Charge Relaxation and Gain Depletion for Candidate Secondary Electron Emission Materials

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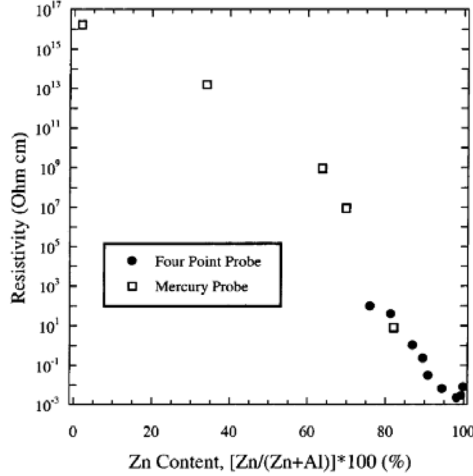

Fig. 1. Resistivity of ZnO/Al2O3 alloy films measured using the four point probe and the mercury probe [1].

ZnO/Al_2O_3 alloy films were prepared using ALD (atomic layer deposition) techniques. By adjusting the ALD pulse sequence, the ZnO/Al_2O_3 alloy film composition was varied from 0-100% ZnO [1]. Fig. 1 shows resistivity of ZnO/Al_2O_3 alloy films that was used in this work.

Materials constants and physical properties of such alloy films, such as surface roughness, resistivity, dielectric constants, film thickness were obtained to be suitable for using these materials as resistive and emissive layers in large-area photo-detecting MCP (multichannel plates), as compared to conventional glass substrates.

Charge relaxation and gain depletion mechanisms, effects of a strong electric field, geometry parameters of coating for a large area fast photo-detectors were analyzed and discussed [2].

A new ambipolar solid state plasma drift-diffusion model of the charge relaxation in such materials as ZnO/ Al_2O_3 in various combination of the content was proposed that included generation of electrons and holes via impact ionization due to acceleration in a strong electric field [3]. Some of the equations of this model are given below [4-7]:

$$\vec{J}_e = eD_e \nabla N_e + e\mu_e N_e \vec{E},$$

$$\vec{J}_h = -eD_h \nabla N_h + e\mu_h N_h \vec{E},$$

$$div\, \vec{E} = \rho / \varepsilon\varepsilon_0 , \rho = N_h - N_e,$$

$$\frac{\partial N_e}{\partial t} = \frac{1}{q} \nabla J_e = D_e \Delta N_e + eN_e \mu_e / \varepsilon\varepsilon_0 (N_h - N_e) + G_{ii},$$

$$\frac{\partial N_h}{\partial t} = -\frac{1}{q} \nabla J_h = D_h \Delta N_h - eN_h \mu_h / \varepsilon\varepsilon_0 (N_h - N_e),$$

$$\mu_{e,h} = \sigma_{e,h} / e\, N_{e,h}, \;\; D_{e,h} = \mu_{e,h} k_B T / e.$$

Here e is the elemental charge amount ($e > 0$), $D_{e,h}$ are the diffusion coefficients, and $\mu_{e,h}$ are the mobilities of electrons and holes at temperature T created by electron impacts and ionization in the space charge field, G_{ii}. The Einstein relationship between the diffusion coefficients and the mobilities $D_{e,h}=\mu_{e,h} k_B T/e$ allows to use the electric-field-dependent diffusion coefficients; $N_{e,h}$ are the corresponding carrier densities. $J_{e,h}$ are the fluxes of carriers.

The following conductivity of *AZO* film with 20% Al was used: $\rho = 10^7$ (Ω cm). The diffusion coefficients of amorphous alumina are unknown. Therefore, we found the diffusion coefficients of alumina via alumina carrier mobilities that are given for some limited mixture content in Ref. [8]. Assuming linear dependence between conductivity and mobility, mobility of a mixture Al_2O_3+ZnO was extrapolated from low to high Al-content.

