Cermet cathodes: A new technology for CRT applications

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Abstract — In this paper, we present results for a new type of cermet cathode (Oxide Plus) in a range of CRT tube types including wide-screen 32-in. and 34-in. tubes together with 19-in. computer-monitor tubes. The results indicate that the cermet cathode exhibits good performance in all types of tube where previously oxide cathodes were not suitable and only Ba-dispnser cathodes could be used. We also illustrate a new suspended cathode structure compatible with RCA-type cathodes that could enable a wider adoption of this new technology.

Keywords — *Oxide cathodes, cathode-ray tube, cermet, suspended cathode, heater, wide-screen TV, computer monitor.*

1 Introduction

In recent years, the trends in CRT development have been toward higher resolution and brightness and for cathodes with higher current densities and lower heater power.[1] All of these requirements have ensured there has been an active interest in developing and improving the performance of the cathodes.

Despite advances in alternative technologies such as impregnated cathodes (Ba dispenser cathodes[2–4]) and metal matrix systems such as the hot isostatically pressed (HIP),[5] cathodes, the oxide cathode remains the workhorse of the CRT industry and, as such, has been the focus of considerable research activity both within L.G. Philips Displays and other companies (Mitsubishi,[6] MEC,[7] Samsung,[8] Thomson,[9] and others).

In this paper, we illustrate the tube performance of a new, improved, oxide-type cathode based on an oxide-metallic composite composition known as a cermet. This new cathode is now in use in several types of tubes including high-end applications where, in the past, impregnated cathodes were necessary. We also describe a new suspended cathode structure that is compatible with RCA-type cathodes and offers the potential for wider applications for the cermet technology.

2 Background to cermet technology

In recent years, LG.Philips Displays has been actively researching oxide cathodes and potential improvement options for gas-poisoning resistance (important for tube processing and cathode robustness) and overall lifetime. In the 1980's for example, Philips patented the use of rare-earth dopants within the oxide spray layer to improve performance.[10] Figure 1 illustrates how doping with rare earths changes the electrical properties of the oxide cathode emissive layer.

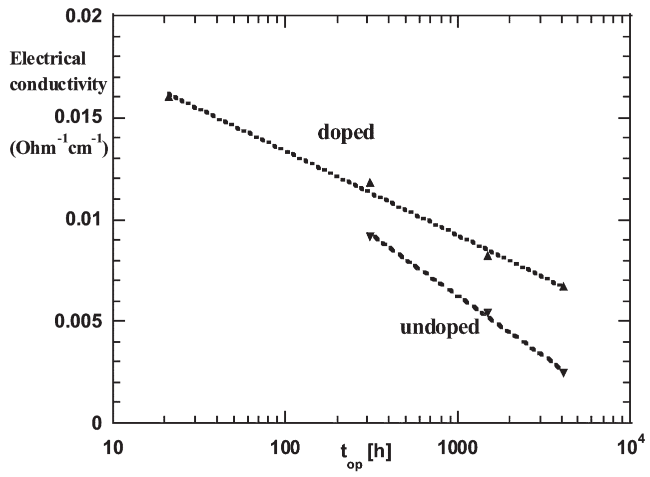

FIGURE 1 — Electrical conductivity s_{el} of rare-earth-doped Ba Sr-oxide cathode compared to non-doped cathode *vs.* operating time.

In more recent years, collaboration with Loughborough University has lead to the study of cermet cathodes doped with Ni particles.[11,12]

Figure 2 illustrates conductivity measurements of the emissive material undertaken at Sheffield–Hallam University for a 5% nickel cermet cathode. These showed about $1 \cdot 10^{-2}$ (W-cm)$^{-1}$ from 1000 K down to room temperature, whereas more conventional oxide-type cathodes without Ni exhibit a strong conductivity decline with decreasing temperature.[12]

For a 2.5% Ni cermet, $\square_{el} = 8 \cdot 10^{-3}$ (W-cm)$^{-1}$ was directly determined under operating conditions at the (true) operating temperature of 1050 K in a planar diode configuration in UHV as described in Ref. 13.

