

## Effect of Sc doping on the electron emission properties of an MgO protective layer.

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### Abstract

*Study of the ion-induced-, photo- and exo-electron emission from a Sc doped MgO protective layer has been performed. It is established that doping with Sc increases photo- and especially exo- electron emission from MgO films while the ion-induced electron emission coefficient  $\gamma$  stays unchanged.*

### 1. Introduction

A protective layer of a discharge cell of a plasma display panel (PDP) plays an important role in an overall performance of the panel. It is well established that the quality of the protective layer has a strong influence on several parameters including the firing voltage of PDP discharge cells and panel lifetime. Currently MgO is used as a material for the protective layer. It has good electron emission properties and resistance against ion sputtering. A lot of efforts were invested in improvement of MgO layer quality and in search for new protective layer materials with higher ion-induced electron yield [1-2]. One of the methods to improve properties of MgO layer is an intentional doping of different elements to MgO. Many chemical elements were tested including usual impurities of MgO (Al, Si, Ca), transition metals (Fe, Cr, Ti), rare earth metals (La, Gd) and many others [3-4]. In this paper we present results of study of electron emission properties for Sc doped MgO. Sc was chosen due to its positive effect on the firing voltage and the delay time of a discharge [5]. To the best of our knowledge, this is the first attempt to study the influence of Sc doping of an MgO layer on its electron emission properties when ion-induced-, photo- and exo-electron emission are measured for the same sample in one experiment.

### 2. Experimental

Undoped and Sc doped MgO protective layers were deposited by Electron Beam Deposition (EBD). As targets for EBD, MgO polycrystalline pellets (undoped and doped with Sc) were used. Si wafers were used as substrates for the layers. The MgO film thickness was around 700 nm in both cases. The MgO films had a polycrystalline, column-like structure with (111) preferential orientation of MgO crystallites.

A Pulsed Ion Beam (PIB) method was used to measure the ion-induced electron emission coefficient,  $\gamma$ . The set-up consisted of an ion source, sample holder and electron collector. The basic pressure during the measurements was  $3 \times 10^{-8}$  Torr. Prior to the  $\gamma$  measurement all samples were cleaned (aged) at 300°C by sputtering with Ar<sup>+</sup> beam (1keV, 1.8 $\mu$ A,  $\sim 1\text{cm}^2$ ) for 240 minutes. A detailed description of the method was presented elsewhere [6].

For photoemission measurements, UV photons were produced by Hamamatsu L937 series UV lamp with the strongest emission line at 254 nm (4.89eV). Such a low energy of photons allowed us to probe filled states in the band gap of studied layers. A more detailed description of the method was given in [7].

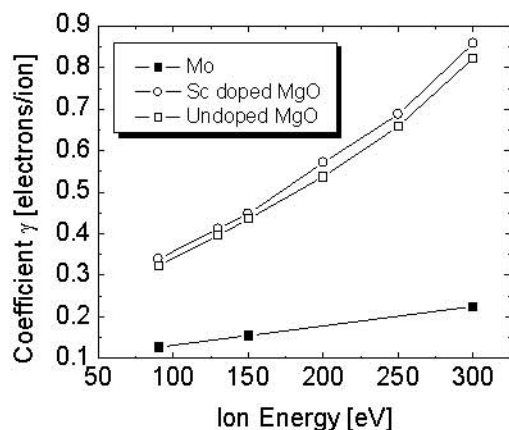
Exo-electron emission of the samples was measured in a following way. Prior to the measurements, undoped and Sc doped samples were exposed for 5 minutes to VUV light of Hamamatsu L8998 series VUV lamp with the strongest emission line around 160 nm (around 7.77eV). The photon energy is very close to the band gap of bulk MgO. Thus, photons of such energy create electron – hole pairs in MgO films. During VUV excitation, the samples were kept at positive voltage of +20V with respect to the vacuum chamber walls. This voltage blocked photoelectron

emission from the samples and attracted photoelectrons from the vacuum chamber walls to minimize the surface charging of the samples. The delayed electron emission was measured 15 s after the VUV source had been switched off. It was measured by an AMPTEKTRON MD-502 electron detector in an electron counting mode. The samples were grounded during the exoelectron emission measurements. The VUV excitation and the delayed (exo-) electron emission measurements were carried out at room temperature.

For each sample, all measurements of ion-induced-, photo- and exoelectron emission were carried out in the same vacuum chamber without breaking the vacuum.

### 3. Results and discussion

The results of measurements of coefficient  $\gamma$  are presented in Fig. 1.

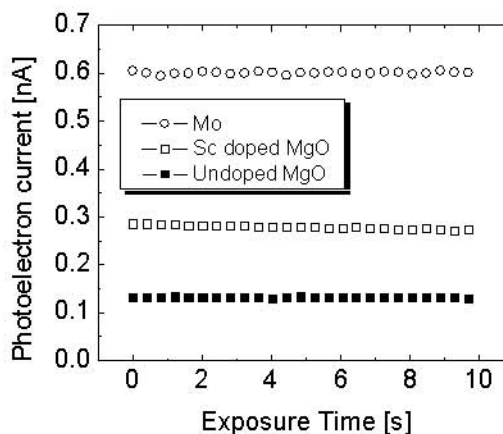


**Fig.1.** The dependence of the coefficient  $\gamma$  on the primary energy of  $\text{Ne}^+$  ions incident on different protective layers. Mo is a reference.

