General Brief Overview about Carried out Research:

Multistage collector systems with recuperation of exhausted electrons are used in travel wave tubes to reach the higher technical efficiency. In multistage collector systems the secondary electron emission essentially influences on recuperator's efficiency, distribution of a current, temperature and power on electrode's surface. Because of impossibility to achieve the complete absorption of electron beam on the electrodes for the first order secondary electron emission, the correct research of this phenomenon is possible only by taking into account the several orders electron emission. It results to complication of the self-consistent problem and increases number of necessary iterations by charge. The first step is the creation of the method for fast calculation of electric fields of collector systems with recuperation and taking into account the space charge caused by noncompensated charge of exhausted electron beam (first part).

The self-consistent interaction of electron beam with electromagnetic fields of collector system is solved by space charge iteration method in a stationary approximation. For defining electric fields created by an electron beam space charge, the boundary problem for Poisson equation is solved on every iteration. The boundary problem of finding electric fields is broken on two: a homogeneous problem with nonzero boundary conditions and nonhomogeneous problem with zero boundary conditions. The complete solution of the problem is introduced as the sum of the solutions of the two problems. The fields corresponding to a homogeneous task are determined by the induced charges on electrode's surface in conditions of electron beam absence. The solution of the non-homogeneous problem is determined by space charges created by an electron beam. To reduce computational volume and time of the nonhomogeneous solution finding, the Green function matrix is built and stored a special way to reduce the volume of required RAM. Then this algorithm for finding self-consistent electric fields was used for calculation with taking into account secondary electrons. In conjunction several numerical algorithms to compute secondary electron emission contribution of several orders were worked out and applied (second part).

<u>Title:</u>

SECONDARY ELECTRONS' CASCADE MODELLING FOR COLLECTOR SYSTEMS

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<u>Abstract:</u>

In the work we consider a numerical algorithm of computing secondary electron emission (SEE) parameters of several orders for collector systems. A comparison of test simulation results with experimental data is carried out for travel wave tube (TWT) three-stage collector with electron energy recuperation. With the help of numerical modeling it is shown, that taking into account secondary electron emission results to increasing of the current absorption on the collector's first stages and decreasing of recuperation efficiency.

<u>Brief Overview of the Article:</u>

In a presence of SEE absorption of primary electron beam on the collector electrodes is a cascade process of sedimentation and emission of primary and secondary electrons. All secondary electrons were divided on <u>tree energy groups</u>: truly secondary electrons, elastic and inelastic. More detailed structure connected with Oje electrons was not taken into account. Dependencies of SEE coefficients on angles and energies of primary beam were taken from published impirical formulas (<u>from the literature list</u>) in the primary beam energy range from several eV till dozens keV. Number of secondary and primary particles in numerical analysis was about several thousands. Due to this it was possible to use Monte-Karlo method for defining energy and angle of emitted secondary particles. <u>The complete electron beam absorption on the electrodes occurred in a certain number of SEE orders (about 5 or 6).</u>

The comparison of test simulation results with experimental data is presented in the table 1 "The currents in Amperes absorbed by collector electrodes": 1st column –

name of electrodes among them precollector, reflector, stages #1 - #4; 2st column – simulation results without SEE; 3st column – simulation results with taking into account SEE; 4st column – experimental data.

Simulation results without SEE qualitatively differ from the experiment. Taking into account SEE leads to increasing of current absorption on the first collector stages, appearance of inverse current from collector to the slow-wave structure of TWT and decreasing recuperation efficiency coefficient. That is in a good qualitative and quantitative agreement with experimental data. One of the reasons for slight difference between simulations (with SEE) and measurements can be usage of copper SEE characteristics taken from the literature, but not the measured ones for the particular real copper collector electrodes. The characteristics of the real copper material and the quality of the surface were unknown (not measured).

Figure titles' translation:

Fig.1. Coefficients of SEE – δ, η, r, σ for two falling angles of primary beam for copper sample, calculated by formulas (1)-(8): 1 – $\theta = 0^0$; 2 – $\theta = 60^0$;

σ – total SEE coefficient;

r – elastic electrons coefficient: is the ratio of the number of elastic electrons to the number of primary electrons;

η – inelastic electrons coefficient: is the ratio of the number of inelastic electrons to the number of primary electrons;

δ – truly secondary electrons coefficient: is the ratio of the number of truly secondary electrons to the number of primary electrons.

Fig.2. Emission energy probability distribution functions for truly secondary $f_\delta^{(E)}$, elastic $f_r^{(E)}$, inelastic $f_\eta^{(E)}$ secondary electrons for copper sample.

Fig.3. Emission angle probability distribution functions for truly secondary $f_\delta^{(E)}$, inelastic $f_\eta^{(E)}$ secondary electrons for copper sample and different falling angles:

1 – $\theta = 20^0$; 2 – $\theta = 40^0$; 3 – $\theta = 60^0$; 4 – $\theta = 80^0$.

Fig.4. Primary beam trajectories.

Fig.5. Trajectories of secondary electrons of several orders: first order – top and sixth order – bottom.