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Characteristics of MgO Layer Deposited under Hydrogen Atmosphere

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Abstract

The characteristics of MgO layer deposited under hydrogen atmosphere were investigated. Hydrogen gas was introduced during e-beam evaporation coating process of MgO layer and its effects on microstructure, cathode luminescence spectra, discharge voltages and effective yield of secondary electron emission were examined. The results indicated that the hydrogen influences the concentration and energy levels of defects in MgO layer, which in turn affects the luminance efficiency and discharge delays of the panels significantly.

Keywords : Plasma display panel, MgO, F and F^+-Center, Hydrogen center

1. Introduction

MgO layer formed on transparent dielectric layer of ac-PDPs emits secondary electrons voltage and protects dielectric layer from ion bombardments. As the MgO is composed of a rare combination of high yield secondary electron emission and resistance for ion sputtering, it has been mainly used as electron emission/protective layer for PDPs so far. To further enhance the luminance efficacy and reduction of firing voltages of PDPs, electron emission characterization such as secondary electron and exo-electron emission from MgO must be improved further.

There have been various attempts to increase the coefficient of secondary electron emission of MgO, which include doping of MgO material [1], patterning of the layer [2], controlling of orientation of MgO layer [3], etc. These approaches, however, have resulted in a marginal improvement of such characteristics. Recently, Okada et. al. [4], has reported that addition of hydrogen during aging treatment which reduces the discharge voltages and aging time. In addition, resulted in the increase of photoelectron emission addition of hydrogen.

MgO is a typical ionic compound and has point defects such as vacancies, interstitials, impurities and non-stoichiometry. As the charge neutrality must be satisfied during the creation of oxygen vacancies, the vacancy traps electrons within. Such defects are called F-type centers. The energy levels of such centers lie within the band gap of MgO and the levels were estimated to locate at ~ 3.0 eV from the top of the conduction band as schematically shown in Fig. 1 [5]. Increase in the concentration of such levels resulted in the reduction of the discharge voltages and increase in the secondary electron emission yield [6,7].

The electrons in F-type centers were excited during the glow discharge of PDPs to the levels near to the bottom of the conduction bands as shows in Fig. 1. These electrons decay with electromagnetic radiations of wavelength 388nm for F^+-type center and 540nm for F-type center, respectively [8]. It is possible that the excited electrons at the trapped levels will quickly decay to ground states of F-type centers in a time scale of few tens of nano seconds. However, this decay time can be increased by two order of magnitude by adding hydrogen into the F-type centers [9]. As the hydrogen atoms are small in size, they can easily be incorporated inside the oxygen vacancies and this would affect electron energy levels within the vacancies. The increased delay time is attributed to the deep electron trap levels follwing the addition of proton in the oxygen vacancies.

Thus, in this study, we attempted to form oxygen vacancies filled with protons in MgO protective layer. For this purpose, MgO layer was formed under various

