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THEORETICAL AND PRACTICAL CONSIDERATIONS CONCERNING THE ARMCO TREATMENT USED TO OBTAIN THE POLAR PIECES FOR THE POWER COAXIAL MAGNETRONE

Petru UNGUR, Mircea GORDAN, Dinu Mircea FODOR, Nicolae CRECAN, Dan CRACIUN, Dumitru UNGUR, Laszlo Csaba BODNAR
Universitatea din Oradea, pungur@uoradea.ro, mgordan@uoradea.ro,
dfodor@uoradea.ro

Abstract:

The paper presents some theoretical and practical considerations concerning the rebaking treatment of the polar pieces from ARMCO, used for the power coaxial magnetrone developed in University of Oradea. After the mechanical processing of the polar pieces, by finishing lathing of the symmetrical equipotential surfaces, it is remaked the iron structure. This operation is usefull to improve the magnetic permeability and it is obtained by strong capillary soldering of the polar pieces to the anodic CuOFHC block inside the electric oven in hydrogen with Ag72Cu eutectic alloy environment. The melting temperature of alloy is 780°C. The process mentioned above replaced with good results the rebaking treatment, known as the Cioffi treatment.

Also is presented in detail the positive influence of the strong soldering physico-chemical process of the CuOFHC ARMCO iron with Ag 72 Cu eutectic alloy inside an electric oven, in hydrogenic environment. This process successfully replaces the Cioffi treatment cycles.

Based on the paper and on the experimental researches developed for a normal working of the coaxial magnetrone can be underlined a conclusion. The electromagnetic conditions that must be fulfilled by the ARMCO polar pieces are:

- opposite polar faces must be symmetrical equipotential surfaces;
- magnetic induction in polar pieces must be smaller then the saturation induction;
- magnetic field from the anode-cathode interaction space must be constant and homogeneous;
- magnetic field force lines, place around the cathode, must be dense and parallel with the cathode axis.

The above mentioned conditions were obtained based on the capillary soldering process of the ARMCO polar pieces, from the CuOFHC anodic block, with Ag 72 Cu eutectic alloy in an electric oven in hydrogen environment. This process has replaced the Cioffi rebaking.

1. INTRODUCTION

To design and develop the vacuum electronic tubes as magnetrons, the polar pieces have two functions. One of the functions concerns the closing of the vacuum space from inside the magnetron and the other focuses the magnetic field lines around and along the cathode [1].

The material used for the lateral polar pieces is ARMCO iron, whose more important properties are: high magnetic permeability, short magnetisation time, minimum coercive magnetic time [1, 2, 3].

To obtain a constant and homogeneous magnetic flux along the cathode, inside the cathode-anode interaction vacuum space, polar pieces must have a magnetic lens role. Because of this, they must have symmetrical equipotential surfaces, which are obtained by mechanical processes.

Because of big ductility of the ARMCO iron, by lathing and mechanical cutting process, the iron crystals superficial layers of the equipotential surfaces are plastic deformed and stressed hardening.

The stress hardening process is followed by the iron particles moving and by the sharpness growing. The result is the growing of the coercive field with 15-20% and also the reducing of the maximum magnetic permeability with 25-30% [5].

In order to improve the magnetic characteristics of the ARMCO polar pieces obtained by mechanical cutting (as for example of the magnetic permeability), the pieces will suffer also a homogeneous rebaking treatment, in hydrogen environment at 880ºC (under Ac_3). This process is known as Cioffi treatment.

In University of Oradea, the authors have applied a kind of Cioffi treatment to the polar pieces of the 800 W magnetron, in parallel with the capillary strong soldering.

$$U_{a_{cr}} = \frac{q}{8m} \cdot r_a^2 \left(1 - \frac{r_c^2}{r_a^2}\right) \cdot B_0^2 \qquad (1)$$

$$U_{a_{pr}} = \frac{?\,n}{n+PN} \cdot \frac{r_a^2 + r_c^2}{2} \cdot B_0 - \left(\frac{?}{n+PN}\right) \cdot \frac{m \cdot r_a^2}{2q} \qquad (2)$$

where:

- $U_{a\,cr}$ - critical power voltage;
- $U_{a\,prr}$ - threshold power voltage;
- m – electron mass;
- r_a – anode interior radius;
- r_c – cathode radius;
- ω - cyclotronic frequency;
- N – resonant cavities number;
- $n = \frac{N}{2}$ - electronic spokes number;
- q – electron charge;
- B_0 – magnetic induction.

Based on equations (1) and (2) and on the graphic in figure 3 results the dependence of the magnetron normal functioning domain on the B_0 (magnetic induction) and on the ARMCO polar pieces symmetrical equipotential surfaces quality.

