducing the surface concentration of the emission-enhancing metal either because of diffusion at high temperatures or removal of the coating by ion bombardment, Falce [4] developed the mixed metal matrix cathode in the early 1970's. This cathode was intended for use in very high current density applications above 5-10 A/cm. The scandate cathode [5] developed by Van Stratum et al. in the late 1970's is yet another development. A more recent development of the scandate cathode is the top layer type reported by Hasker of Philips [61 and Yamamoto [7] of Hitachi. All the cathodes described above are impregnated cathodes where an approximately 80-percent dense metal matrix is impregnated with either barium calcium aluminate or a similar material that includes scandium oxide (5c203) and may also include a surface treatment for emission enhancement. Impregnated cathodes are currently used in some limited applications in CRT's, in virtually all TWT's, and are widely used in magnetrons, klystrons, and other types of vacuum/gas devices. However, it has been reported in private communications to the author that problems have been experienced with activation of these cathodes as well as unwanted emission from the Gl. This is due in part to high barium evaporation in early life and increased operating temperature compared to currently used oxide cathodes. Additionally, the cost to manufacture impregnated cathodes has greatly limited their use in CRT's.

III. CAVITY RESERVOIR DISPENSER CATHODES

The original dispenser cathode was the L-type cathode [8], which was a reservoir type that utilized a porous tungsten disk over a reservoir of barium oxide (BaO). This cathode was difficult to process because barium carbonate used as the BaO source was decomposed to an oxide (BaO) as part of the tube processing ~nd the carbon diokide (C02) produced had to pass through the porous tungsten. This required considerable time. The work function of this cathode type was still lower than its successor, the impregnated B-type cathode described above, but the difficulty in processing limited its use. Another reservoir cathode called the M-K cathode, was developed by Katz [9] and was an improvement on the Ltype cathode. It has been employed for many years at Siemens in high-power microwave tubes. This cathode addressed the problems of processing experienced in the Ltype by use of preprocessed BaO in the reservoir and a tungsten wool insert between the reservoir and the cathode pellet to consume potential by-products created by the gases evolved in the barium generation reaction. In 1978, Falce and Thomas reported on the controlled porosity dispenser (CPD) cathode [10]. This was a further refinement of the cavity reservoir concept using a precise array of laser drilled 5-mm-diameter holes in a thin (25 mm) sheet of iridium over a reservoir of preprocessed BaO. This was later modified to include barium calcium aluminate in the reservoir and the sheet was changed to tungsten [11]. A high current density (10 A/cm2) and long-life (100 000 h) cathode is presently under development by NASA at Varian. This is a cavity reservoir cathode using a barium oxide source behind a porous iridium tungsten emitter. All the above cavity reservoir cathodes share the capabilities of high current density, long life, and a constant rate of barium dispensation.

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Fig. I shows a relative comparison of evaporation rates from an impregnated cathode and a cavity reservoir cathode. In early life, the evaporation rate of the impregnated cathode can be as much as an order of magnitude greater than that of a cavity reservoir cathode. This is due to the fact that the barium compounds in early life are virtually at the surface of an impregnated cathode, and the rate of barium evaporation does not fall until the supply recedes into the pores of the matrix. The cavity reservoir, however, dispenses barium at a constant rate since the supply is always separate from the emitting surface throughout the life of the cathode. After considering the requirements of CRT's and low-cost high-performance TWT's, it was decided to concentrate on exploiting the advantages offered by the cavity reservoir cathode. First of all, it is capable of being economically produced. One of the most expensive processes in producing an impregnated cathode is the impregnation process. It requires very close controls on time and temperature at the molten stage and additional clean up afterward. In the case of the CRT cavity reservoir cathode, a barium containing ceramic is dry pressed into a pellet in a simple high-speed operation. This pellet is placed in a formed metal cup that is sealed to a porous metal disk that has been dry pressed and sintered. This assembly is spot welded to a refractory

Fig. 2 is a schematic representation of the completed assembly. At this stage, the assembly looks no different than an oxide cathode assembly. When tested in a CRT gun, the comparison ceases. Fig. 3 shows a typical set of cathode current density versus cathode temperature curves, with space-charge limited current densities of 5 A/cm2 and above at various anode voltages. Fig. 4 shows these characteristics at lower voltages and corresponding space-charge limited current densities. It can be seen that a 1-A/cm2 space-charge limited current density can be obtained as low as 8500C brightness temperature.