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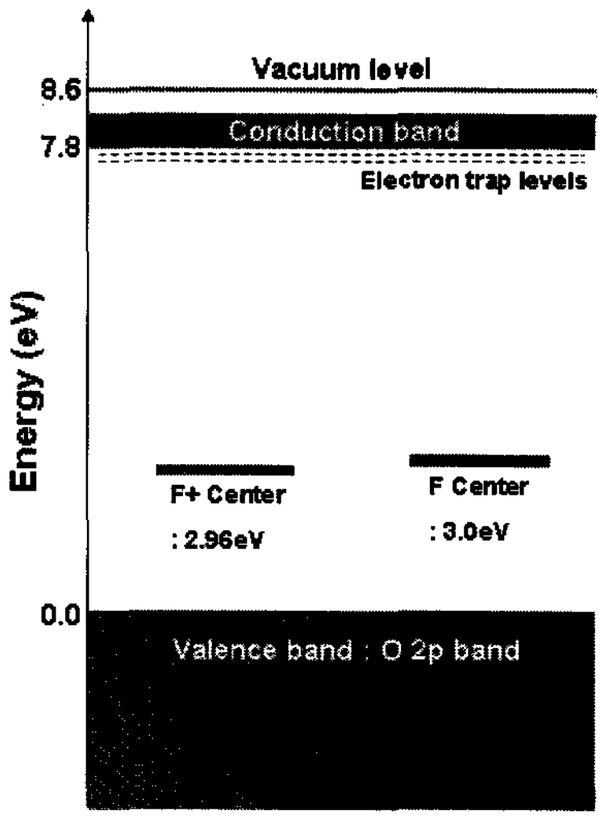
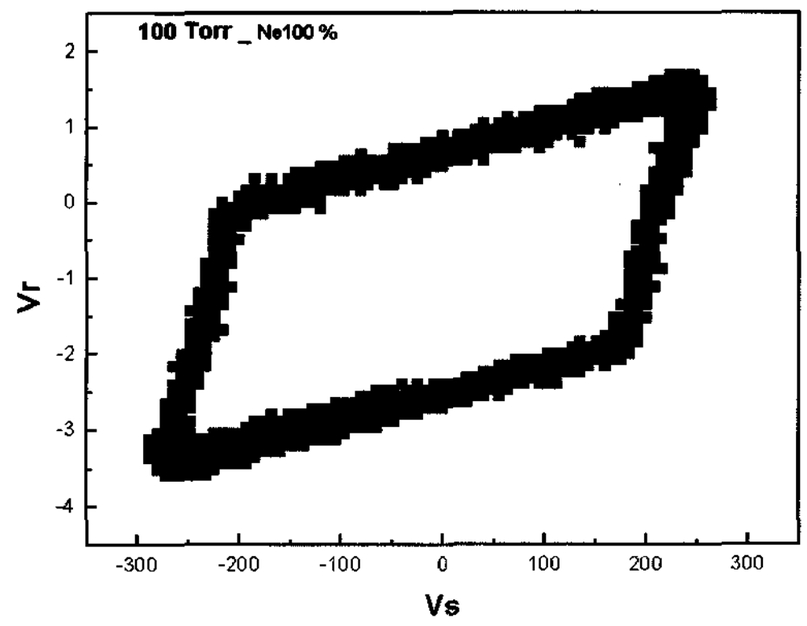


Fig. 1. Energy band model of MgO and F, F^+-center and electron trap levels



$$V_f = \frac{0.5 \cdot C_D}{C_g + 0.5 \cdot C_D} V_s + \frac{C_r}{C_D} V_r$$

Fig. 2. Lissajous curves obtained during the measurement of the discharge voltages.

hydrogen partial pressures. Cathode luminescence of MgO was measured to characterize its defect levels. In addition, the firing voltage and effective yield of secondary electron emission were estimated for MgO layers formed under hydrogen atmospheres and compared with MgO formed under vacuum atmosphere. These results indicate that the addition of hydrogen during the MgO layer affects the defect levels and types, and this influences the performance of PDPs significantly.

2. Experiments

MgO layer was formed using an e-beam evaporator under various hydrogen partial pressure, $1.3x10^{-4}$Pa~$1.3 x10^{0}$Pa. The base pressure was higher than 1.0×10^{-4} Pa and the substrate was heated to 300°C. The thickness of the film formed was ~ 5000 Å±500 Å. The cathode luminescence of the films was measured using a SEM equipped with vacuum double monochrometer. In addition, the orientation and microstructure were analyzed using XRD, FE-SEM, and UV/VIS light Transmittance.

The firing voltage and coefficient of secondary electron emission were measured with the MgO layers formed under hydrogen atmospheres and compared with the MgO formed under vacuum atmosphere. The measurements were conducted using a set-up similar to that described in other works [10,11]. Figure 2 illustrates Lissajous curve along with the equation used to calculate the wall charge-corrected firing voltage V_f. The data were collected under dynamic, panel-like discharge conditions. In this figure, $C_{D.}$, C_G, and $C_{R.}$ are the capacities of the glass substrates, the gap, and a calibrated reference capacitor, respectively. V_s is the measured voltage at which the discharge starts, V_R is the voltage measured across the reference capacitor. V_a is the voltage applied. Measurements were performed using 2 kHz sine wave signals.

