Study of the correlation between doped MgO workfunction and address delay

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Abstract

The MgO protective layer of PDP has a strong influence on address delay. The relation, however, is not clearly understood due to the difficulty of analysis which is caused by surface charging. This paper suggests a way to avoid the charging problem and shows the correlation between workfunction measured by UPS and address delay.

1. Introduction

In terms of resolution, the FPD(Flat Panel Display) market trends recently have changed from HD(High Definition) to FHD(Full High Definition). The reason is that TFT-LCD devices lead the FPD market with their relative ease of realizing FHD.

Due to the FHD trend which requires addressing more cells within the same fixed time of TV sub-frame, PDP devices must reduce address delay. It is essential to understand principles of address delay to realize FHD-PDP.

The address discharge formation time usually depends on the number of initial electrons, gas type, gas pressure and electric field, which is related with cell structure and applied voltage and so forth. The discharge properties particularly rely on the electron emission. The MgO band-structure that is measured directly by UPS(Ultraviolet Photoelectron Spectroscopy) can contribute to understanding the electron emission from the surface of MgO which is related to the address delay mechanism[1]. The UPS spectrums for thick MgO film in this paper may be the results are measured for the first time in the world.

2. Experimental

To measure the band-structure of metal film, UPS has been used as one of the most popular method. UPS originated from photoelectron effect suggested by Einstein. The workfunction of metal has been measured to determine electrical and electronic properties of metal film which is used in electronic devices. This means that workfunction of insulator may be characterized as crucial index of electrical and electronic properties. In the case of insulator MgO, workfunction is defined by difference between vacuum level(E_O) and Fermi level(E_F). The Fermi level of insulator is shifted by foreign dopant which replaces Mg or O at substitutional lattice-site.

In this experiment, the sample is irradiated with HeI(21.2eV) UV. The intensity of UV source is minimized to reduce surface charging. The UPS spectrum of MgO is acquired by radiatively heating the MgO sample at 300℃ to avoid the surface charging that is caused by UV irradiation. The bias voltage between sample and detector is applied at negative 15V to collect all of the photoelectrons emitted from surface of MgO film as in Fig. 1.

Fig. 2 shows that UPS spectrum has shifted by heating because the electrical conductivity of insulator is increased as the sample temperature increases and the emitted electrons near the surface of MgO film are refilled with the electrons transported from earth to MgO surface. The two spectrums at Fig. 3 that are taken consecutively almost overlap. Finally, Fig. 2 and Fig. 3 show that the spectrums measured under the conditions above are the results nearly free of surface charging.

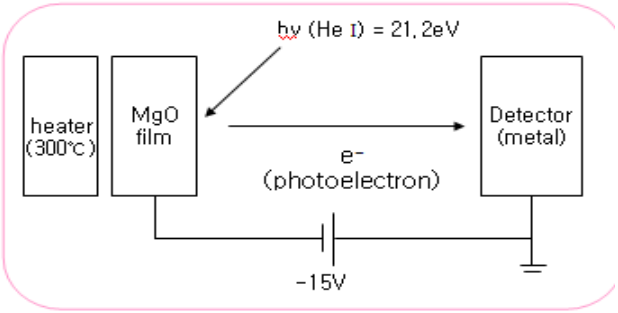

Fig. 1. Schematic diagram of UPS measurement system

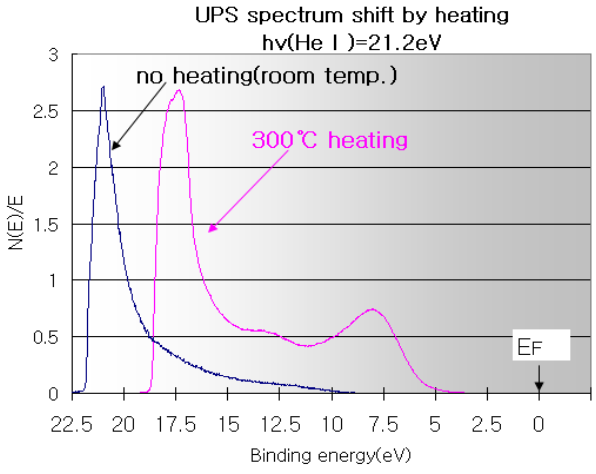

Fig. 2. Confirmation of heating effect for reducing the surface charging.

