Lifetime Experience with low Temperature Cathodes equipped in Super Power Klystrons.

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0. ABSTRACT

When Philips started the production of super power klystrons in 1976 the electron emitter was a tungsten dispenser cathode of the well- known Philips "B" type. One disadvantage of this cathode type is the relative high cathode temperature. Many efforts have been spent from researchers world-wide to decrease the operating temperature of the dispenser cathode.

Since 1990 we have tested several sputter coated Os/Ru cathodes in cw super power klystrons. The expected decrease of the temperature has been entirely confirmed. Measured emission data compared to "B" cathodes during factory acceptance test are presented. Positive experience concerning lifetime under real operation conditions has been gained at different internatiol accelerator centers and will be reported.

1. INTRODUCTION

The Philips Röhren- und Halbleiterwerke in Hamburg, Germany, is a manufacturer of high power microwave tubes. In the scope of current production are klystrons and inductive output amplifiers (IOA) for the UHF-TV market and high power continous wave klystrons for high energy research and puls klystrons for radar application.

Most of the cathodes equipped in tubes are tungsten dispenser cathodes of the well-known "B" type developed in the Philips research laboratories in the Netherlands and the United States of America [1]. The cathode consists of a porous tungsten body with roughly 80% density. The pores are filled with a mixture of bariumoxid, calciumoxid and alumina with a molar ratio of 5:3:2.

In 1976 Philips started the production of super power cw klystrons with 600kW RF output power installed in high energy research laboratories. For this application the proven technology of the Philips "B" cathode was chosen too.

A typical operating temperature of the "B" type cathode is about 1040°C_B. This relative high temperature creates a number of problems related to the evaporation of barium from the cathode:

- Electrical breakdown strength across ceramic insulators.
- Primary electron emission from the focus electrode.
- Flaking of condensated barium from the anode under electrical forces.

Due to this disadvantages it is one main goal of thermionic cathode improvement to increase the electron emission density at a given operation temperature permitting the same current at reduced temperature.

2. LOW TEMPERATURE CATHODES

2.1 The "M" type Cathode

A significant improvement in dispenser cathode technology was made in the 1969`s at the Philips research laboratories in Eindhoven [2]. Zalm and van Stratum found that a coating of the cathode emission surface with a metal of the platinum group (osmium, iridium, ruthenium or rhenium) gives a reduction in work function of about 0.2eV. This means in practice that the cathode can deliver the same current density as the "B" cathode at 60°C to 100°C lower temperature. The "M" type cathode was born.

2.2 The Philips "M" type Cathode

In the present state the Philips "M" type cathode is a conventional "B" type cathode with a osmium-ruthenium coating of about 1µm thickness.

3. CATHODE PREPARATION

Deposition of Os/Ru films on porous tungsten with modern sputtering facilities is an usual process in Philips cathode ray tube production.

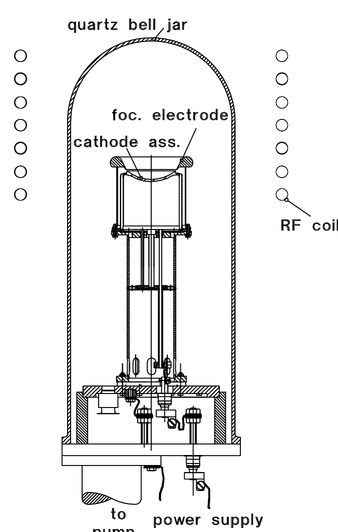

Fig.1 Gun Pretreatment Station

The emitting surface has a diameter of 1mm. Five thousand cathodes are sputter coated in one procedure. These cathodes give good results in Philips TV colour tubes with respect to grid emission and lifetime.

In recent years this technique was also been used for the large cathodes (up to 80mm in diameter) of super power conontinous wave klystrons. There is only one additional step in the cathode production line:

After impregnation the pellet is sputter etched and than coated with Os/Ru.

Before installation into the gun structure each cathode assembly will be vacuum fired in a quartz bell jar (Fig.1) for several days. The reason is to degas the cathode assembly and to evaporate residual impregnant from the cathode surface. During pre-firing the pressure is be maintained at less than 5×10^{-6} torr while the cathode temperature is slowly increased up to the operating value.

The relationship between heater power and cathode brightness temperature (°C_B) was measured by an optical pyrometer through a 0.650 µm filter.

4. RESULTS

4.1 Factory Test

After tube bake-out and burn-in a detailed underheating characteristic was measured at constant gun voltage. Fig.2 shows the measured normalized cathode emission curve (Miram plot) of three Os/Ru coated cathodes compared to a standard "B" cathode.