In addition, test panels were prepared using MgO layers formed under different partial pressures. The panels have stripe type barrier ribs of 430μm pitch and were sustained with square type voltage pulses at a frequency of 30kHz. The panels were filled with Ne-Xe discharge gas of 400 torr. With the panels, the luminance efficiency and address discharge delay were evaluated.

3. Results and discussion

3.1. Effect of hydrogen on microstructure of MgO film

Figure 3 shows the surface morphology of MgO film formed at various hydrogen partial pressures. As can be seen from the micrographs, the grain size becomes larger with the increase in hydrogen partial pressure. In addition, the pyramidal morphology becomes more pronounced with the increase in hydrogen flow rate until 120 sccm. Further increase in hydrogen flow rate resulted in grains of triangular morphology and more porous microstructures.

The preferred orientation of MgO film was affected by the partial pressure of hydrogen. As shown in Fig. 4, the

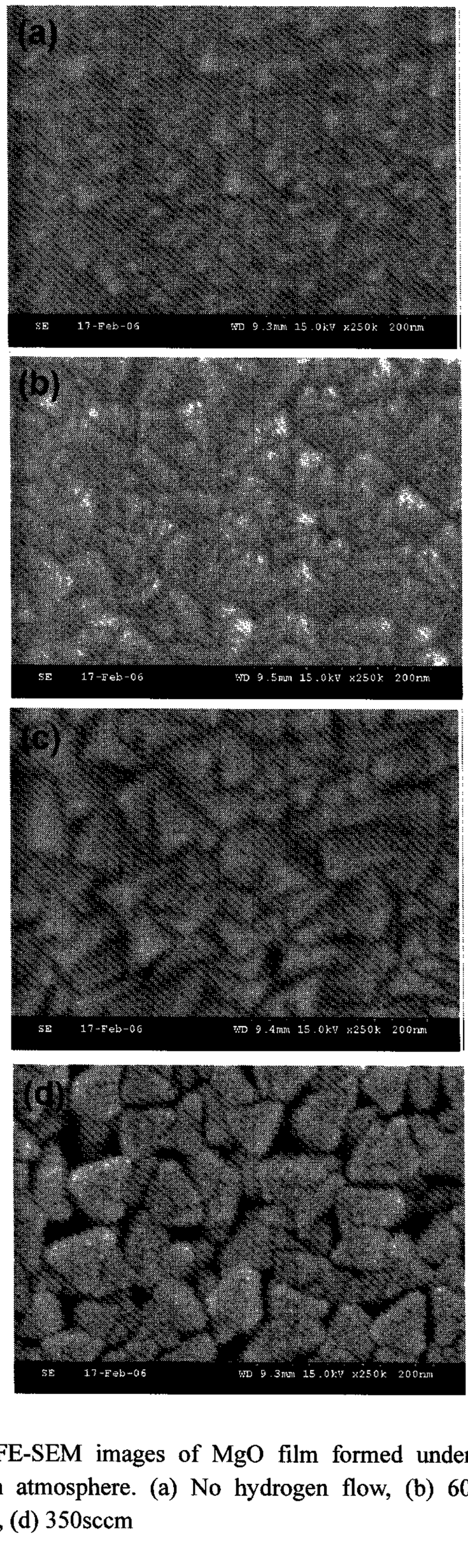


Fig. 3. FE-SEM images of MgO film formed under different hydrogen atmosphere. (a) No hydrogen flow, (b) 60sccm, (c) 120sccm, (d) 350sccm

increase in hydrogen partial pressure resulted increase in the peak intensity of (200) orientation compared with that of (220).

The change in orientation must have influenced the change in morphology and density of the film as observed in Fig. 3.