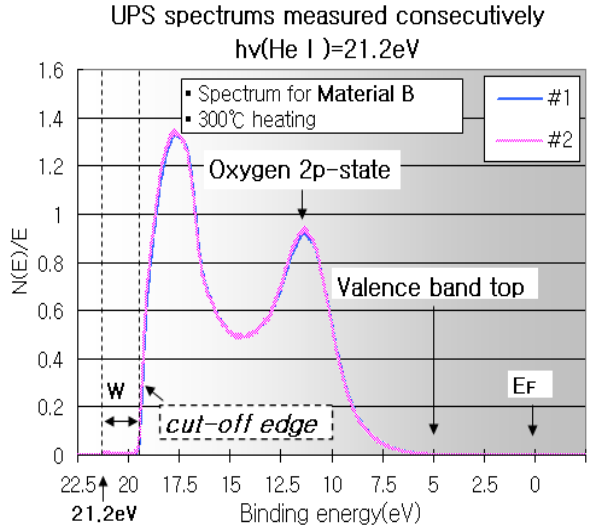

Fig. 3. UPS spectrums measured consecutively.

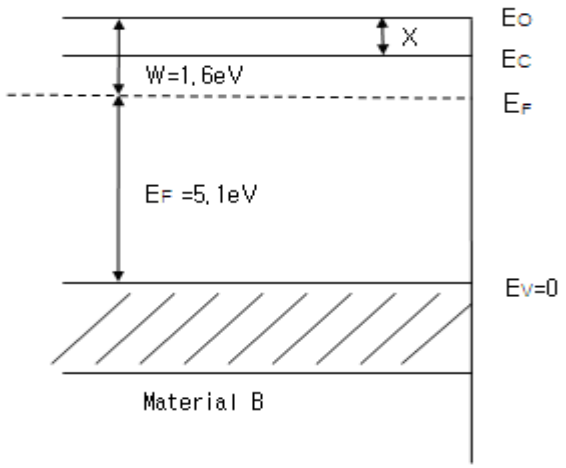

Fig. 4. Band-structure of B doped-MgO assigned from Fig. 3 ; x(electron affinity) .

In Fig. 4, the band-structure of B doped-MgO is assigned based on Fig. 3. And the workfunction is defined by the distance from cut-off edge slope around 20eV to 21.2eV. The maximum peak around 17.5eV is not the occupied state of MgO film but the signal of background electrons which increases exponentially as scanning binding energy from 0 to 21.2eV. Background electrons are generated as scattering with phonon and electron in MgO lattice and losing their original kinetic energy.

The address delay has been measured under the same conditions of panel, gas type, gas pressure, waveform and applied voltage for dopant A and dopant B respectively, at 5points on PDP panel. The statistical address delay time that is commonly used for discharge characteristic assessment is denoted as ts.

T has been measured to evaluate the discharge characteristics of address delay in SDI company. T is conceptually similar to the jitter, mentioned elsewhere.

The secondary electron emission coefficient(γ) has been measured by same method as ref [3]. The gamma of Ne and Xe ions has been measured for the ion kinetic energy from 30 to 250eV. The gamma of Ne ion is about 0.3 at 0eV. The gamma value around 0eV is caused by AN(Auger Neutralization) effect [3], [4]. Xe ion gamma is almost zero for the ion kinetic energy from 0 to 50eV. And the gamma of MgO doped with A and B has same value for both Ne and Xe ion in all range of kinetic energy. The gamma graph is not shown in this paper and will be given at the conference.