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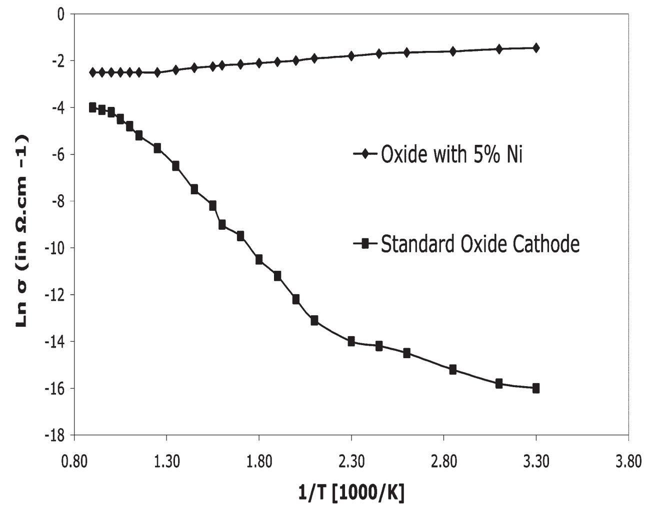

FIGURE 2 — Electrical conductivity *vs*. reciprocal absolute temperature for Philips's standard oxide cathode with 5% Ni particles added.

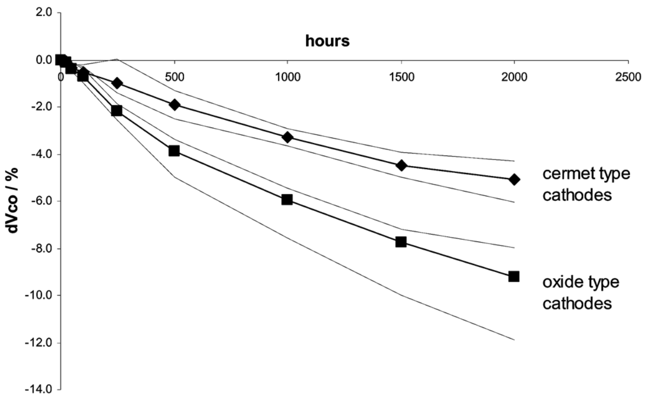

FIGURE 3 — Influence of cermet technology on cathode cut-off performance on life.

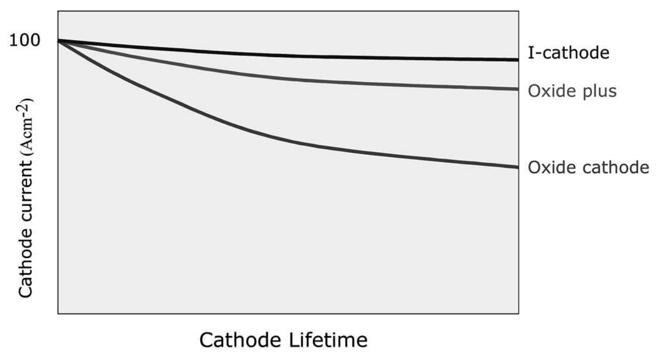

FIGURE 4 — Typical life performance of oxide, Oxide Plus (cermet), and I-cathodes.

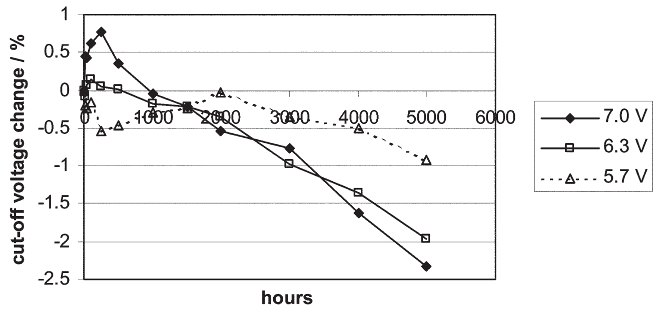

FIGURE 5 — Comparison of cut-off performance for cermet cathode at different heater voltages in a 32-in. tube.

For a more detailed discussion of the background to these studies and a general review of recent developments in the field of oxide cathode research, see Refs. 14 and 15 and references therein.

3 Tube performance

In addition to altering the electrical properties of the cathodes, the adoption of cermet technology (based on nickel filaments) has also been found to improve cut-off drift in CRT applications as seen in Fig. 3. Data shown compare cathode compositions based on cermet technology, with samples based on traditional oxide-cathode technology.

