THEORETICAL CALCULATION OF THE INTERNAL POTENTIAL BARRIER FOR THE METAL/ SEMICONDUCTOR FILM STRUCTURE

Lyudmyla G.Il'chenko[1] and Vasyl V. Il'chenko[2]

[1]Institute of Surface Chemistry NAS of Ukraine, Generala Naumova st.17, Kiev, 03164,

[2]Radiophysical Dept., Kiev University, Volodimirska st. 64, Kiev, 02033, **UKRAINE**

ABSTRACT

The layered cathodes are considered as perspective materials for the field emission devices. The theoretical solution in the framework of nonlocal electrostatics taking into account the space dispersion effects in the metal and dielectric film has been found. The decreasing of the external potential barrier for the electrons emitted from the diamond film can stimulate the lowering of the threshold voltage of the cold field emission for the layered cathodes.

1. INTRODUCTION

Recently the layered cathodes are considered as perspective materials for the field emission devices. It is known, that the deposition of semiconductor (metallic) coatings on a surface of the metal (semiconductor) results in a significant modification of the emission characteristics of a baseline material. The emission properties of ultrathin films are expected to deviate from those of the corresponding bulk materials [1] and can not be predicted simply on the basis of their bulk structure.The influence of the potential barrier to an inner interface on the performances of the layered cathodes was investigated in [1-3].

II. THEORETICAL CONSIDERATION

In this work we propose the theoretical method of the direct calculation of the potential barrier $V(x,F)$ for the metal/thin semiconductor film intimate junction based on the account of screening properties of the metal and semiconductor in the framework of nonlocal electrostatics. It is shown that the potential barrier on the internal metal/semiconductor film interface can be theoretically calculated without introduction of the additional parameters. For the system in the current regime in result of contact the common electronic subsystem is formed (the common Fermi level of the metal and semiconductor film). The potential barrier height $h(L)$ on the internal interface is determined by the contact potential $\Delta\Phi$ and by the screening properties of the metal and semiconductor film with thickness L.

In the present work we consider the n-type semiconductor film on the metal substrate: thin heavily doped diamond film (n-type) on the molybdenum, when the electrons emit from the diamond film into vacuum. The screening properties of the metal (Mo) was taken into account in Thomas-Fermi approximation (TFA). The screening properties of the semiconductor film $\varepsilon_2(\vec{k})$ was taken into account in Deby-Hukel approximation (for a nondegenerate electron gas) and in the interpolation Inkson model (for the bound electrons of ion islands).

On the Fig.1 the potential $V(x,F)$ for the considered system, when $L = 15\,\overset{o}{A}$, in the external electrical field $F = 3.10^7\ V/cm$ (solid curve 1) and $F = 6\cdot 10^7\ V/cm$ (solid curve 2) is shown. The following paramrters were used: temperature is $T = 293°\ K;$ for the molibdenum: $n_1 = 4\cdot 10^{22}\,cm^{-3}$ is the concentration of the electrons; $\varphi_{met} = 4.6eV$ is the work fuction and $m^* = 0.7759m_0$ is the effective mass, m_0 is the mass of the free electron; for the diamond film (*n*-type): bulk density of

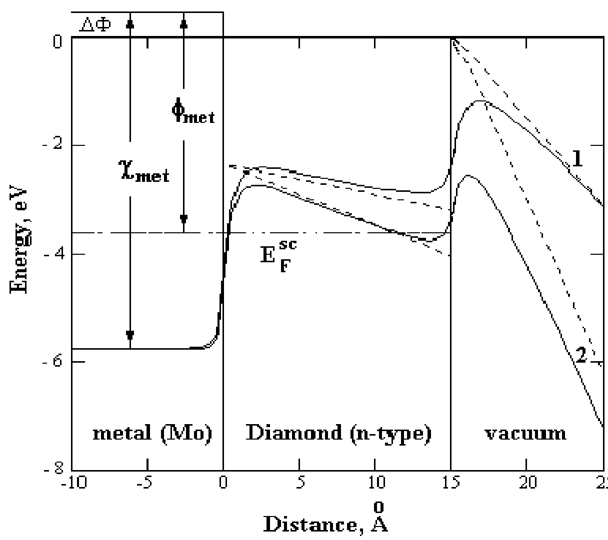

Fig. 1

the free electrons is $n_2 = 5\cdot 10^{17}\,cm^{-3}$; dielectric constant is $\varepsilon = 5.6$; effective masses are $m_\perp = 0.36$ (transverse) and $m_l = 1.4$ - (parallel); electron affinity in the bulk is $\chi = -E_c = 3.34eV$, where E_c is the bottom of the conduction band. [4].

In the case of intimate contact the thickness of the double electrical layer on the internal interface d is about one lattice constant (or close it). In our calculations the thickness of the double electrical layer is $d = 2\,\overset{\circ}{A}$. For the above mentioned parameters the charge density $\sigma(L)$ on the internal interface is $\sigma(15\,\mathring{A}) = 2.276\cdot\ 10^{13}\ {}^{e}\!/\!{}_{cm^2}$, the contact potential is $\Delta\Phi = 0.985 eV$ and the potential barrier height (without the image forces lowering) is $h(L) = 1.316 eV$. It was shown, that the potential barrier height $h(L)$ essentially depends on the thickness L and the doped concentration n_2 of the diamond film and is very sensitive to the preparation conditions.

The appropriate dotted curves in Fig.1 show the distribution of the potential $V(x,F)$ in the considerd structure calculated in the framework of the local (classical) consideration.

III. CONCLUSION

As shown in our preliminary calculations the existence of the superthin heavily doped diamond coats on the metal surface brings to the significant downturn of the external potential barrier in comparison with the clear metal surface. This decreasing of the external potential barrier for the electrons emitted from the diamond film can stimulate the lowering of the threshold voltage of the cold field emission for the layered cathodes.

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