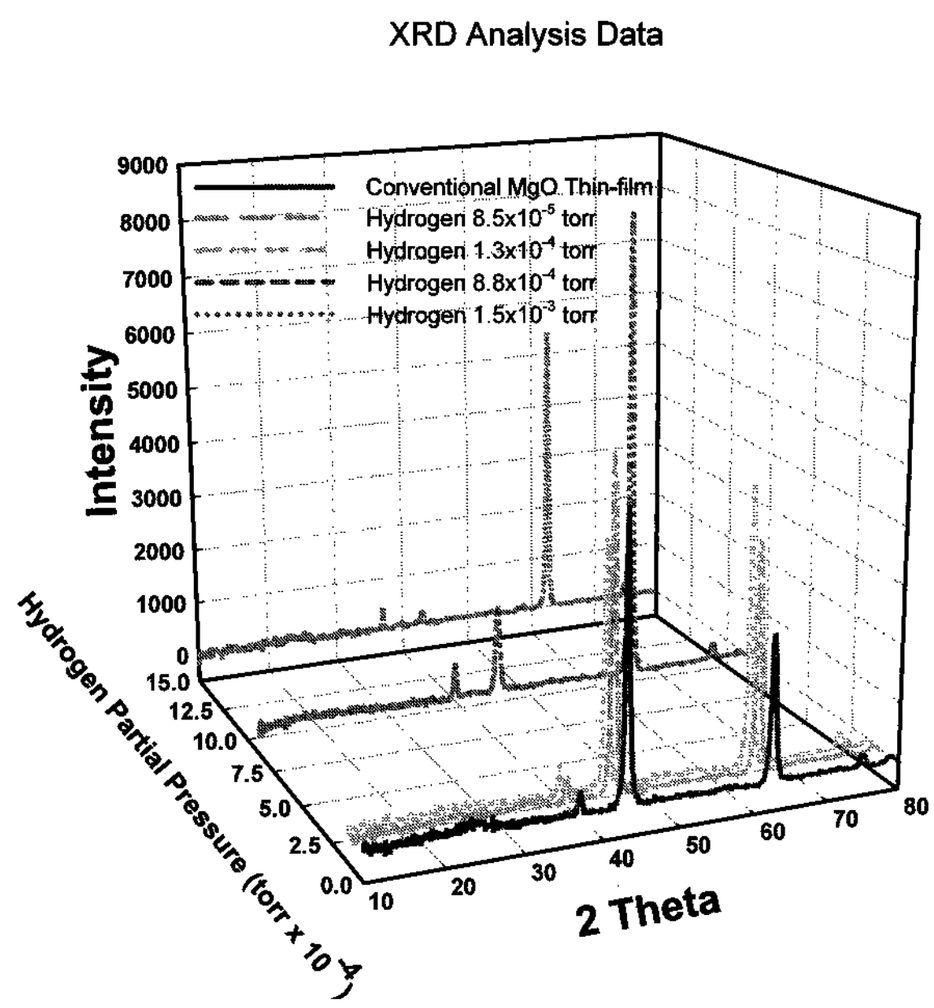


Fig. 4. XRD patterns of MgO films formed under various hydrogen flow rates.

The grain size estimated from half-width of the peaks indicated that the average grain size increases monotonically with the increase in the flow rate.

3.2. Effect of hydrogen on discharge voltage and yield of secondary electron emission of MgO film

The discharge voltages estimated from Lissajous curve was affected by the addition of hydrogen. Fig. 4 shows the discharge voltages of MgO layer formed under partial pressure of hydrogen of $1.3x10^{-2}$torr. The measurement was conducted under pure Ne and Ne-4%Xe discharge gases. As can be seen from this figure, the discharge voltage appears to be similar with MgO layer formed without hydrogen, i.e., reference MgO layer. The discharge voltage of the sample with MgO layer formed under hydrogen flowing with the mixed discharge gases, however, was significantly lower than those of the reference MgO layer.

