The Effects of Synthesis Process on Aluminate Emitters Thermionic Properties

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Abstract: *This paper describes some different synthesis methods of barium-calcium aluminate to be used as a thermionic emitter. It is also investigated thermionic emission measurement techniques to characterize the impregnated cathodes under development. A Pierce type electron gun is scaled up to match the electron gun designed with the desirable beam parameters like applied voltage and cathode emission current density in order to determine the space-charge current limit.*

Keywords: Aluminate emitters; Pierce electron gun; power microwave devices; thermionic characteristics.

Introduction

A suitable emission current and lifetime of a given microwave power tube depends upon the efficiency which free electrons are produced by its thermionic cathode. It is known that the emitter chemical composition influences the thermionic emission cathode properties (emission current density, lifetime and work function) and, therefore, the emitter material manufacture process also influences them [1]. In this work, barium-calcium aluminate synthesize process has been investigated in order to improve the microwave power tube performance: emission current density, tube lifetime and susceptibility of poisoning.

It was also investigated the material phases presented in barium-calcium aluminate (5:3:2). It is well-known that barium-calcium aluminate consists of three phases: $Ba_3Al_2O_6$, $Ba_2CaAl_2O_6$ and CaO [2]. These phases influence the chemical reaction between free barium and tungsten matrix and, also, active layer formation. This layer reduces the work function of the surface cathode and, the emitter composition influences its value.

This paper also presents the features of Pierce electron gun used in thermionic measurements obtained from the input parameters: beam voltage, beam current, radius waist, and cathode current density [3].

Experimental Procedure

Three types of experiments were performed to evaluate the synthesis process of barium-calcium aluminate. First, the thermal behavior of the raw materials of each synthesis process was studied using thermogravimetric (TG) in controlled atmosphere. Temperature and atmosphere of each process were established (between 800-1000°C). Qualitative X-ray analysis was then used to identify the reaction products (the phases of barium-calcium aluminate). The aluminate fabrication processes sequences were described previously in other works [4].

The electron gun geometry and the beam parameters of the Pierce gun are presented in Table 1. The geometry parameters of electron gun were optimized using numerical simulation.

Table 1. Input parameters used to design of the Pierce electron gun.

Parameters	Value
Cathode disk area (cm^2)	1.35
Cathode radius (mm)	12.9
Anode radius (mm)	5.12
Anode-cathode spacing (mm)	7.77
Anode voltage (kV)	30
Convergence half-angle (degree)	29.4

For the emission experiments, it was used the film cathode. The investigated cathode was assembled in a molybdenum body and in its porous tungsten surface a barium-calcium aluminate coating was deposited. Barium-calcium aluminate film was obtained by spraying a mixture of aluminates and organic solvents. Emission characteristics were measured using a modified power TWT (traveling-wave tube) instead of the conventional close space diode structure. This modification was made to improve the emission experiments and it provides better results in an investigation TWT manufacture process.

Results and Discussion

Figure 1 shows the TG curves of three different samples. One of them was obtained from solid-state reaction, a second from the precipitation techniques, and the last one, by crystallization techniques. Crystallization TG curves evidences that its thermally stable temperature is shorter than the carbonates mixture. It is also verified that firing of the crystallization product may be carried out at 800°C under oxidant atmosphere. The precipitation product thermally stable temperature was about 1000°C (same as

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solid state reaction). By means of X-ray diffraction, it was analyzed the phases presented after firing. The diffraction pattners of differents techniques shown the following phase: $Ba_3Al_2O_6$.

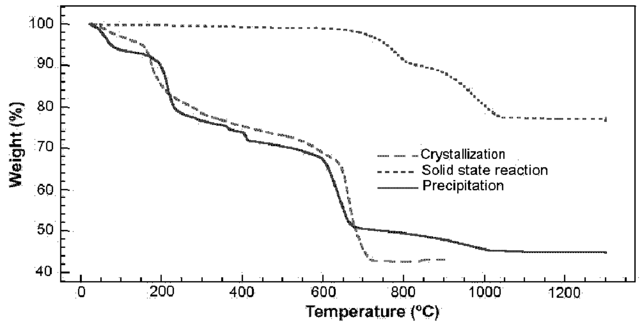

Figure 1. TG curves of the carbonates mixture, the product obtained by precipitation techniques, and the product obtained by crystallization techniques under following dynamic atmosphere (100 mL min^{-1}): H_2 (solid state reaction and precipitation) and O_2 (crystallization), β = 10°C min^{-1}.

Figure 2 shows some thermionic emisson's curves for aluminate obtained by solid-state reaction. These curves represent a typical Schottky plot. Using this plot the saturated emission current at different temperatures can be determined.

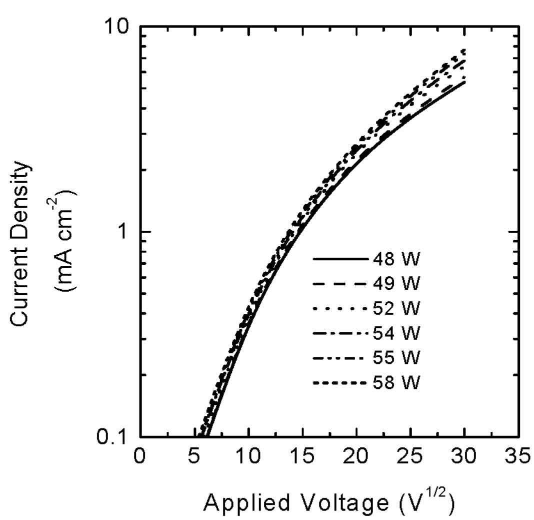

Figure 2. Schottky plots for six different cathode heating powers.

Conclusions

By means of the results presented, it was observed that the crystallization technique showed a better result related to temperature and atmosphere of synthesis.

References

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