So, for example, to appreciate the quality of a complete physical process from inside the magnetron can be defined a function Γ, called the magnetron sensibility.

$$G = \frac{?y}{B_0} \qquad (3)$$

G function shows the trajectory of the cathode emitted electron versus the magnetic induction unit, where:

Δy - electron amplitude variation in the case of the magnetron dynamic regime inside the cathode – anode vacuum interaction space [cm];

B_0 - magnetic induction field [Tesla];

A negative deviation from the value of B_0 (0,14 T), for a continuous functioning 800 W magnetron, determines the exit of the magnetron from the functioning domain (figure 3). Critical field magnetic induction is given by the following relation:

$$B_{cr} = \frac{6{,}72 \cdot \mu \sqrt{U_a}}{d} \qquad (4)$$

where:

- U_a –anodic power supply (kV);
- m - magnetic permeability of the environment;
- $d = r_a - r_c$ – distance between the anode and cathode inside the interaction space.

For such a critical value of the induction has to result a constant and homogeneous magnetic field H, having the force lines parallel with the cathode axis (figure 4). This result was obtained using a PC specialized program based on the finite element method.

The growing of the magnetron Γ sensibility can be obtained also using a proper homogenizing rebaking thermic treatment of the ARMCO polar pieces. This treatment is developed at 880ºC (under Ac_3), in hydrogen environment. The result is that the concentration of the iron crystals particles is growing, the equipotential faces superficial sharpness in a diminishing and the polar pieces magnetic permeability is growing.

2. THEORETICAL CONSIDERATIONS

The 800 W coaxial magnetron developed at University of Oradea [1, 2, 3, 4] has a modular construction presented in figure 1.

The scheme contains: *a* – anodic block; *b* – gettering cathode ensemble; *c* – closing inferior lid ensemble; *d* – closing superior lid ensemble; *e* – superior glass case; *f* – inferior glass case; *e* – cooling ensemble.

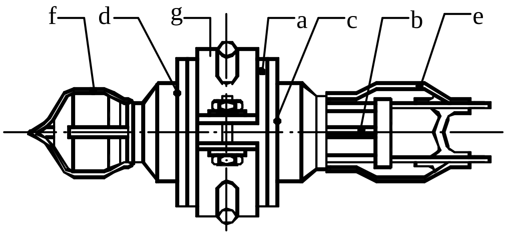

Figure 1 – 800 W coaxial magnetron modular scheme (developed at University of Oradea)

The ensembles closing inferior lid and closing superior lid contain also the ARMCO lateral polar pieces (figure 2).

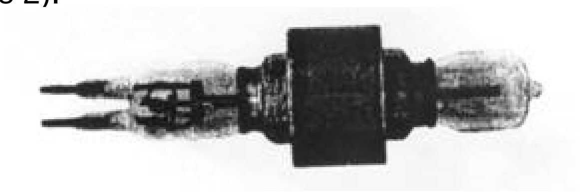

Figure 2 – Magnetron anodic block

It is well known that the magnetron normal functioning and its stability are ensured by the active compounds elements surfaces state, by their physical and chemical properties (as structure and rugosity).

Active surfaces properties are ensured by the correct choosing the main technology and by the correct development of the entire technological process. This way are ensured the optimal items functioning properties of the magnetron active elements and are positively influenced the magnetron functioning parameters.

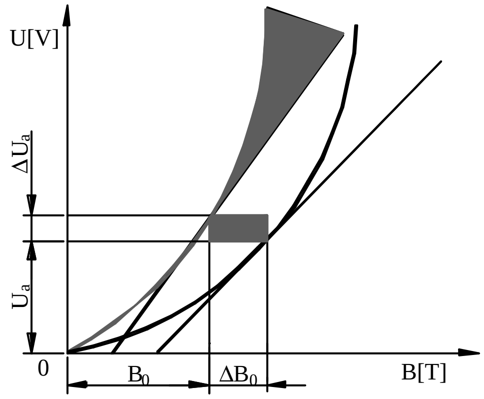

Figure 3 – Magnetron functioning domain

The magnetron optimal functioning domain (figure 3) is defined by the Hall parable equation and by the Hartree line equation [2].

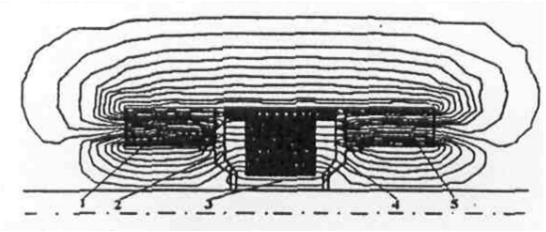

Figure 4 – Magnetic field lines. Axial section of the 800 W magnetron; 1, 5 – assembly; 2, 4 – polar pieces; 3 – interaction space

An ARMCO homogeneous rebaking thermic treatment cycle, known as the Cioffi treatment [5], is presented in figure 5.