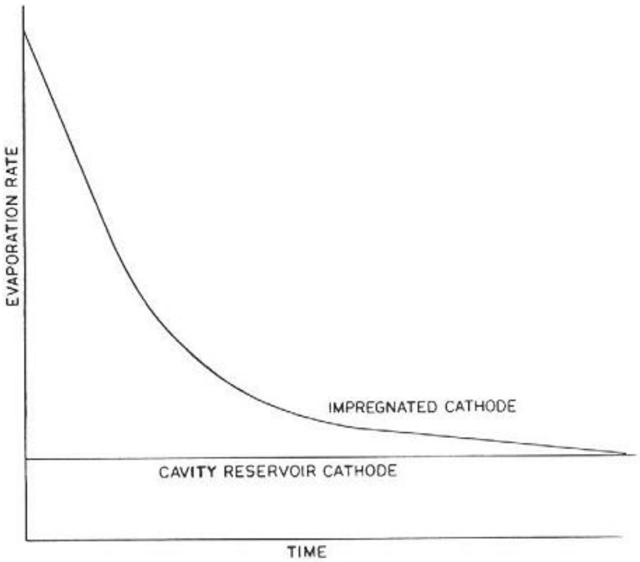

Figure 1 Comparison of evaporation rates of cavity reservoir and impregnated dispenser cathodes.

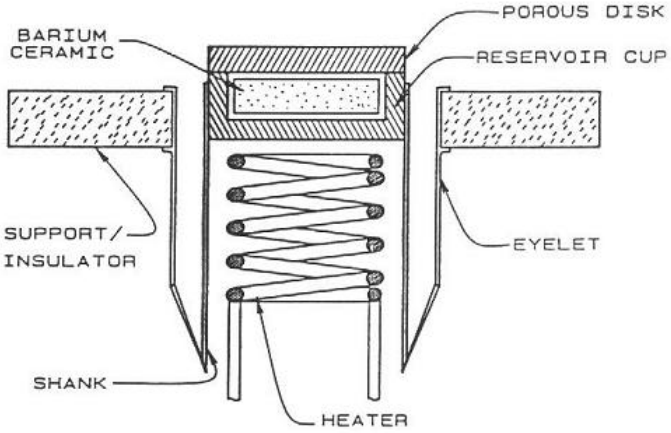

Fig. 2. Schematic representation of a completed assembly of a cavity reservoir dispenser cathode for a CRT application.

Note the sharpness at the transition region (knees) of the curves indicating very uniform emission. Fig. 5 summarizes data from emission current versus temperature tests of 75 cathodes. The curve in Fig. 5 is a plot of the maximum space-charge limited current density (the point on the curves in Fig. 3 where the transition between temperature limited and space-charge limited emission is completed) versus cathode temperature.

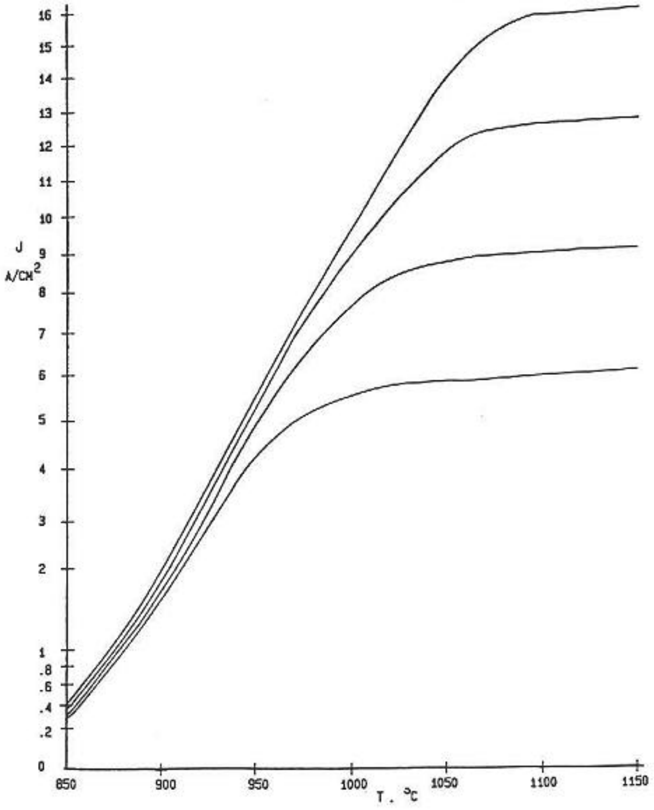

Figure 3. Current density versus temperature at various anode voltages.

