

Analysis of materials for protective layers in AC PDPs.

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Abstract

To clarify processes responsible for improved characteristics of protective layers (e.g. SrCaO) the ion-induced electron emission and photoemission from these layers were analyzed. Additionally, a study of ternary Mg-, Ca-, Ba-based compounds as candidate materials for a protective layer of Plasma Display Panels has been performed as well.

1. Introduction

In the world of Plasma Display Panels (PDP) many important parameters like power consumption, luminescence efficiency and panel lifetime depend on the properties of a protective layer of a PDP discharge cell. For many years MgO is used as a material for the protective layer due to its good electron emission properties and resistance against ion sputtering. In recent years a lot of efforts were invested in improvement of MgO layer quality as well as in search for new protective layer materials with higher ion-induced electron yield. [1-2]. Recent highlights in this area include Crystal Emissive Layer (CEL) [3] and SrCaO protective layer [4]. The goal of our study was to clarify processes responsible for improved characteristics of protective layers (e.g. CEL, SrCaO) by analysis of the ion-induced electron emission and photoemission from these layers. Additionally, several ternary Mg-, Ca-, Ba-based compounds were tested as candidates for a PDP protective layer by measuring the firing voltage (FV). Alkaline earth oxides are known to have a high ion-induced electron emission but they are very reactive with respect to ambient H₂O and CO₂. To minimize contamination by H₂O and CO₂, ternary compounds were used.

2. Experimental

Two types of substrates were used for deposition of protective layers. Si wafers (p-type) from Siltron Inc. were used in studies of the ion-induced electron emission and photoemission. Special glass plates were used for measurements of the firing voltage (FV). MgO protective layers (~700 nm thick) were deposited by Electron Beam Deposition (EBD) from polycrystalline MgO pellets. The films were polycrystalline with (111) texture and column-like grains, typical for PDPs. Non-MgO protective layers, used in our study, were deposited by Pulsed Laser Deposition (PLD) from polycrystalline pellets of corresponding materials. A KrF excimer laser (wavelength 248 nm, pulse energy 150-350 mJ) was used for PLD. All PLD films were amorphous and around 100 nm thick. CEL samples were prepared by spraying a mixture of an MgO powder in alcohol onto Si substrates and subsequent drying in a vacuum

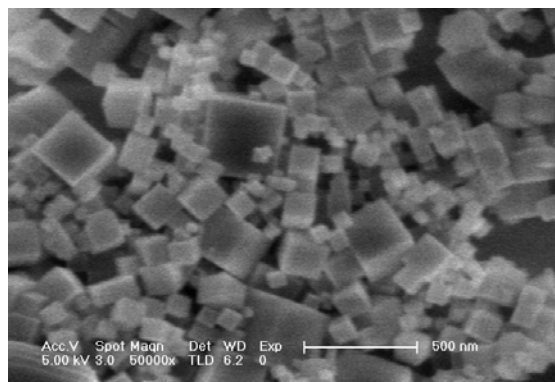


Fig. 1. SEM image of the surface of a CEL sample.

oven at elevated temperature. In Fig.1 a SEM image of a typical CEL sample is presented.

A Pulsed Ion Beam (PIB) method was used to measure the ion-induced electron emission coefficient, γ . The set-up consisted of an ion source, sample holder and electron collector. The basic pressure during the measurements was 3×10^{-8} Torr. Prior to the γ measurement all samples were cleaned (aged) by cycles of sputtering with Ar^+ beam (1keV, 1.8 μA , $\sim 1\text{cm}^2$) and annealing at 300 $^\circ\text{C}$. A detailed description of the method was presented elsewhere [5].

Photoemission was measured in the following way. UV emission was produced by Hamamatsu L937 series UV lamp with the strongest emission line at 254 nm (4.89eV). The surface of a tested sample was exposed to UV photons through a transparent Al_2O_3 window. Emitted photoelectrons were collected by an electron collector and resulting current was measured by a picoamperimeter.

3. Results and discussion

The results of measurements of coefficient γ are presented in Fig. 2 and Fig. 3, where the dependences of the coefficient γ on the primary energy of incident Ne and Xe ions are shown for MgO, SrCaO and CEL layers cleaned for 300 min by Ar sputtering.

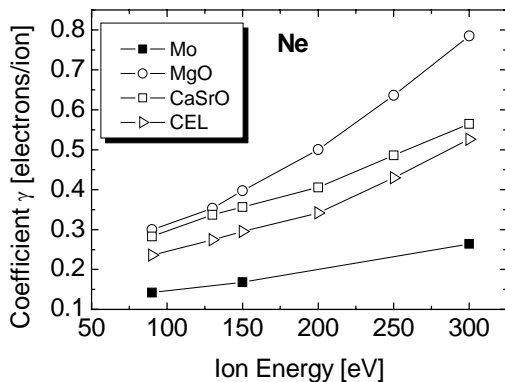


Fig. 2. The dependence of the coefficient γ on the primary energy of Ne^+ ions incident on different protective layers. Mo is a reference.

