Measurement of Energy bands of the MgO Layer in AC-PDPs

S. J. Jeoung, H. J. Lee*, C. G. Son, J. H. Kim, E. Y. Park, Y. J. Hong, N. L. You, S. B. Lee, Y. G. Han, S. H. Jeoung, K. B. Song, M. W. Moon, P. Y. Oh and E. H. Choi

Charged Particle Beam & Plasma Lab. PDP Research Center
Department of Electro physics, Kwangwoon University, Korea
* Samsung SDI, Korea
seungjun9981@naver.com

Abstract

The secondary electron emission coefficient (γ) of the cathode is an important factor for improving the discharge characteristics of AC-PDPs because of its close relationship to discharge voltage. In AC-PDPs, MgO is most widely used as a surface protective layer. In this experimental, we have investigated the electronic structure of the energy band structure of the MgO layer responsible for the high γ. The MgO layers have been deposited by electron beam evaporation method, where the O_2 partial pressures have been varied as 0, $5.2x10^{-5}$ torr, $1.0x10^{-4}$ torr, and $4.1x10^{-4}$ torr, in this experiment. It is noted that work function that is energy gap between surface and first defect level of MgO layer has the lowest value for the highest O2 partial pressure of $4.1*10^{-4}$ Torr.

1.Introduction and experimental set up

Within AC-PDPs potential electron emission is the important source of secondary electrons, as the average energy of the ions are very small (~eV). The relevant mechanisms are Auger neutralization and resonance neutralization followed by Auger de-excitation. Fig. 1 shows a schematic diagram of the Auger neutralization process. As an ion with ionization energy E_i approaches the insulator surface, it undergoes a neutralization process whereby one electron in the valence band of the insulator is captured by the ion. The Auger transition implies that the energy gained by this neutralization process is simultaneously used to excite a second electron to a higher energy level. If it exceeds the surface barrier energy E_o the excited electron can escape from the surface and becomes a secondary electron. The maximum kinetic energy of the secondary electrons ejected is given by

$$E_{kmax} = E_i - 2(E_g + \chi)$$

χ is the electron affinity, E_g is the band gap energy of the solid, and E_i is the ionization energy of the gas ion. It is reported that the theoretical gamma values of MgO without defect energy bands in the band gap for Kr and Xe ions become zero from Hagstrum's theory. But MgO with defect energy bands in the band gap affects work function and secondary electron emission. And the γ of MgO with defect energy band in the band gap was calculated theoretically for Kr and Xe ions [3][4]. Also, we can measure γ of MgO for Xe ions by using γ-FIB system. We thought that these energy bands by defect state are affected deposition condition of MgO layer by E-beam evaporation. It is reported that the Cathodo-luminescence spectra that has relation to the energy bands depend on these factor[6]. When we have measured γ by γ-FIB system, we have observed the current signals that have step shape, where the defect states are assumed. It is observed that energy level by the defect state of MgO layer exist between conduct band and valence band.

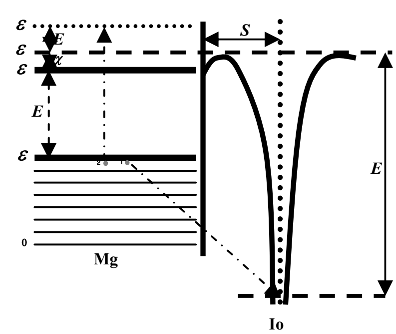

Fig. 1 Schematic diagram of the Auger neutralization process

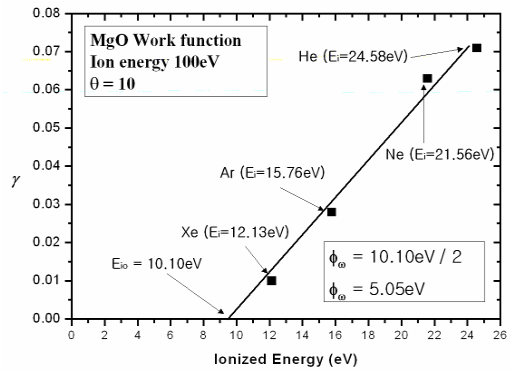

Fig. 2 Measurement of work function of MgO layer by γ-FIB system

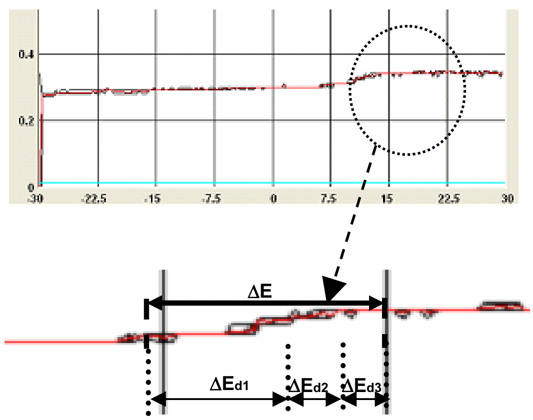

Fig. 3 Current signal at point of converting ion current into total current which is sum of ion current and secondary electron current of MgO layer versus collect voltage