The central curves represent the average of all cathodes of each type. Also shown are maximum and minimum lines that represent the average of several samples of the worst/best cathode compositions within each class. These results clearly demonstrate that all compositions based on cermet technology have superior cut-off performance over cathode lifetime.

Changes in cut-off performance over cathode lifetime can be attributed to a number of factors. There is good evidence, for example, of shrinkage (sintering) of the cathode spray layer over operating life[16] and the introduction of cermet technology may alter the sintering characteristics of the spray layer.

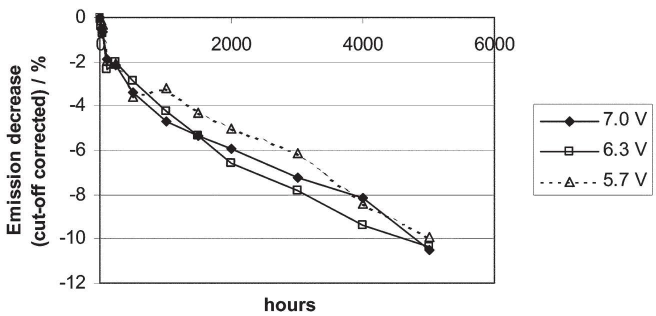

FIGURE 6 — Comparison of emission performance for cermet cathode at different heater voltages in a 32-in. tube.

TABLE 1 — Comparison of dV_{co} at different V_f.

	4000 hours		5000 hours	
V_f (V)	dV_{co} (%)	StDev	dV_{co} (%)	StDev
All	–1.0	1.3	–1.6	1.3
5.7	–0.5	0.4	–0.9	0.4
6.3	–1.2	1.5	–1.8	1.6
7.0	–1.4	1.4	–2.1	1.5

TABLE 2 — Comparison of dIk at different V_f.

	4000 hours		5000 hours	
V_f (V)	dIk (%)	StDev	dIk (%)	StDev
All	–8.7	2.9	–10.3	3.2
5.7	–8.4	4.1	–9.9	4.8
6.3	–9.4	2.9	–10.4	2.4
7.0	–8.1	1.0	–10.5	1.8

3.1 Performance in wide-screen picture tubes

Based on these preliminary findings, one particular composition was chosen for industrialization and Fig. 4 illustrates 5000-hour life-test results for 32-in.-wide screen tubes.

Figure 5 illustrates the change in the cut-off voltage (percentage) at three different heater voltages, 5.7, 6.3, and 7.0 V. A typical heater voltage for normal applications would be in the region of 6.1–6.3 V. Table 1 summarizes the data at both 4000 and 5000 hours.

Figure 6 represents the change in the emission (measurement corrected for cut-off change) again at 5.7-, 6.3-, and 7.0-V heater voltage (V_f), while Table 2 summarizes the dIK results at both 4000 and 5000 hours of lifetime.

In these tests we have measured performance at values both below and above the normal operating value. At a heater voltage of 6.3 V, the change in cut-off is just below 2% (even after 5000 hours) and the cut-off corrected emission has decreased by only around 10%. Under stressed-life conditions (at the higher heater voltage of 7.0 V) there is no significant change in performance compared to the results seen at 6.3 V (V_f), with cut-off at just above 2% (after 5000 hours) and emission decrease equivalent to that seen at 6.3 V.

The performance of the cermet cathodes is maintained at different current loads and across a range of different tube types. Table 3 compares data at 2000 hours from 32-in. and 34-in. screens using a different gun design with a slightly higher cathode loading than in the above example and at two different heater voltages (6.3 and 7.0 V).

Despite the higher cathode load in these tubes, the percentage change in cut-off voltage after 2000 hours is around the same (at an applied heater voltage of 6.3 V) as that seen in the previous example. Stressed-life testing of these tubes (increasing the heater voltage to 7.0 V) does lead to an increase in the percentage change in cut-off voltage compared to the previous example, but the decrease in emission is no worse than is seen at the lower (normal operation) heater voltage.

TABLE 3 — Comparison of 2000 hour data for 32- and 34-in. tubes at different heater voltages.

	2000 h 34-in. 6.3 V	2000 h 32-in. 6.3 V	2000 h 34-in. 7.0 V	2000 h 32-in. 7.0 V
dIk0.5	–6.7%	–11.6%	–6.6%	–10.3%
dV_{co}	–0.5%	–0.6%	–2.4%	–1.5%

3.2 Comparison of spot-size performance

This stable tube performance for cermet cathodes is also reflected in the measured spot performance after life testing in large-screen (high-end) CPTs. The results illustrated in Fig. 7 were obtained with equivalent gun designs in a jumbo-screen tube after several thousand hours of life testing.