The electron emission for ions with kinetic energy below 100 eV is dominated by potential electron emission, mainly due to Auger neutralization of incident ions, and is considered to be the most

relevant for PDP discharges. In case of Ne ions, the coefficient γ below 100 eV is almost the same for MgO and SrCaO while it is somewhat smaller for CEL. At 90 eV $\gamma_{\text{Ne}}(\text{MgO})=0.30$, $\gamma_{\text{Ne}}(\text{SrCaO})=0.28$ and $\gamma_{\text{Ne}}(\text{CEL})=0.24$. For Xe ions, the coefficient γ below 100 eV is the same for MgO and CEL while it is bigger by $\sim 50\%$ for SrCaO. At 90 eV $\gamma_{\text{Xe}}(\text{MgO})=0.016$, $\gamma_{\text{Xe}}(\text{SrCaO})=0.023$ and $\gamma_{\text{Xe}}(\text{CEL})=0.015$.

In a gas discharge of mixed Ne and Xe gases, the role of the coefficient γ for Xe ions increases when Xe content in a gas mixture increases. This is related to a lower ionization potential of Xe atoms. As a result, at a high Xe content the number of Xe ions in a discharge is much higher compared to Ne ions. From our analysis it follows that SrCaO protective layer has a better electron emission properties for Xe ions. It is more suitable for gas discharges with high Xe concentrations. In case of CEL, the coefficients γ for Ne and Xe ions do not exceed the corresponding coefficients γ of MgO. It means that good discharge characteristics of protective layers with CEL are not related to the ion-induced electron emission.

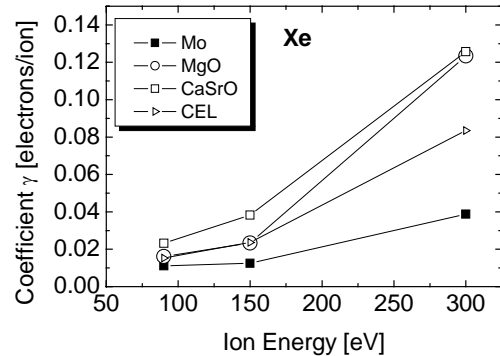


Fig. 3. The dependence of the coefficient γ on the primary energy of Xe^+ ions incident on different protective layers. Mo is a reference.

In Fig. 4 the dependence of photoelectron current from the same MgO, SrCaO and CEL layers on UV exposure time is presented. A low energy of UV photons (4.89eV) allows us to probe filled states in the band gap of studied layers. The band gap of MgO is around 7.6 eV [6]. SrCaO has a smaller band gap. We did not measure its value for the tested SrCaO protective layers. We estimate it to be between the band gap of CaO (7.0 eV) and SrO (5.9 eV) [7].

The energy of UV photons is smaller than the band gap of the tested materials. These materials are essentially transparent for the UV photons of 4.89 eV.

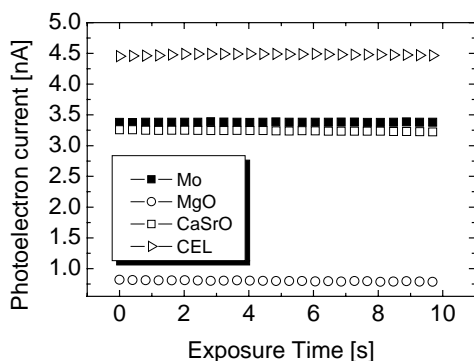


Fig. 3. The dependence of the photoemission current on the UV exposure time. Mo is a reference.

Photoemission, caused by these photons, is related to filled states, that lie less than 4.89 eV below the vacuum level in the band gap of the studied materials. Taking into account the electron affinity of the materials, kinetic energy of the emitted photoelectrons will not exceed ~4 eV. The mean escape depth of electrons with such energies is around several nm. Only photons absorbed in this very thin surface layer will contribute to a measured photoemission current. Photons absorbed in deeper layers will contribute to the photo-induced conductivity. Usually absorption of UV photons increases when the band gap of a material decreases. It means that CaSrO films should have a higher photoemission compared to MgO films. It was confirmed by our experiments. Surprisingly, the photoemission from CEL was very high exceeding the photoemission for Mo and SrCaO. It should be stressed that the value of the photocurrent of CEL, presented in Fig. 4, is one of the highest among tested CEL samples. There was a substantial deviation in photoemission current for different CEL samples. Nevertheless, photoemission of CEL samples always was higher compared to MgO films.

In Table 1 the firing voltages for some Mg-, Ca-, Ba- based compounds are presented. The discharge cell used for these tests consisted of two identical glass plates with circular silver electrodes covered by SiO₂-PbO-B₂O₃ dielectric (35μm) and a tested film. The glass plates were separated by a 120 μm quartz spacer. FV was measured in 350 Torr Ne-10%Xe

TABLE 1. The applied voltages U_a and the calculated firing voltages FV for different ternary compounds.

Sample	U_a, V_{eff}	FV, V
BaGa2O4	171.76	257.7
C12 A7	185.32	246.6
MgGd2O4	161.59	216.9
BaY2O4	155.94	210.3
MgO	123	175.5

mixture using 2kHz sine waveform voltage. It is easy to see that FV of MgO is more than 35 V lower compared to other compounds. BaY2O4 has the lowest FV among the tested ternary compounds.

4. Summary

Analysis of both the ion-induced and photon-induced electron emission from SrCaO and CEL revealed that good discharge properties of CEL are most likely related to the increased photoemission from CEL while for SrCaO a higher coefficient γ for Xe ions probably plays more important role. Unlike alkaline earth oxides, the tested ternary compounds with Mg, Ca and Ba showed much higher FV than MgO.

5. References

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