The effective coefficient of secondary electron emission estimated from the curves of Fig. 5 shows a similar trend. Details of the estimation method for the coefficient can be found elsewhere [11]. When measured under pure Ne discharge gas, the effective yield of MgO layer formed under hydrogen flowing was slightly larger than that of the reference MgO layer. The effective yield was significantly different when measured under the Ne-

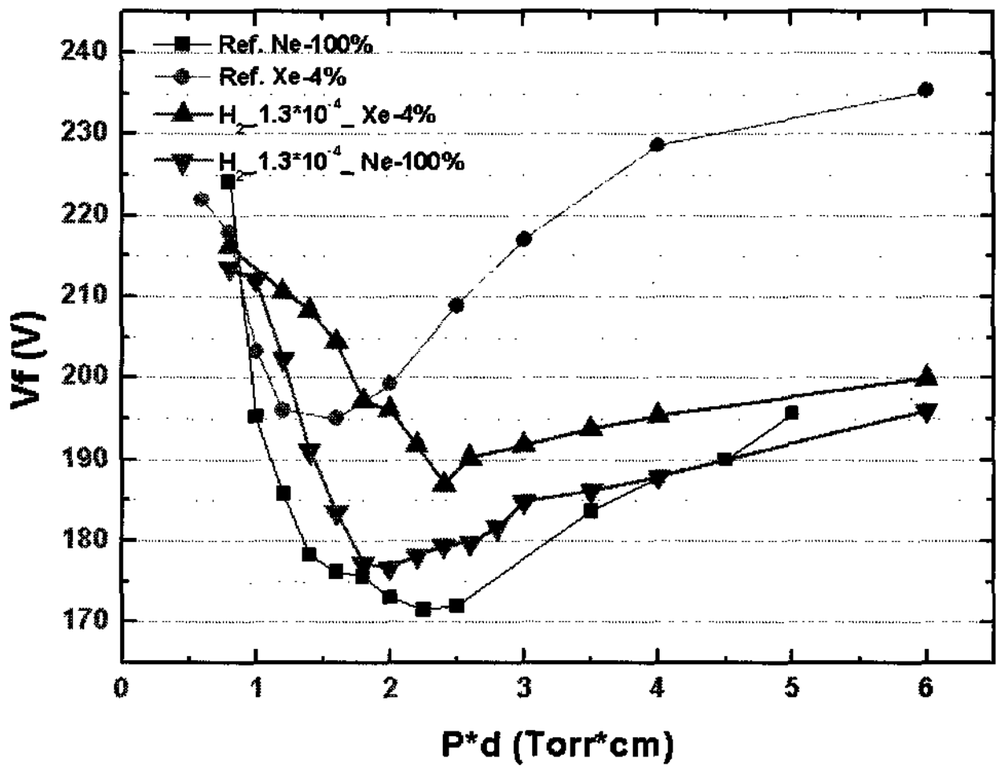


Fig. 5. Effect of hydrogen atmosphere on discharge voltage.