The results clearly show that there is no major difference in the spot performance of cermet and Ba-dispenser cathodes even after several thousand hours of life testing.

3.3 Comparison of oxide and cermet cathodes at high current loadings

In comparing conventional oxide cathodes with Ba-dispenser cathodes, there has always been a disadvantage in terms of dc loadability for the oxide cathodes. The new cermet technology cathode has been developed at least in part to address this disadvantage.

As part of our studies aimed at exploring the performance limits of the new cermet technology cathodes we have carried out a number of laboratory trials similar to that illustrated in Fig. 8 and have found the same general trend holds over a very large range of cathode loads.

In general terms, it is well known that for traditional oxide cathodes, increasing the cathode load results in an increase in the rate of emission degradation over time and

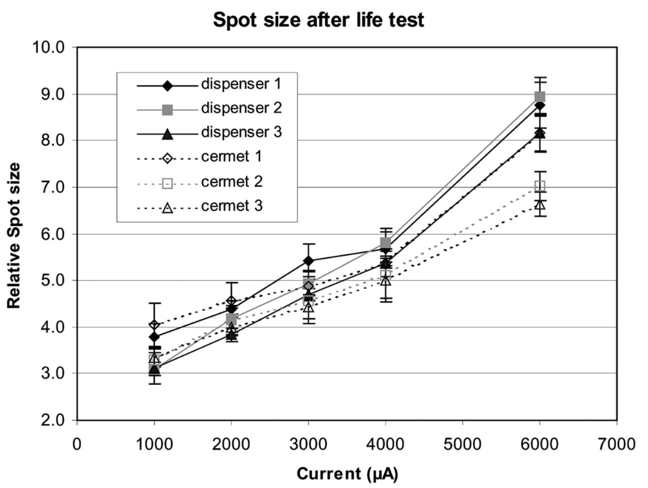

FIGURE 7 — Comparison of cermet and Ba-dispenser cathode spot performance after life testing.

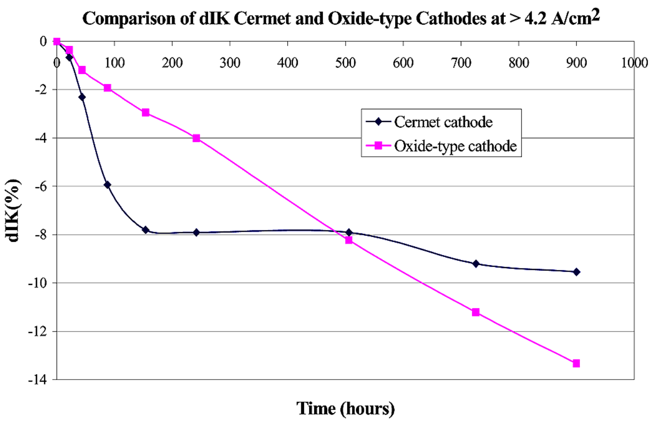

FIGURE 8 — Comparison of emission decay (percentage) over time for oxide and cermet cathodes at >4.2 A-cm^{-2}.

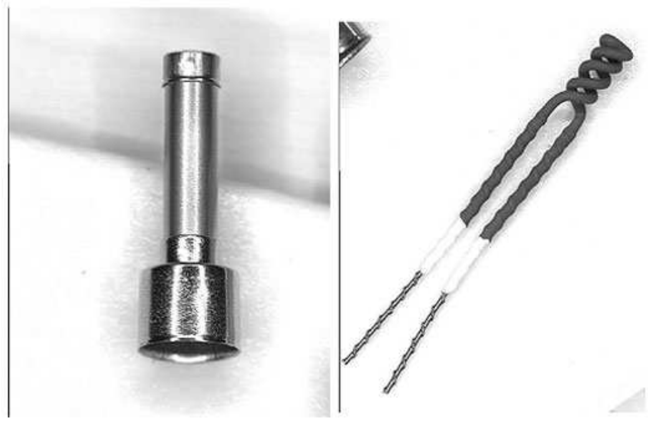

FIGURE 10 — Typical RCA-type cap-tube assembly and heater unit.

this is invariably load dependant and this is one of the reasons why, in the past, Ba-dispenser cathodes were used in higher load applications.