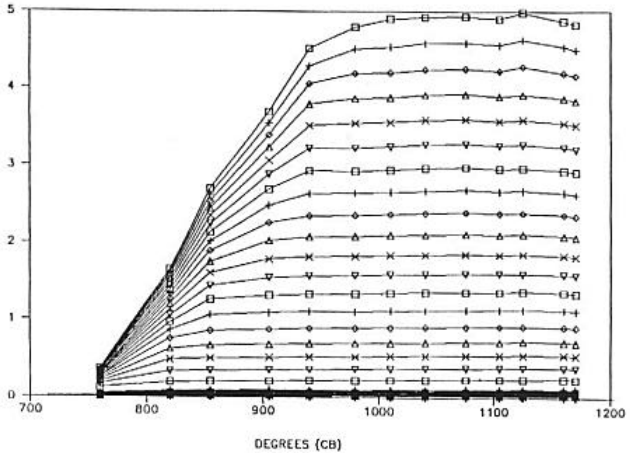

Figure 4. Current density versus temperature at lower voltages.

As seen on the graph, fully space-charge limited emission of 5 A/cm2 can be obtained at 10000C. It is significant that these data were obtained in actual CRT guns. Other tests were performed in laboratory diodes and conventional Schottky plots were obtained. These are shown in Fig. 6. J0 (zero field emission) at 10000C is over 7 A/cm2. Testing of the cavity reservoir cathodes in CRT's is taking place currently in several locations throughout the world.

IV. CONCLUSION

The advantages of the cavity reservoir cathode are 1) its low early in life and constant barium evaporation rate; 2) its uniform emission as a result of barium dispensation to the emitting surface that is unhampered by plugged pores as a result of reaction by-products and impregnant residue present in the pores of an impregnated cathode; 3) its equal or better current density capability compared to impregnated cathode types; 4) its long-life capability as a result of its controlled dispensation and the possibility of an unlimited size reservoir; and 5) its relatively low manufacturing cost. The cavity reservoir cathode described here is expected to meet most, if not all, of the demands for high-resolution and high-brightness CRT displays, as well as the low-cost high-performance demands of expendable TWT' 5.