3. Results and discussion

The formation of self-sustained discharge is completed via formation of electron and positive ion mainly when sufficiently strong electric field is applied between anode and cathode. The discharge current growth can be expressed as in the following Equation (1).

$$i_1(t) \approx i_0 + \mu\, i_1(t-\tau) \approx i_0 + \mu\,[i_1(t) - \tau di_1(t)/dt] \quad (1)$$

$$\mu = \gamma[\exp(\alpha d) - 1] \quad (2)$$

where α is ionization coefficient of gas, d is distance between the electrodes and τ is the time required to pull an ion from the anode to the cathode.

In equation (1), the left side describes discharge current at a moment t. The first term on the right side of equation (1) means initial current i_0 which is the seed current due to the spontaneous electrons emitted from MgO surface. One electron emitted by cathode

produces exp(αd) – 1 ions. The number of secondary electrons generated by one primary electron is expressed by μ in equation (2). Therefore, the second term in the right side of equation (1) signifies the number of secondary electrons generated by one primary electron emitted at the time t-τ.

Integrating equation (1) with the initial condition $i(0)= i_0$ at the moment of switching on the electric field, the following equation(3) can be obtained [5].

$$i(t)=i_1(t)e^{\alpha d}=i_0(1+\mu/\gamma)[(\mu/\mu-1)\exp(\mu-1/\mu)(t/\tau)-1/\mu-1] \quad (3)$$

Fig. 5 and Fig. 6 show the results of address delay and workfunction for dopants A and B, respectively. Fig. 5 shows that the address delay of B is faster than the address delay of A in case of both ts and T. Fig. 6 shows that the workfunction of A has larger value in comparison with the workfunction of B. This indicates that doping A and B into MgO contributes to the shift of Fermi level and material B has shallower level compared to material A, as shown in Fig. 7. It can be anticipated that the electron is ejected from material B more easily than from material A. Finally, address delay has the positive correlation with workfunction, as shown in Fig. 8.

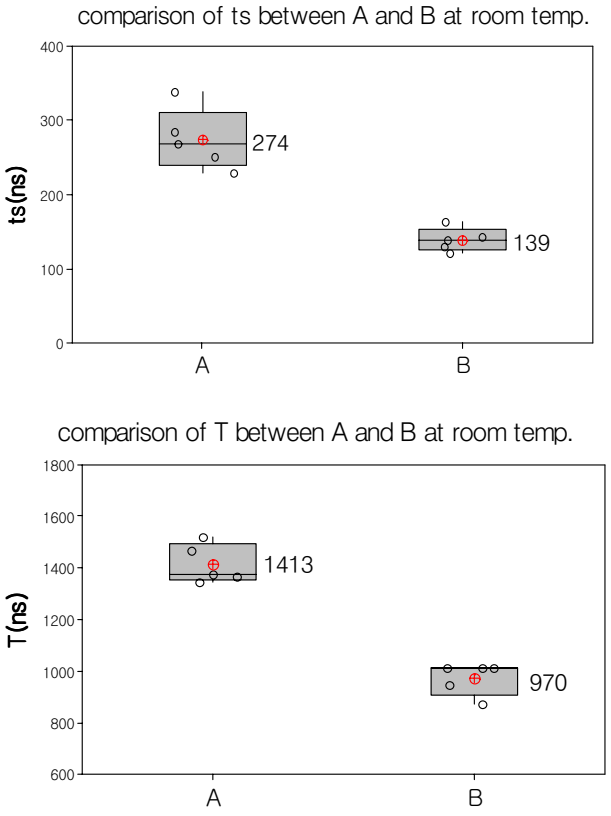

Fig. 5. Comparison of ts and T between A and B.

