

Comparative High-Current-Density Emitters Poisoning of Hollow Cathodes Electric Propulsion

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Abstract: Thermoemission properties of cathode materials in ultra-high vacuum and their poisoning at air leaking were studied. Objects of research were hot-pressed cathodes based on barium hafnate with tungsten ($\text{BaHfO}_3 + \text{W}$) and barium scandate with tungsten ($\text{Ba}_3\text{Sc}_4\text{O}_9 + \text{W}$) and also hot-pressed lanthanum hexaboride (LaB_6) and eutectics based on LaB_6 ($\text{LaB}_6 - \text{MeB}_2$, where $\text{Me} = \text{Ti, V}$). The dependences of degree poisoning on residual atmosphere pressure are obtained at different temperatures of studied emitters. Also comparison of degree poisoning at the same value of thermoemission current density $j = 5 \text{ A/cm}^2$ was carried out. Investigation results indicate to a possible effective utilization of hot-pressed emitters on the bases of barium hafnate with tungsten and barium scandate with tungsten in hollow cathodes electric propulsion in oxygen-containing media.

Nomenclature

T	=	temperature
j	=	thermoemission current density
j_m	=	saturation current density
φ	=	electron work function
p	=	pressure

I. Introduction

Demountable vacuum benches are used in the technique of research and experimental updating of the electric propulsions, which include cathode-compensator as a hollow cathode with pressure of residual gases $(1.3-7) \cdot 10^{-3} \text{ Pa}$ and with evacuation by the diffusive steam-oil pumps. The operating mode of such experimental assemblies supposes the frequent interruptions with the practically complete loss of vacuum, what it is not assumed for standard oxide cathodes, which assumed for the durability in several thousand hours. The last circumstances (low working vacuum in chamber and complete revacuumization the switching-off mode) sets developers of hollow cathodes two basic tasks.

The first one is the possibility verification of the utilization as electron emitters, which have been already developed before and applied in the modern devices and arrangements of electronic engineering both hot-pressed cathodes based on BaO , and ones based on individual LaB_6 , and eutectics compositions based on LaB_6 .

The second one is the searching of new emission materials among hot-pressed composition dispenser cathodes, which were already created with subject to concrete specific requirements to the working conditions of hollow cathode.

Solution these tasks under development of hollow cathode with the acceptable durability requires the preliminary attestation of thermoemitteres (specimen-«witness») in the conditions of ultrahigh vacuum. The obtained thermoemission descriptions in such vacuum conditions would serve by the basic «reference» data for the determination of influence degree of the other secondary factors (residual gases pressure in the vacuum chamber, revacuumization et cetera).

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II. Experimental and results

The work objectivities were the following:

- investigation of thermoemission properties of the composition cathodes based on BaHfO_3 with W, $\text{Ba}_3\text{Sc}_4\text{O}_9$ with W, LaB_6 with $\text{Me}^{\text{IV}}\text{B}_2$, where $\text{Me}^{\text{IV}} = \text{Ti, Zr, Hf}$;
- research of cathodes poisoning at leaking of the air;
- comparison poisoning degree of investigated cathodes;
- selection of the emitter composition, which has the highest poisoning resistance.

Experiments were carried out in the flat diode system under pressure $5 \cdot 10^{-6}$ – $1.3 \cdot 10^{-2}$ Pa. The pulse current take-off was used: pulse duration — 5 μs , signal frequency — 0.5–4 Hz, maximum of electric sweeping field intensity — 3.6 MV/m. Volt–ampere characteristics were measured in the temperature range 1050–2150 K after cathodes activation. Measured values of j_m were obtained at such electric field intensity, which corresponded to E near the hollow cathode surface in the arc discharge cathode layer. Then the cathode temperatures and work functions were determined for $j_m = 5 \text{ A/cm}^2$ for all cathodes (see table).

Table

Cathodes temperatures and electron work functions for $j_m = 5 \text{ A/cm}^2$

Cathode	LaB_6	$\text{LaB}_6 - \text{VB}_2$	$\text{LaB}_6 - \text{TiB}_2$	$\text{BaHfO}_3 + \text{W}$	$\text{Ba}_3\text{Sc}_4\text{O}_9 + \text{W}$
$j_m, \text{ A/cm}^2$	5	5	5	5	5
T, K	1760	1630	1630	1405	1415
$\varphi, \text{ eV}$	2,75	2,53	2,53	2,14	2,15

Later emission characteristics were measured for chosen values T from table at air leaking. Results are presented by dependences $j/j_m = f(p)_{T = \text{const}}$ for every cathode on figure, where j/j_m is poisoning degree.

The comparison of poisoning characteristics allows seriously to make a choice of cathode–compensator thermoemission material of plasma ionic propulsion for the concretely accessible vacuum level in the test bench altitude chamber. Usually maximum accessible vacuum under pumping by diffusive steam–oil pumps equals $(1-3) \cdot 10^{-3}$ Pa (until the leaking of working gas xenon).

If it is assumed that used xenon is «chemically» pure and oxygen-containing gases are absent in it, the investigated cathodes, as it is shown on figure, are poisoned at $p = (1-3) \cdot 10^{-3}$ Pa by the oxygen-containing gases only from the residual atmosphere. At pressures $p > 3 \cdot 10^{-3}$ Pa the least poisoned cathodes are LaB_6 and $\text{LaB}_6 - \text{VB}_2$. At $p < 2 \cdot 10^{-3}$ Pa it gives preference to the impregnated cathode based on barium scandate with tungsten.

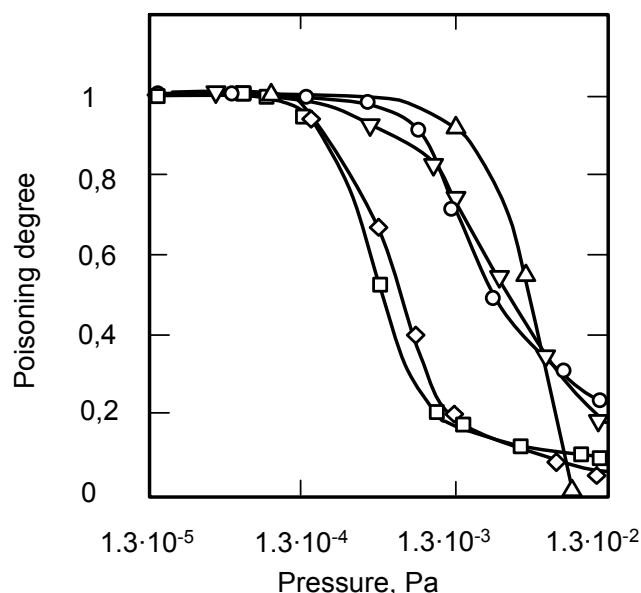


Figure. Poisoning degree as a function of pressure at air leaking.

- – LaB_6 ; ▽ – $\text{LaB}_6 - \text{VB}_2$; □ – $\text{LaB}_6 - \text{TiB}_2$;
- ◇ – $\text{BaHfO}_3 + \text{W}$; △ – $\text{Ba}_3\text{Sc}_4\text{O}_9 + \text{W}$.

III. Conclusion

The obtained experimental results of the pressed cathodes poisoning investigations at a different vacuum level allow to correct cathodes working temperatures T with purpose of decreasing their poisoning. Comparative high-current-density emitters poisoning expands selection possibility of thermoemission material for the hollow cathodes electric propulsion.