From Fig.1, the difference in the coefficient  $\gamma$  for Sc doped and undoped MgO is very small (<5%) at different energies of primary ions. It indicates that both films have nearly identical electron emission by Ne ions. In case of Xe ions the curves were almost identical too (data are not presented here). Ion-induced electron emission properties of MgO are not strongly affected by a weak doping (<0.5mol%) used in our experiment. This is related to a small number of defects induced by a weak Sc doping, so that main contribution to a total electron emission under

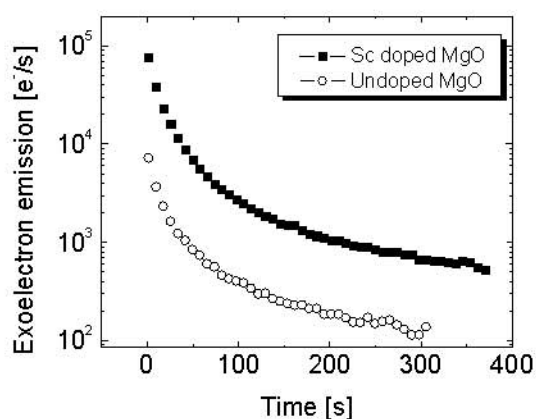
exposure to ions is determined by a much bigger number of regular MgO sites.

In Fig. 2 the dependence of photoelectron current from the same undoped and Sc doped MgO layers on UV exposure time is presented. In case of photoemission, the difference between undoped and Sc doped films is substantial. For the samples tested, photoemission for the Sc doped film is approximately two times higher than for the undoped one. Electrons, emitted by 4.89 eV photons in the photoemission experiments, correspond to filled states in the band gap of the studied samples. Our data indicate that Sc doping creates or promote formation of additional defect states in an upper part (the electron binding energy <4.89eV) of MgO band gap. Nature of these defects is currently not clear and needs additional study.



**Fig. 2.** The dependence of the photoemission current on the UV exposure time. Mo is a reference.

In Fig. 3 the dependence of delayed electron emission on time is presented. Intensity of the delayed electron emission decreases very fast (note a logarithmic scale of the plot). Our attempt to fit the curves with one or two exponential decay functions was not successful. When logarithmic scale is used, an exponential decay function looks as a straight line on a plot. For the curves measured, only a tail of each curve ( $t > 200\text{s}$ ) can be approximated by a single exponential decay function, while for an initial part of each curve a hyperbolic function gives a better fit. We used a hyperbolic function  $N(t) = A/(1+Bt)^2$ , where  $N(t)$  - an electron emission count rate,  $t$  - time,  $A$  and



**Fig. 3.** The dependence of delayed electron emission intensity on time. VUV excitation was switched off at  $t = -15$  s.

B – fitting constants. Thus, we were able to obtain a good fit for the curves of Fig.3 when a fitting function  $N(t) = A/(1+Bt)^2 + C \exp(-t/t_0)$  was used, where C and  $t_0$  are fitting parameters for the exponential decay function. It should be mentioned that we were not able to fit each curve by the hyperbolic function only, even when more general form of a hyperbolic function  $N(t) = A/(1+Bt)^P$  was used, with P – a fitting parameter. This complex structure of the fitting function may indicate presence of at least two relaxation processes with different relaxation times in VUV excited MgO. In [8] another relaxation channel – thermoluminescence – was considered. From this paper, a hyperbolic (second-order) or an exponential (first-order) dependence of thermoluminescence intensity on time is determined by competition of recombination and re-trapping of electrons and holes. If re-trapping dominates, than the hyperbolic (second-order) kinetics is observed. If re-trapping is negligible, than the exponential (first-order) kinetics is present. Similar behavior may be expected from exoelectron emission, where an electron (instead of a photon) is emitted during recombination process.

From Fig.3, exoelectron (delayed) electron emission from the Sc doped MgO film is approximately 10 times higher compared to the undoped MgO. The Sc doped sample also shows a slower exoemission decay in time. Our data suggest that doping has a very strong effect on exoelectron emission of MgO, excited by VUV light with wavelengths around 160 nm. It should be stressed that excitation of MgO by 254 nm UV photons did not result in any exoelectron emission.

#### 4. Summary

Several approaches to improve properties of an MgO protective layer are used by modern R&D groups. They include development of different deposition methods (sputtering, CVD, sol-gel), multi-layered structures and doping of MgO source. Doping of MgO has an advantage of relative simplicity. Our study demonstrated that an important effect of doping is related to a strong change in exoelectron emission from doped MgO. In case of Sc doping, exoelectron emission rates are around 10 times higher if compared to undoped MgO. For other doping elements the value of this effect may be smaller or bigger. It also depends on concentration of a doping element, as was indicated by our tests of Sc doped samples with different Sc content. Sc doping slightly increases number of filled electron states in the band gap of Sc doped MgO film, as revealed by photoemission measurements. The nature of these states is unclear from our experiments but they are probably responsible for the increased exoelectron emission of the sample. The ion-induced electron emission does not change much in a case of weak doping (<0.5mol%) which is used in our experiments. The complex approach, used by us, allows to study correlations between doping and electron emission properties of MgO films. This approach is based on measurements of ion-induced, photo- and exoelectron emission for the same sample in one experiment.

#### 5. References

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