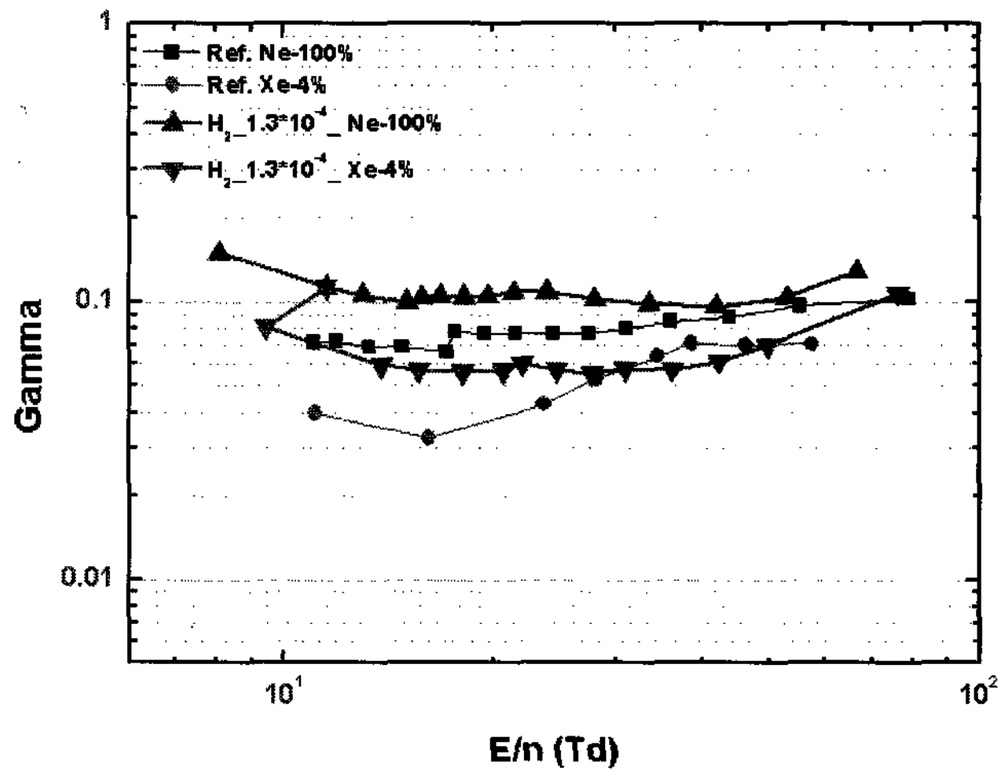


Fig. 6. Effects of hydrogen atmosphere on effective coefficient of secondary electron emission.

4%Xe mixed discharge gas. These results suggest that the addition of hydrogen during the e-beam evaporation process may have increase the trapped electron levels in MgO layer, which in turn may have enhanced the effective yield and reduced the discharge voltages when tested in Ne-Xe mixed gas as reported in Motoyama et. al [6].

In order to investigate the effect of hydrogen addition during the e-beam evaporation process on defect levels and concentration, cathode luminescence (CL) of MgO films was measured. As shown in Fig. 7, the CL spectra of reference MgO layer were measured to have a major luminescence peak around 490nm and a minor peak around 400nm. This result suggests that the major defect formed within the reference MgO layer is F-type center. The defect that is responsible for the emission around 400 nm needs to