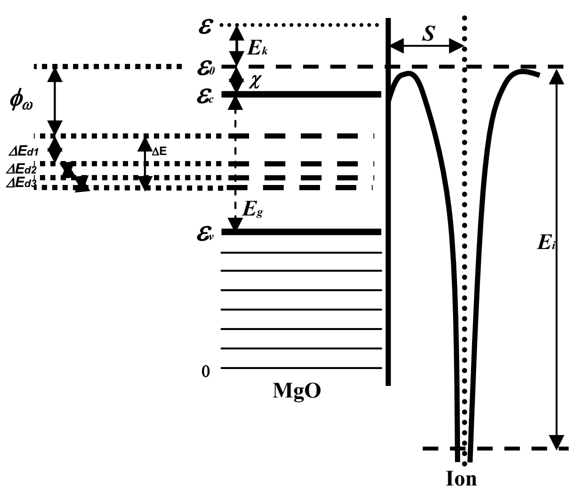

Fig. 4 Schematic diagram of electronic structure including energy band in energy gap of MgO layer

For schema of electron structure including energy bands by defect state of MgO layer, the current signal of MgO layer versus collect voltages is obtained for Ne gases by γ-FIB system. As seen in the Figs. 2 and 3, we have calculated work function and defect energy between energy bands in energy gap of MgO layer. As a result, we obtained the electronic structure diagram of MgO layer, as Fig. 4. If the first defect energy band is nearer the conduction band then MgO layer has lower work function and higher γ.

2. Results

In the experiment, the MgO layers have been deposited by electron beam evaporation method under evaporation rate 5 Å/s, thickness 7000 Å, substrate temperature 200 ℃, and vacuum annealing process at 300 ℃ during 30 min. Also the O_2 partial pressure has been varied as 0, 5.2×10^{-5} torr, 1.0×10^{-4} torr 4.1×10^{-4} torr, in this experiment.

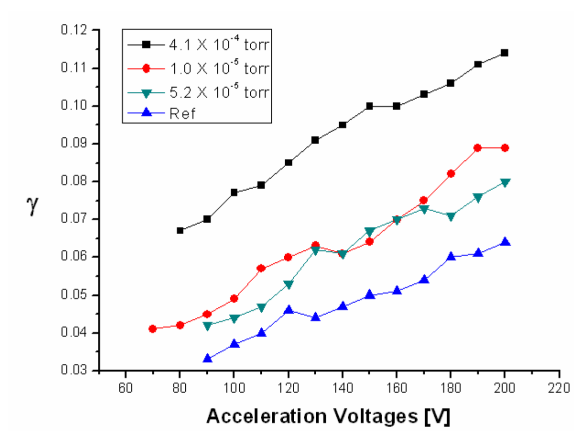

Fig. 5 Secondary electron emission coefficient of MgO layer according to O_2 partial pressure

We have measured the γ of MgO, work function and total current signal which includes the ion and secondary electron current. In the Fig. 5 as the O_2 partial pressure increase, the γ vaule increase. Especially at the highest O_2 partial pressure the γ vaule is the highest among the other conditions. The reason is that work function becomes smaller.

Figure 6 shows the work function.

O_2 pressure	Ref.	$5.2x10^{-5}$ torr	$1.0x10^{-4}$ torr	$4.1x10^{-4}$ torr
Work function	4.48eV	4.16eV	4.18eV	3.95eV

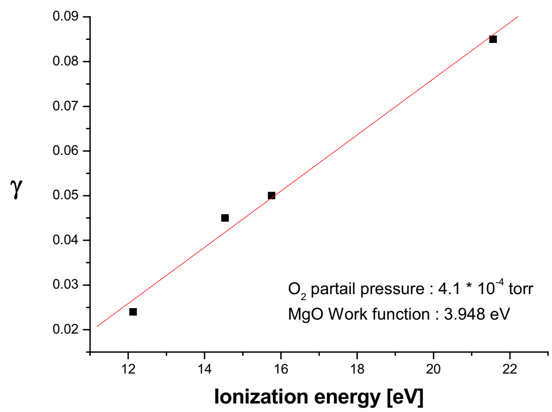

Fig 6. Work function of MgO layer according to O_2 partial pressure.