In contrast, the cermet-technology cathodes display very different (but no less consistent) behavior. In our laboratory trials, there is always an initial emission degradation and after a certain period of time this degradation stops (even up at very high cathode load values at or above 4.0 A-cm^{-2}). In our laboratory experiments this degradation appears to be independent of the applied cathode load.

The major difference observed in our laboratory results is in the time taken for the emission to reach this stable (equilibrium) value. Increasing the cathode load appears to merely reduce the time required to reach the equilibrium value. This is an aspect of the cermet-cathode performance that is still under investigation.

In the laboratory experiment illustrated here, the normal oxide-type cathode shows an almost linear decline in emission with time and after 900 hours dIk is already approaching 15%. The cermet cathode, on the other hand, displays different behavior in as much as, after an initial period of around 150–200 hours, the emission becomes stable and does not significantly decline further over life.

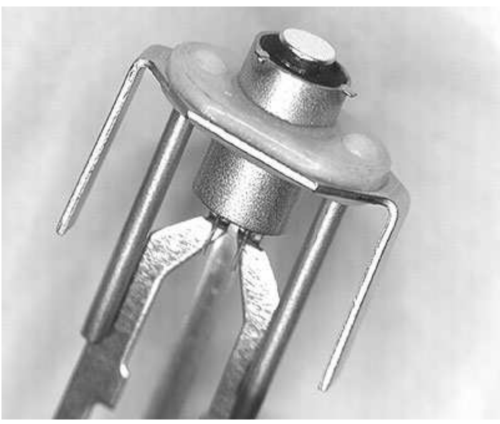

FIGURE 9 — Philips 0.65-W integrated cathode unit.

It is important to note that this is a laboratory experiment and uses a much higher cathode loading than would normally be seen in day-to-day applications. Nevertheless, the experiment serves to illustrate the differences between traditional oxide-type cathodes and the new cermet technology and in particular in terms of their respective behavior under higher cathode loadings.

It is also important to note that the emission performance of any cathode depends to a large extent upon the activation and aging process used. For the laboratory experiments described here, both the oxide and the cermet cathodes used the same activation and aging cycles (that had been optimized for the oxide and not the cermet cathode).

Changes in the cathode processing would lead to a different result in terms of the degradation seen with the cermet cathode. The more important factor is the extremely stable emission seen once the equilibrium level has been reached. It is this property that makes the cermet cathode different from a normal oxide cathode and offers an interesting range of possibilities for gun and tube designers.

4 Cathode construction

There are essentially two basic designs of cathode for CRT applications on the market at present. The integrated design (as pioneered by Philips) includes the cathode and heater in a single unit and is illustrated in Fig. 9.

The alternative design (commonly referred to as an RCA type) includes a separate cap-tube assembly and cathode heater. The two components are brought together usually at the gun assembly stage. Figure 10 illustrates a typical RCA-type cathode and heater combination.

In addition to the differences between integrated and separate heaters and cathode holders, the other main difference between the Philips and RCA designs is the fact that the cap-tube assembly of the Philips cathode is a suspended unit. This brings a number of performance benefits particularly in relation to cathode warm-up time and white balance drift.