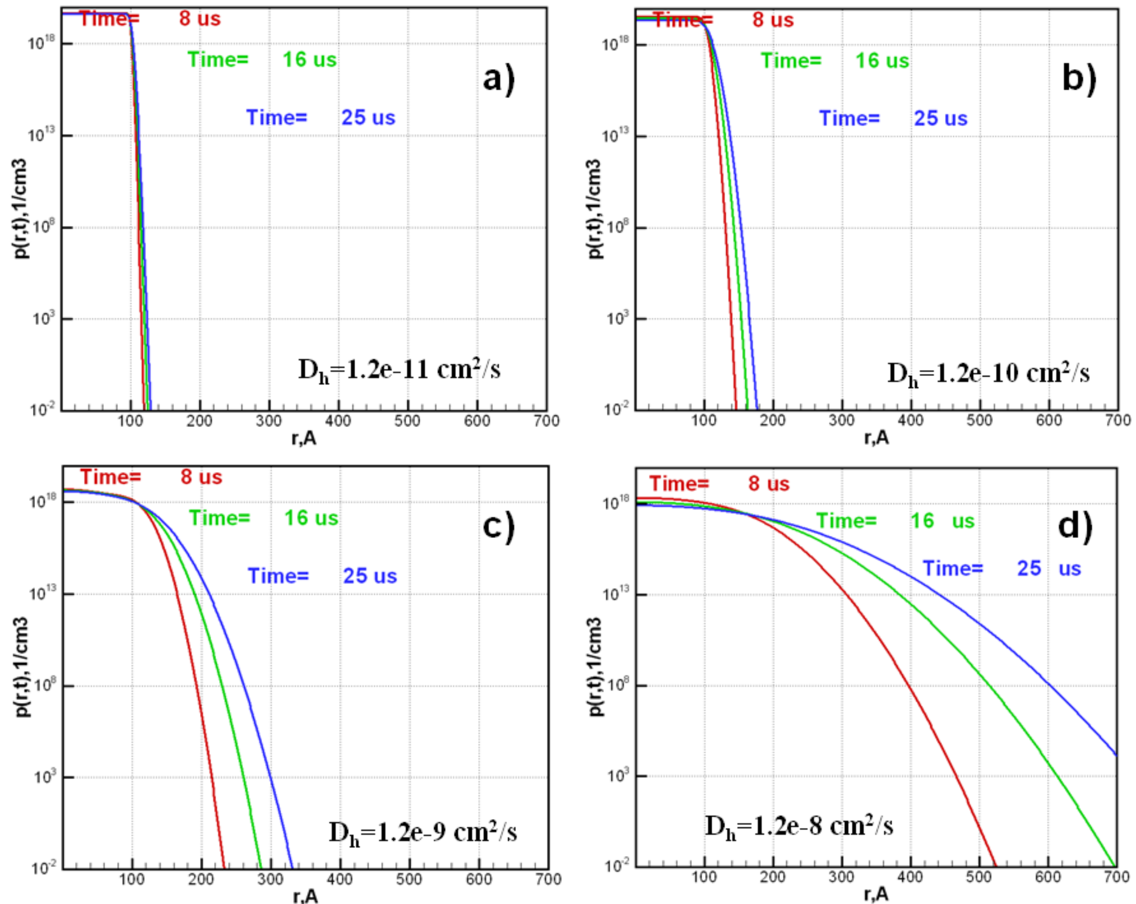

Fig. 2. The results of our calculation via the drift-diffusion model in spherical geometry, with the diffusion coefficients shown in the plots: a) 1.2×10^{-11}, b) 1.2×10^{-10}, c) 1.2×10^{-9}, and d) 1.2×10^{-8} cm^2/s.

The calculated results were compared to the results of a simple Maxwell relaxation time model and with the circuit charge relaxation model developed for the MCP device [9]. A pump-probe experiment has been discussed that will be capable of measuring charge relaxation time, and to clearly demonstrate gain depletion [10]. It is based upon the attenuation of pulses traveling along a microwave strip line on an MCP beyond that due to normal resistive losses [11].

References:

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