Long-Lived Electron Emitters Stable to Electron and Ion Bombardment

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Electron emitters (cathodes) from Al-based alloys containing 1–3 mass% of Li are studied. Activation regimes of cathodes are optimized and their emission properties, vacuum sublimation, surface sputtering under ionic bombardment are investigated. During the study secondary electron emission of cathodes it was observed that rather high maximum value of secondary electron emission factor ($\sigma_{\max} = 7$) is reached. Special attention is given to discuss the possibility of using aluminum-lithium alloys as cathode materials for gas lasers. For these alloys it was shown that emission layer recovery is found during the surface bombardment by gas ions. It is initiated by the effect of radiation-induced segregation of lithium on alloys surface.

The development of effective electron emitters (cathodes) for electric vacuum and gas-discharge installations is a very serious problem. The exploitation reliability of products mainly depends on the solution of this problem. Based on the requirements that are made for the electronic devices the secondary emission cathodes must have a low value of the first critical potential E_p^1, high σ coefficient of secondary electron emission (CSEE) and stability to the continuous electron and ion bombardment [1]. Under the conditions of intensive bombardment these requirements must be combined with the high thermal and heat conductivity.

In the paper the effectiveness of electron emitters based on aluminum with the admixture of a small quantity of lithium (2–3 mass%) is considered. It is known [2] that to obtain the optimal value of emission quality it is necessary to create the oxide film at the alloy surface. This process goes during the so-called cathode material activation which includes in heating and exposure of it at a definite temperature (as a rule higher than the working cathode temperature). To determine an optimal mode of activation the sample of the investigated alloy was heated at a given temperature for two hours and than measure the dependence of CSEE on the energy of primary (bombarding) electrons E_p. The CSEE measurements of samples was carried out at the temperature of 300 °C. The measurements of CSEE samples proactivated at lower temperatures was carried out at the temperature of activation. The experimental dependence of maximal CSEE value ($\sigma_{\max}$) on the temperature of activation is presented in Fig. 1.

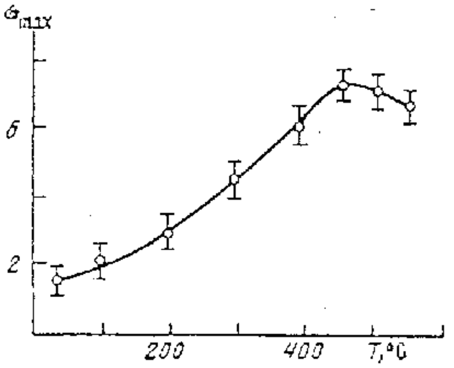

Fig. 1. The dependence of maximal value of coefficient of secondary electron emission of aluminum-lithium alloy Al – 2.2 %Li on the activation temperature

It is stated that the optimal mode of activation is the alloy sample heating for two hours at the temperature of 450 °C. The further activation temperature increase as it is seen in Fig. 1 does not show the significant increase of $\sigma_{\max}$ and at high temperatures more than 600 °C the $\sigma_{\max}$ value decreases. Moreover, in our experiments on sublimation of aluminum-lithium allow it is shown [3] that at such high temperatures the intensive depletion of surface layer by lithium takes place that is why to carry out the activation at these temperatures does not seem to be expedient.

Figure 2 shows the dependences of CSEE on the energy of primary (bombarding) electrons E_p.

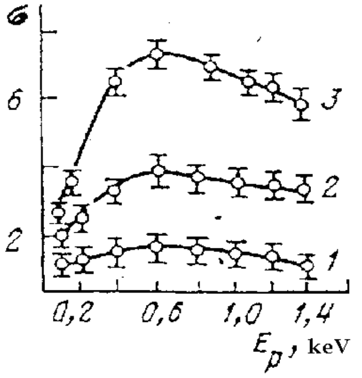

Fig. 2. The dependence of secondary electron emission coefficient on the energy of primary electrons for inactivated and activated samples of aluminum-lithium alloy Al-2.2%Li: *1* – inactivated sample; *2* – inactivated sample, measurement temperature 20 °C; *3* – activated sample, measurement temperature 300 °C. T_a = 450 °C.

