Surface electron emission model of Ba dispenser cathodes, especially of Ba scandate cathodes

G. Gaertner, consultant, Aachen, Germany; Email: georg.f.gaertner@t-online.de

Abstract

Currently Ba scandate cathodes exhibit the highest emission capability of all thermionic cathodes and are very promising for future applications [1]. They are essentially based on Ba dispenser matrix cathodes modified with differently distributed additions of scandia. High pulsed emission current densities in the order of 100 - 400 A/cm^2 at about 1030 °C true temperature correspond to a very low work function of 1.15 eV for different types of Ba scandate cathodes. Yet the low WF is also accompanied by a low Richardson constant, which could be improved from 2 to 7 [Acm^{-2}K^{-2}], but which is still much lower than the thermionic constant [2]. Hence this feature seems to be consistent with strongly localized emission and could open possibilities for further increase.

At the last conference the peculiarities of Ba scandate cathodes have already been discussed [3] and a model of highly emitting patches superimposed on I cathode type saturated emission surroundings was presented. Yet the emission from ultrafine patches and the space charge cloud around them cannot easily be solved from the Poisson equation in local cylindrical coordinates centered at such a patch. Hence a different approach first introduced by Hasker can be used for model calculations. This is based on the so-called beamlet effect and makes use of the scaling properties of the Poisson equation for space charge. Hasker has shown, that for circular beamlets, where the radius r of the emitting beam area is much smaller than the cathode to anode distance D in a close-spaced diode, the beamlet current density $\mathbf{j_b = (D/r)^{1/2} * j_{Ch}}$ is much higher than expected from the Child-Langmuir equation, but is still space charge limited [4, 5]. This effect was nicely supported by measurements of Free and Gibson of the Ba diffusion length on the surface of controlled porosity dispenser cathodes [6]. In a first step it is shown, that the so-called anomalous Schottky behavior of scandate cathodes in the "saturated region" of the current voltage (I/U) characteristics can be explained by a superposition of the emission of highly emitting Ba-scandate patches still in space charge limitation, with I cathode type saturated emission of their surroundings. This leads to a power law $I = \gamma U^x$, with x being smaller than 1.4 or the respective SCL power, for the "saturation" range of scandate cathodes, which eventually is only a transition range before saturation. In the next step the beamlet effect is used for evaluation of Richardson plot data to estimate the number density and area contribution of the ultrafine Ba-scandate patches. The difference between Ba scandate cathodes on tungsten and on Re bases is discussed.

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