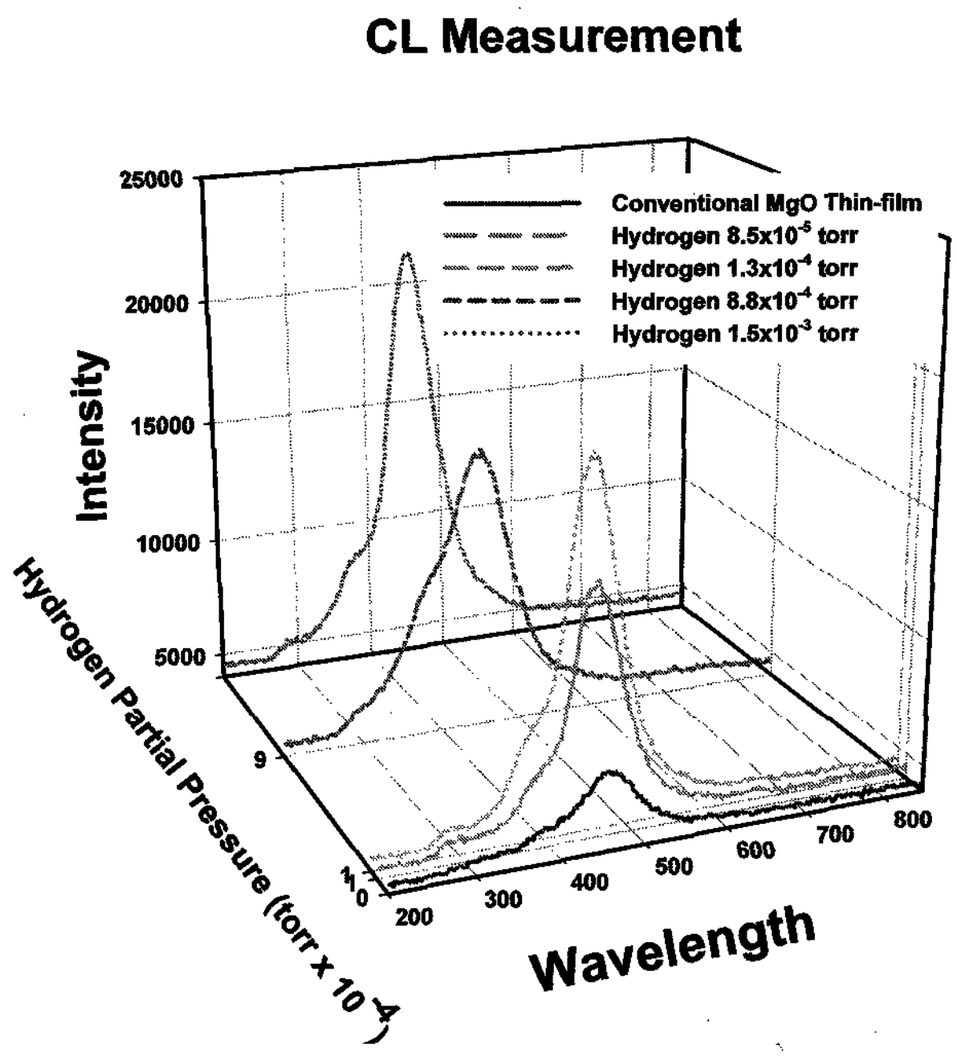


Fig. 7. Effect of hydrogen on the CL spectra of MgO films.

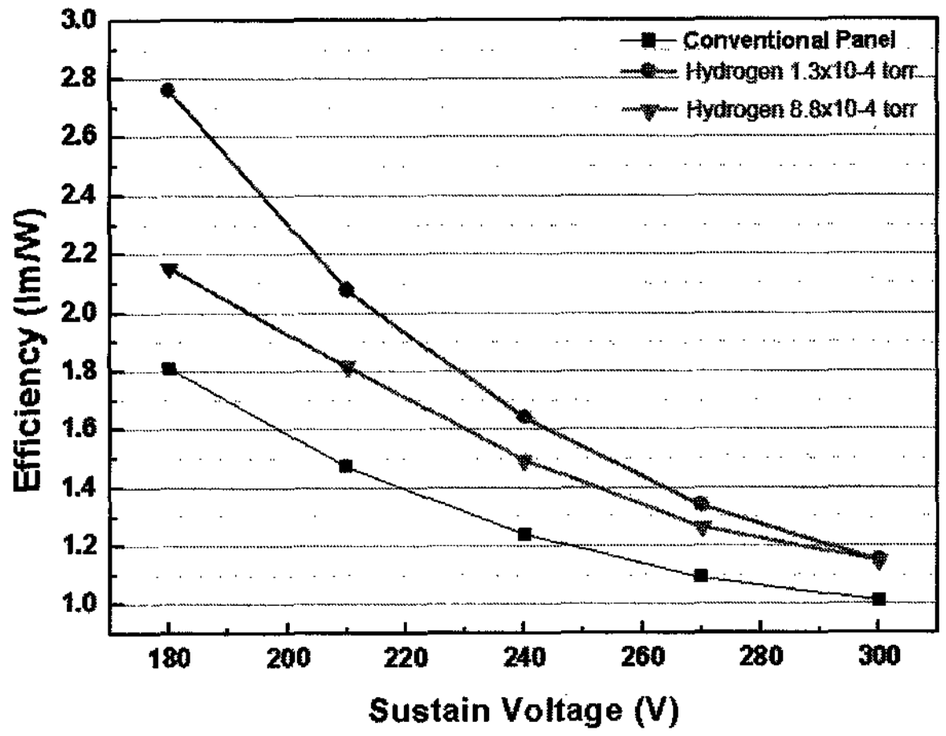


Fig. 8. Luminance efficiency of test panels prepared using MgO layers under flowing hydrogen gas.

be identified and this will be investigated in our future research work. The addition of hydrogen gas during the MgO formation has moved the major peak of the CL spectra to a shorter wavelength radiation, i.e., to higher radiation energy. The major peak was located around 400 nm. In addition, a small peak was observed at longer wavelength, of ~ 700 nm, indicating that the addition has caused energy levels to become relatively lower than that of F-type centers.