The analysis of the obtained dependences showed that the maximal SCEE value ($\sigma_{\max}$) can be achieved at the energy of the primary electrons of ~600 eV. It was also stated that for optimal mode of activation the value of the first critical potential E_p^1 was 15 ± 2 eV. The activation significantly increases the $\sigma_{\max}$ value and with the measurement temperature increase it grows more. Probably, at the increased temperatures the processes of lithium output to the surface and oxide film reconstruction which was destructed under the influence of electron bombardment intensify.

So it was shown that the aluminum–lithium alloys are effective electron emitters with high secondary emission qualities. At that a rather high value of the secondary electron emission coefficient ($\sigma = 7$) can be achieved at a comparatively low energy of primary electron $E_p = 600$ eV. The very important advantage at the aluminum-lithium alloy application as a secondary-emission cathode is a rather low activation temperature and exploitation.

The second direction of effective emitter development made of aluminum-lithium alloys is their possible application as materials of cold cathodes for gas lasers. The main requirements to the cathode materials of gas lasers are the following: high emission qualities, durability according to the ion bombardment (first of all low scattering) and long-lasting quality stability.

Gas laser pumping is carried out due to the glow discharge in the active environment. The discharge is supported by electron emission from the cold cathode caused mainly by ion bombardment of its surface. The cathode material scattering under the influence of ion bombardment leads to its emission quality change what causes the instability of normal cathode voltage drop and also of other parameters which determine the installation efficiency. The reason of the undesirable consequences can be the deposition of atoms knocked out from the cathode surface to the surrounded it device details.

The cathode of modern gas lasers with inertial filling material particularly helium-neon ones work under the conditions of low pressures of gas mixture ($P = 90–500$ Pa) and high values of current density ($j = 0.1–0.2$ MA/cm^2). At that the factor of increased cathode durability in relation to the ion scattering of its surface is especially important exactly for helium-neon lasers which work under the conditions of low gas mixture pressure (unlike to nitrogen and CO_2 lasers for which $P \sim 2.7 \cdot 10^3$ Pa).

The carried out comparative tests of life duration of several cathode materials (aluminum, duralumin D16T, alloy Al–2.5%Li, beryllium) under the conditions which simulate the exploitation ones (the focusing mode of helium–neon plasma influence with particle flux density of $6 \cdot 10^{15}$ cm$^{-2} \cdot$s^{-1}) showed the perspective of aluminum–lithium alloy application as cold cathodes for helium–neon lasers.

The cathode made of aluminum–lithium alloy showed a rather high durability comparable to beryllium durability and approximately increases by 4 times the aluminum durability. The increased effectiveness of aluminum–lithium cathodes can be explained by the formation and continuous renovation due to the effect of radiation induced segregation of lithium film at the alloy surface in the process of long radiation [4]. In the result of the carried out tests and subsequent evaluations of the predictable life time the following was stated: at current density of 0.15 MA/cm^2 in the helium–neon mixture with the pressure of 400 Pa the electron emitter on the bases of aluminum-lithium alloy should not change its parameters for 10^5 hour.

References

[1] G.G. Bondarenko, A.P. Korzaviy, V.I. Cristya, V.V. Prasitskiy, Metals, No. 6, 83–87 (1994).

[2] L.N. Dobretsov, M.V. Gomoyunova. *Emission Electronics*, Moscow, Nauka, 1966, 564 pp.

[3] G.G. Bondarenko, L.I. Ivanov, S.I. Kucheryaviy, Physics and Chemistry of Material Treatment, No. 4, 93–95 (1987).

[4] G.G. Bondarenko, Materials Science Forum **97–99**, 695–718 (1992).