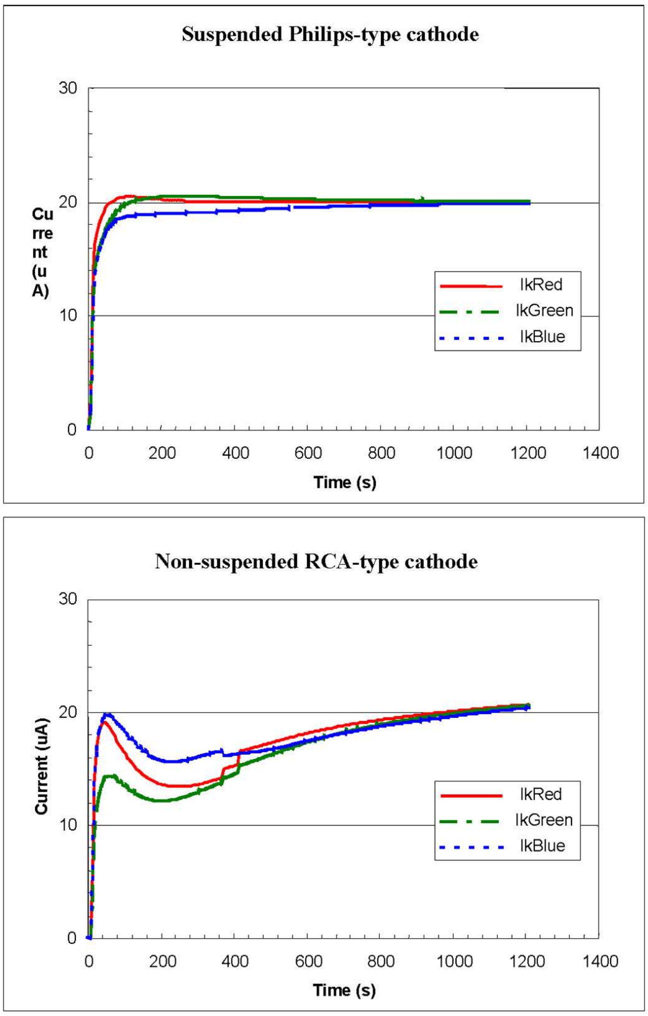

FIGURE 11 — Influence of cathode construction on white-balance drift.

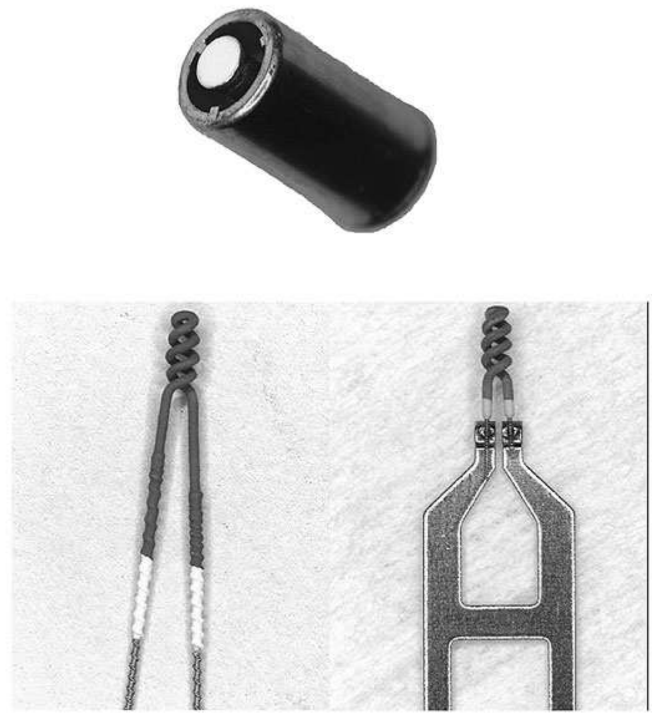

FIGURE 12 — RCA-compatible suspended cermet cathode assembly and heater units.

Figure 11 illustrates the difference in white-balance drift comparing a suspended Philips-type cathode with a typical non-suspended RCA-type construction, As can be clearly seen, the suspended structure stabilizes much more quickly and shows less difference between colors during the initial warm-up period.

In order to enable a wider application of cermet technology in different CRT and gun designs, LG.Philips has developed an alternative design of suspended cathode that more closely resembles the RCA-type structure together with two different variations of heater units as illustrated in Fig. 12.

Preliminary results for these cathodes are in line with our expectations based on the Philips construction. These alternative structures enable a wider potential adoption of cermet technology.

5 Conclusions

The results presented clearly illustrate that the newly developed cermet cathode (Oxide Plus) is capable of good performance in large-sized tubes, an application where, in the past, impregnated Ba-dispenser cathodes have been used. In terms of both emission degradation and spot performance, in certain applications the cermet cathode is almost indistinguishable from a Ba-dispenser cathode.

With the trends towards larger screen sizes along with the requirements for higher current densities (ideally at lower operating temperatures and lower power consumptions) for new applications such as internet TV and higher brightness computer monitors (for video streaming applications for example), the newly developed cermet cathode (Oxide Plus) offers a viable alternative to Ba-dispenser cathodes. In order to facilitate the wider adoption of cermet technology in other (non-Philips design) gun and tube types we are also actively developing an RCA-compatible version of the Philips suspended cathode with the cermet emission system.

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