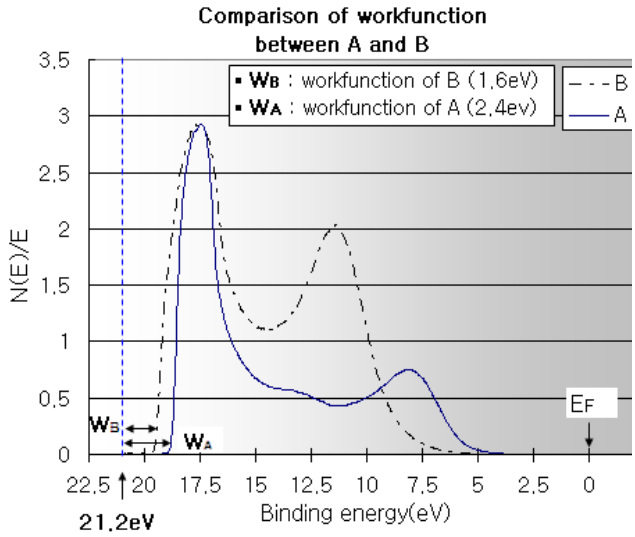

Fig. 6. Comparison of workfunction value between A and B on UPS spectrum.

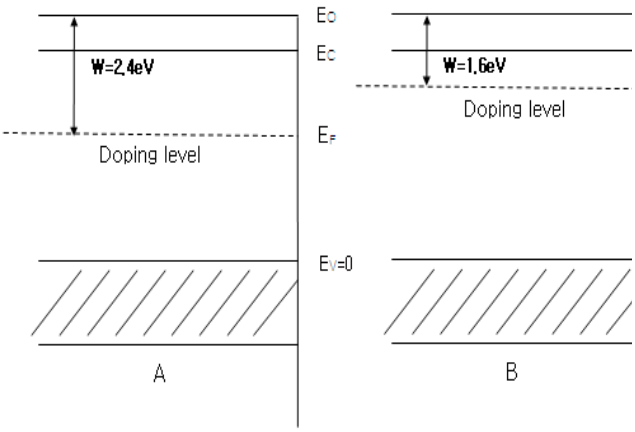

Fig. 7. Comparison of doping level for A and B in band-structure assigned from Fig. 6.

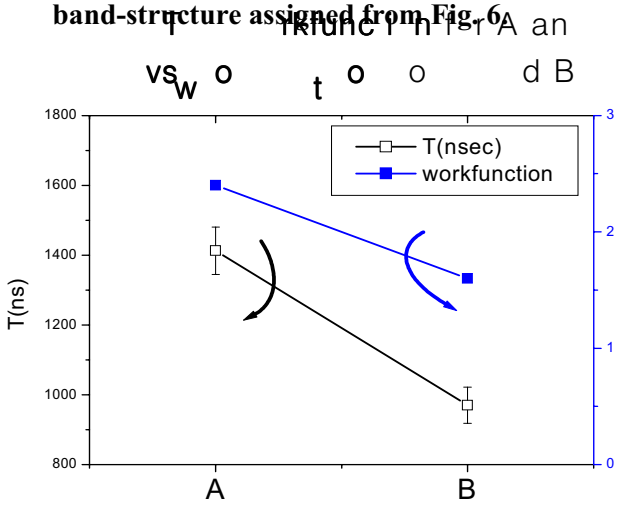

Fig. 8. Analysis of correlation between T and workfunction.

The reason for the positive correlation between addressss delay and workfunction can be explained as follows. The discharge current is approximately 5 ~ 8 ㎂ per cell for various gas composition and pressure[6]. The electrical current threshold value of below 1 ㎂ can be used to determine the moment of discharge initiation. From equation (3), if the value of γ, μ, τ are same for both A and B as in this experiment, the discharge current depends only on i_0, which differs for A and B. In conclusion, address delay is determined by initial electrons emitted from MgO surface.

4. Summary

In this study, we have shown two important things. First, UPS measurement for the insulator MgO can be carried out via the thermally enhanced electrical conductivity used to keep the MgO surface almost free of positively charging during the measurement. Second, the address delay has positive correlation with the workfunction which is changed by doping. The smaller workfunction MgO film has the electron states more closed to the vacuum level. This means that the small workfuntion MgO has lower energy barrier for electron to escape from MgO surface to vacuum. Finally, the change of workfunction allows various doped MgO films to control the number of initial electrons used to determine the address delay time.

5. Acknowledgements

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6. References

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