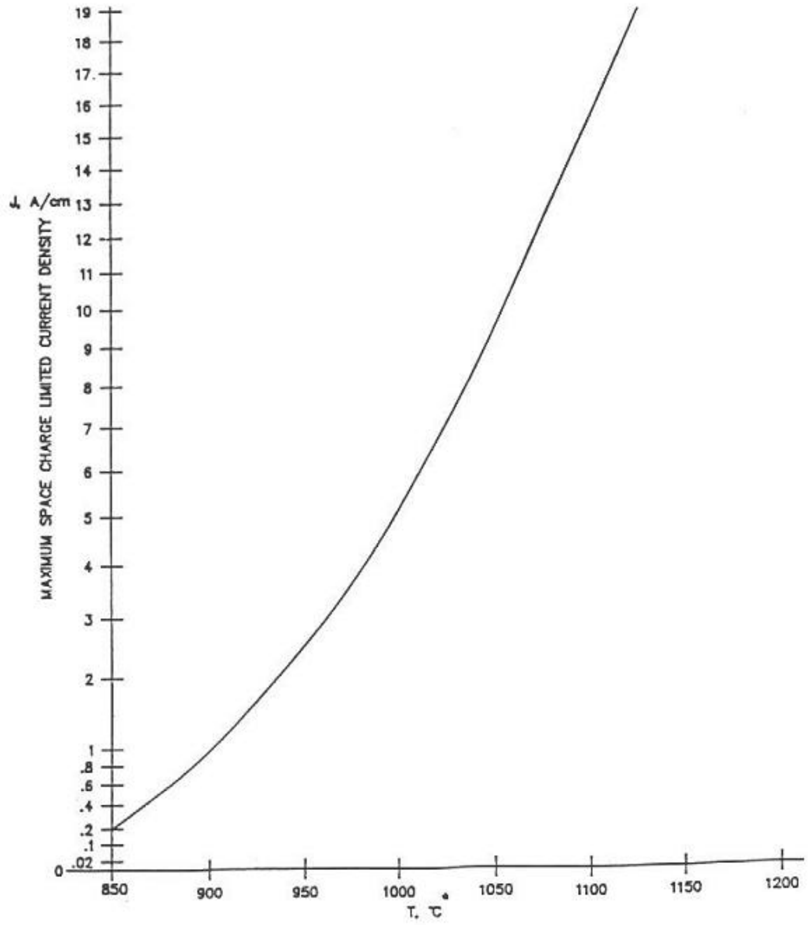

Figure 5. Maximum space-charge limited current density versus cathode temperature.

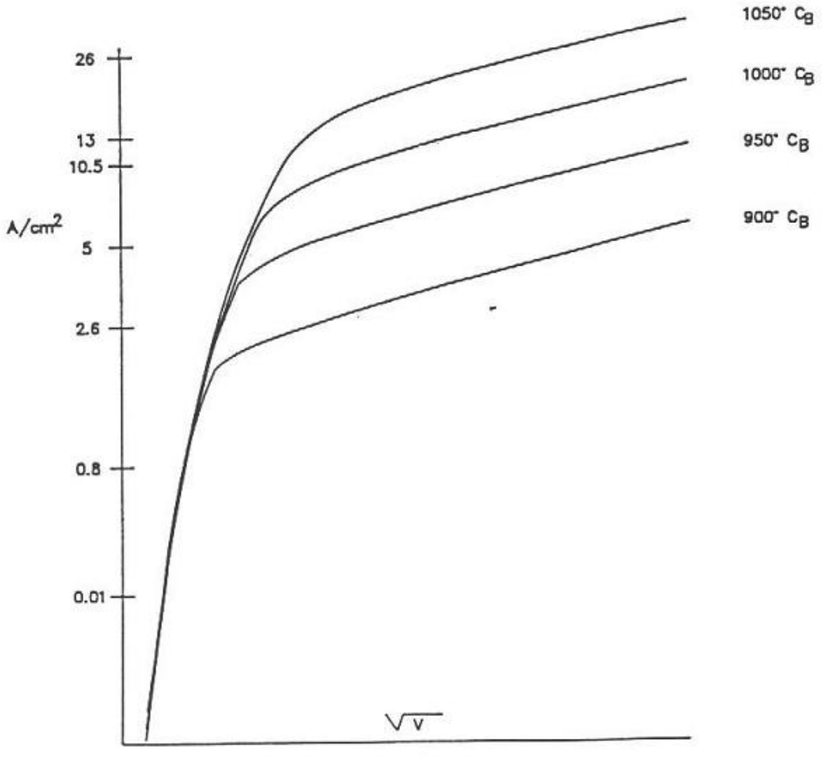

Figure 6. Current density versus square root of voltage.

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Received a B.Sc. degree from Rutgers University in 1952. He also attended the University Pittsburgh, Carnegie Institute of Technology (now Carnegie Mellon) and U.C.L.A. He served in the U.S. Marine Corps as a Radar Communications and Electronics Officer. In 19 years at Varian Associates Microwave Tube Did nine years at Hughes Aircraft ElectronDynamics Division, he was responsible for the development of a number of microwave tube fabrication techniques that included the use of lasers for welding and drilling, various film coating applications using vacuum sputtering, helix brazing, and other high power interaction circuit fabrication processes. He developed the manufacturing technology for Samarium Cobalt magnets at Var-ian. He invented the mixed metal matrix cathode. Working under contract for the Naval Research Laboratory, he developed many of the techniques for controlled porosity dispenser (CPD) cathodes. In 1985, he founded Ceradyne Electron Sources and has served as its president since then. The cavity reservoir cathode described in this work has been under development there since 1986. He holds 10 patents and has authored 25 technical publications.