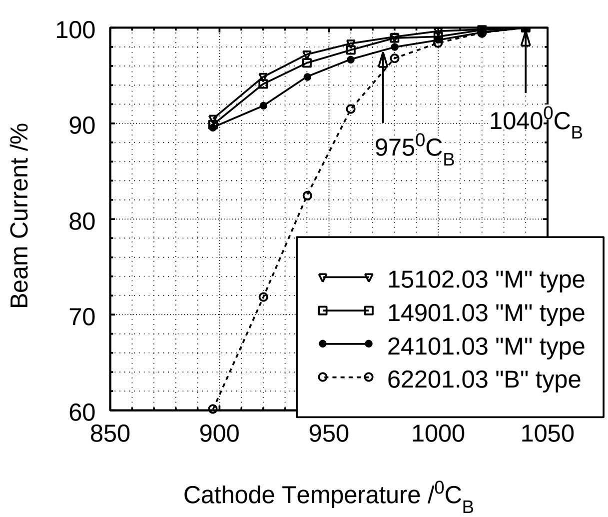

Fig. 2 Underheating characteristic plot measured during factory test. Comparison between "B" cathode and "M" cathode

The transition point between the temperature limited zone and the space charge limited region was shifted to lower temperatures. A decrease of about 65K in cathode operating temperature can be allowed to guarantee stable emission conditions. The temperature was fixed at 975°C_B instead 1040°C_B for standard "B" cathodes. This reduction gives a decrease in barium evaporation down to about 25%.

4.2 Emission Tests during Life

Since 1990 more than twenty five super power klystrons of various types were equipped with Os/Ru coated "M" type cathodes.

Some tubes are under special lifetime observation at the customer.

Cathode current measurements are carried out periodically and with the known relationship between heater power and cathode temperature beamcurrent-temperature plots can be made.

The behaviour of one tube during life is shown in Fig. 3.

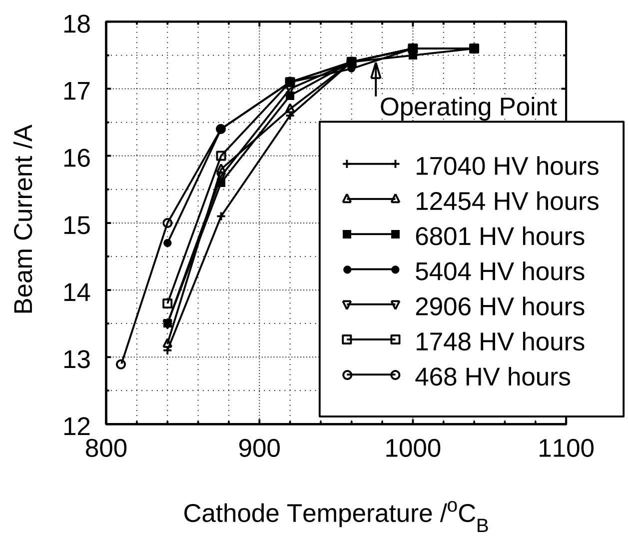

Fig. 3 YK1304 Underheating characteristic during life. The operating temperature is fixed at 975^0C_B.

Another indicator of cathode emission condition is the tube perveance. The operating time dependence of perveance shows Fig. 4. In the beginning a little fluctuation can be observed. After about 5.000 hours the perveance increases slowly. A reduced anode voltage can be applied to achieve the same beam current.

From [3] it is known that at normal cathode operating temperatures interdiffusion of tungsten substrat and the osmium-ruthenium layer occurs. The cathode performance first improves with life because the work function will go through a minimum (that means a maximum in emission) at 80% W concentration in surface. When the surface became more rich in tungsten the emission decreases.

The time for degradation is temperature dependent. The expected time to reach the minimum in work function at 975°C_B is more than 100.000 hours.

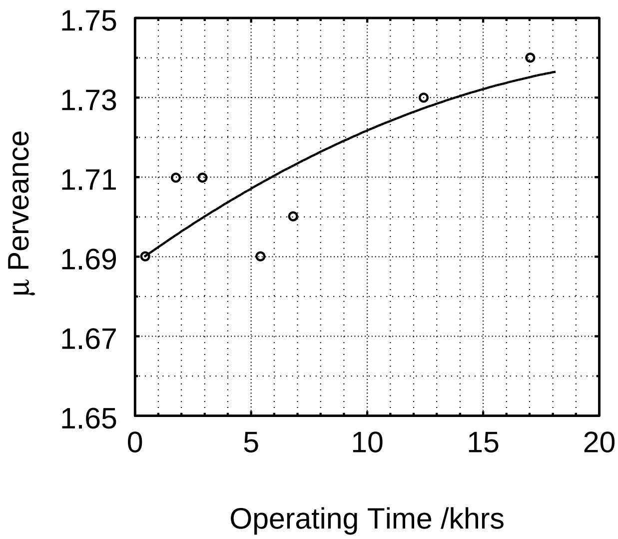

Fig. 4 Perveance during life

5. CONCLUSION

In total more than twenty five Philips super power klystrons equipped with Os/Ru coated "M" type cathodes are working trouble-free in different accelerator centers world-wide. The RF output power is between 800kW and 1.3MW. Some tubes have exceed 18.000 high voltage operating hours.

The Philips low temperature "M" coated cathode accomplishes the strong demands in super power klystrons.

The advantages for running tubes in transmitters are:

- Low evaporating rates of the impregnants.
- Low operating temperature.
- Temperature decrease of focusing electrode leads to depression of unwanted primary emission
- Long-term stability of emission.
- Long service life of klystron.

The emission behaviour of the Philips "M" type cathode also has been tested with success in several TV klystrons and inductive output amplifiers. A lifetime testprogramme is started in cooperation with the German Telecom.

6. REFERENCES

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