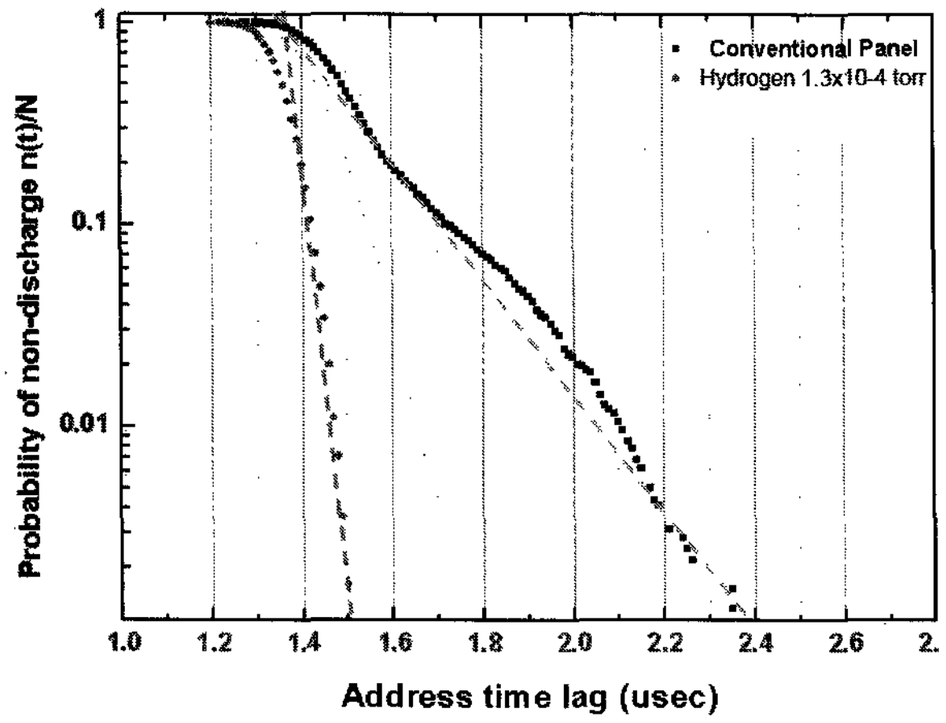


Fig. 9. Laue's plot of address delay time measured from test panels.

Table 1. Address delay estimated from Laue's plot of Fig. 9.

Panel	Slope	Tf (usec)	Ts (usec)
Conventional Panel	1.10	About 1.3	0.335
Hydrogen 1.3x10-4 torr	7	About 1.25	0.053

3.3. Effect of hydrogen on luminance efficiency and discharge delays

The luminance efficiency of test panels using MgO layers formed under various flowing rate of hydrogen was evaluated. Figure 8 shows the experimentally measured results. The luminance efficiency was enhanced up to 30% with the addition of hydrogen during the e-beam evaporation process. The enhancement was mainly due to reduction in power consumption rather than increase in luminance. The enhancement was at a maximum when the hydrogen partial pressure was $1.3x10^{-2}$Pa. When the partial pressure was increased further, the efficiency decreased.

Figure 9 shows a Laue's plot of address delay measured from a single cell in the test panel. In order to increase the reliability of the measurement, the measurement was conducted up to 3,000 times. For the measurement, ramp-type wave form as shown in a reference [12] was applied to a single cell. The discharge delay, which consists of formative and statistical delays, was calculated from the plots and is shown in Table 1. As can be seen from this table, the addition of hydrogen resulted in the significant reduction of the statistical delay. It is believed that the electrons trapped in shallow energy levels, as shown in Fig. 7, may have contributed to the exo-emission of electrons and reduced the discharge delays with the test panels.

4. Conclusions

Based on the experimental measurements of CL spectra, discharge voltage, and effective yield of secondary electron emission of MgO layer formed under hydrogen environment, the hydrogen introduced during e-beam evaporation coating of MgO layer influences the density and energy levels of defects, especially oxygen vacancies formed within and surface of MgO layer. These results, shows that, enhances the luminance efficiency and reduce discharge delays as measured from test panels prepared using MgO layer formed under flowing hydrogen.

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