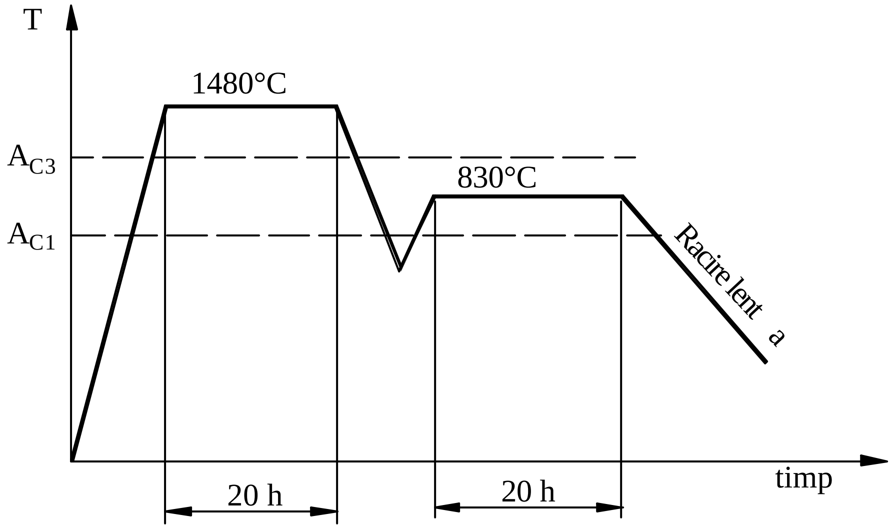

Figure 5 – An ARMCO rebaking thermic treatment cycle, in hydrogen environment

3. PRACTICAL CONSIDERATIONS AND EXPERIMENTAL RESULTS

The 800 W coaxial magnetron have the wave length $l = 12,24$ and f = 24,1 GHz frequency and it is developed at University of Oradea, by the Microwave researching team leaded by prof. eng. Teodor Maghiar, PhD. The magnetron polar pieces are from ARMCO (99,1 Fe + 0,1 I) and have the following magnetic characteristics: B_S = 2,12 T (saturation magnetic induction); $m_i = 0{,}314 \cdot 10^{-3}$ H/m (magnetic permeability); $m_m = 8{,}792 \cdot 10^{-3}$ (maximum magnetic permeability); H_C = 63,66 kA/m (coercive force).

Magnetic induction $\overline{B}$ from the interaction space depends on the exterior magnetic field intensity $\overline{H}$ and on the polar pieces magnetization $\overline{M}$, according to the following relation:

$$\overline{B} = m_0\left(\overline{H} + \overline{M}\right) = m_0\overline{H} + \overline{I} \tag{5}$$

where:

- $\overline{I} = m_0\overline{M}$ is the polar pieces magnetic polarization.

At University of Oradea the Cioffi homogeneous rebaking thermic treatment applied to the ARMCO polar pieces after their mechanical processing, was replaced with a capillary strong soldering. This soldering process is applied to the ARMCO polar pieces, which are vertically soldered on the CuOFHC anodic block in electric ovens, in hydrogen protecting environment, with Ag72Cu eutectic alloy.

The strong soldering process diagram is presented in figure 6. The melting temperature of the Ag72Cu eutectic alloy is about 780ºC. Because of this reason, the processto be soldered will be heated to 850-880°C. This temperature is smaller Ac_3 and it corresponds to the ARMCO Cioffi thermic treatment.

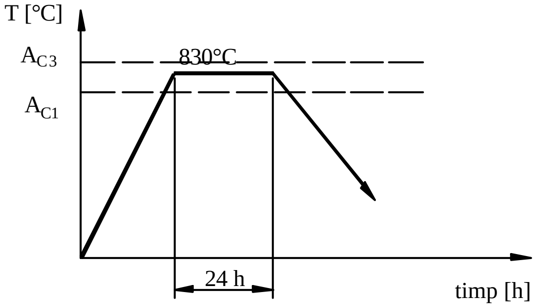

Figure 6 – Soldering process diagram of the polar pieces to the anode

Figure 7 presents a photo of the anodic bloc ensemble, having the polar pieces soldered. Figure 8 presents the soldered structure at a 200:1 scale, obtained by using a PC microscopic image.

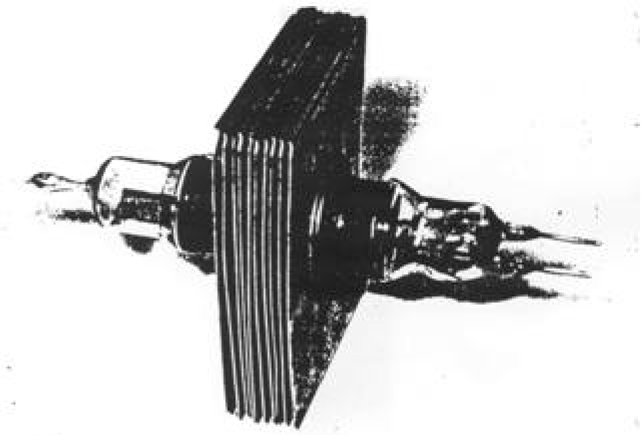

Figure 7 – Anodic block and strong soldered polar pieces photo

Figure 8 – PC microphoto at 200:1 scale

4. CONCLUSIONS

Based on the considerations presented in the paper and on the experimental results obtained for a coaxial magnetron normal functioning, the following electromagnetic conditions (in the case of ARMCO polar pieces) must be fulfilled:

- opposite polar faces must be symmetrical equipotential surfaces;
- polar pieces magnetic induction must be smaller than the saturation induction;
- magnetic field inside the cathode-anode interaction space must be constant and homogeneous;
- magnetic field force lines around the cathode must be dense and parallel with the cathode axis.

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