When O_2 partial pressure is zero, the work function is 4.48eV. However, when O_2 partial pressure is $4.1x10^{-4}$ torr, which we injected the O_2 gas by 30 sccm , the work function is 3.95eV. As the O_2 partial pressure increases, work- function decreases. This shows that there are defect levels in MgO energy band gap between conduction band and valence band. So the work function decreases, hence the ion-induced secondary electron emission increases. Fig 7 is current signal versus collector voltage of γ-FIB system for O2 partial pressure of $4.1x10^{-4}$ Torr. Fig 8 is energy band according to O_2 partial pressure.

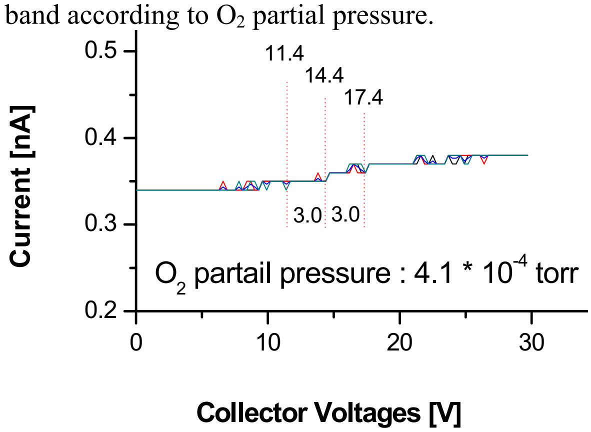

Fig. 7 Current signal versus collector voltage with O_2 partial pressure of $4.1x10^{-4}$ Torr.

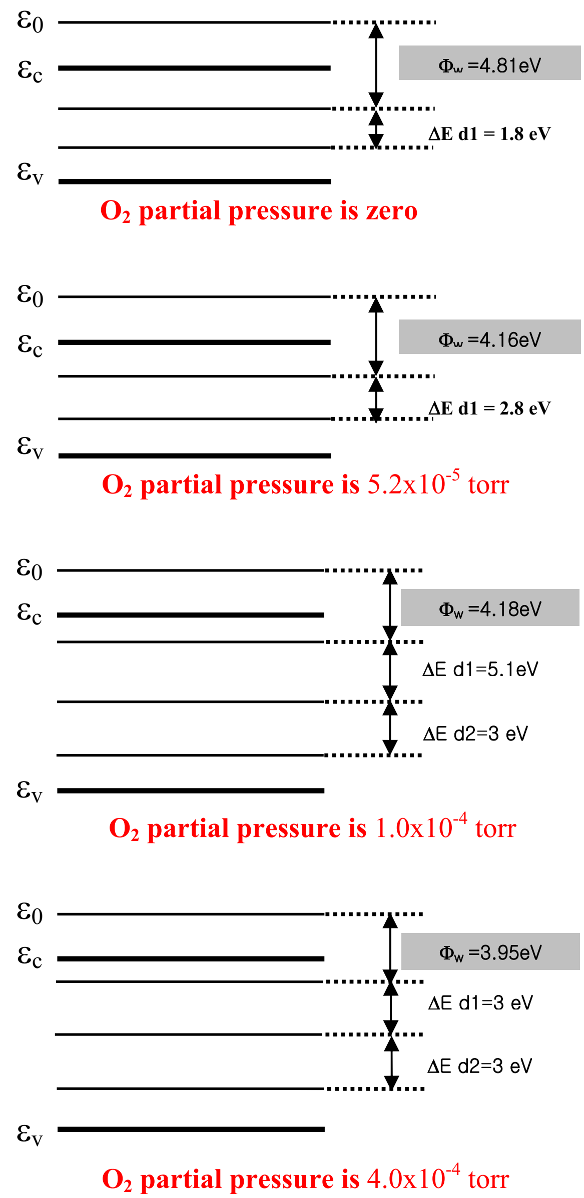

Fig. 8 Energy band including defect levels

We confirm that as O_2 partial pressure increase, defect levels increase.

3. Conclusion

We know that dielectric protective layer with high secondary electron emission coefficient (γ) is an important factor in lowing breakdown voltage. We have investigated on the defect energy levels inside the MgO energy bands, which are assumed to be important to γ. So we have approached and presented the electronic structure of defect energy levels in MgO protective layer according to the various O_2 partial pressure. As a result, we have known that the defect levels give an influence on the secondary electron emission.

4. Reference

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