Common principles of Ba and Th dispenser cathodes for high emission applications

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Abstract

Nearly all successful types of thermionic cathodes such as impregnated Ba cathodes, Ba scandate cathodes and thoriated tungsten cathodes are dispenser cathodes, which rely on the continuous supply of a monoatomic surface layer consisting of Ba or of Th. Ba dispenser cathodes typically consist of a porous tungsten matrix, which is impregnated with Ba.Ca.aluminate, f.e. of 4BaO.CaO.Al2O3 composition (the so-called 411 impregnate). During activation and operation a chemical reaction between the tungsten walls of the pores and the impregnate takes place, generating tungstates, aluminates and free Ba, which diffuses over the cathode surface [1,2,3]. Depending on the cathode base coating, which can be W, Os, Ir, Re or a Ba-Scandate, the work function of Ba, typically bound via an O-bridge (surface dipole) to the outermost surface atoms, is lowered by different amounts. Models of this work function lowering will be discussed in the presentation. Thus at operating true temperatures of 1030°C and a typical vacuum pressure of 10^{-9} mb, emission current densities of 3 A/cm^2 to 400 A/cm^2 can be achieved, depending on the nature of the surface coating [1,3].

In the case of thoriated tungsten, it is necessary to carburize the tungsten surface to tungsten carbide, in order to ensure a continuous resupply of monoatomic Th on the surface via the reaction [1]

$2\ W_2C + ThO_2 \rightarrow 4\ W + 2\ CO + Th.$

Th is migrating to the surface via grain boundary diffusion and spreads on the surface via surface diffusion, in order to compensate desorption and evaporation of Th. One can also see, that continuous pumping is needed, e.g. by an ion getter or turbo pump, to avoid gas poisoning by CO. Fortunately the operation temperature of Th-[W]$_c$ cathodes is at about 1600°C, where the poisoning tendency is reduced. At this temperature dc emission of 1.5 A/cm^2 could be maintained for 2000h with cathodes manufactured by PCVD [1,5]. The highest saturated pulsed emission current density of 30 A/cm^2 was obtained at about 1900°C. There is new interest in this cathode type for application in nuclear fusion micro-reactors [6]. Of course there exist further types of dispenser cathodes such as lanthanated Molybdenum (La-[Mo]), consisting of Mo with embedded La_2O_3 particles, or cathodes of tungsten doped with CeO_2, which were not exploited for commercial applications so far, which will be discussed in this context [1].

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