Technical Notes

The Effective Coefficient of Secondary Electron Emission in Plasma Display Panel

Min Sup Hur, Jae Koo Lee, Hyun Chul Kim, and Bong Koo Kang

***Abstract*—The effective secondary electron emission coefficient (SEEC) in a plasma display panel (PDP) is estimated by comparing the Paschen breakdown curves from simulations with the experiment. It is found that the effective SEEC in PDP is dependent on the ratio of electric field to pressure. The estimated values are 0.59~0.79 for the pure Ne and 0.1~0.13 for the Ne–Xe (96/4) mixture, respectively.**

***Index Terms*—Back-scattering, discharge, Paschen breakdown curve, plasma display, secondary electron, simulation.**

I. Introduction

The secondary electron emission coefficient (SEEC) is a very important parameter in determining the physics of discharge in a plasma display panel (PDP). The firing and sustaining voltages of PDP are largely dependent on the SEEC of the MgO protective layer. These voltages are closely related to the product cost and the light efficiency of PDP. Therefore, developing materials with a high SEEC and measuring the SEEC of existing materials are important issues in the research of PDP.

There have been many experiments and theories that attempted to determine the value of the SEEC [1]–[7] of MgO. However, the results are controversial because the measured or calculated values of SEEC vary by a factor of as much as ten. For the mixture of more than two kinds of ion species, the following equation can be used:

$$\Gamma_{\rm se} = \left(\frac{\Sigma\gamma_{\rm i}\Gamma_{\rm i}}{\Sigma\Gamma_{\rm i}} + \frac{\Sigma\gamma_{\rm e}\Gamma_{\rm e}}{\Sigma\Gamma_{\rm i}} + \frac{\Sigma\gamma_{\rm p}\Gamma_{\rm p}}{\Sigma\Gamma_{\rm i}} - \frac{\Gamma_{\rm b}}{\Sigma\Gamma_{\rm i}} \right) = \gamma_{\rm eff}\Sigma\Gamma_{\rm i} \qquad (1)$$

where

i represent ion;
e excited atom;
p photon;
b backscattering.

$\gamma_{\rm eff}$ is called the effective SEEC. Most experiments were conducted with ion beams ($\Sigma\Gamma_{\rm i}$) injected to the MgO surface. They measured the current of secondary electrons to calculate $\gamma_{\rm eff}$ from (1). There are several reasons why it is difficult to accept the values measured in the beam-experiments as the relevant SEEC of MgO in PDP. The energies of the ion beams in most experiments are very high (larger than 50 eV) [1], [3]–[6]. However, the Monte Carlo simulation [8] has shown that most of the secondary electrons are emitted by ions with low energy (significantly lower than 50 eV). The beam experiments were conducted at a relatively low pressure, although PDP is a high-pressure system. Because there are many additional effects such as electron-emission by photons and excited atoms and back-scattering of emitted electrons [9], [10] in the high pressure discharge, $\gamma_{\rm eff}$ is possibly modified significantly. Therefore, the discharge in a realistic PDP is not completely described by the experimental $\gamma_{\rm eff}$. Since there is not much theoretical and experimental information available regarding the combined effects by ions, excited atoms, photons, and back-scattering, it is worth estimating $\gamma_{\rm eff}$ in plasma-modeling or other fields.

Manuscript received September 6, 2000; revised June 12, 2001. This work was supported by LG Electronics and the Ministry of Education of Korea through its BK21 program.

The authors are with the Department of Electrical Engineering, Pohang University of Science and Technology, Pohang 790-784, South Korea (e-mail: jkl@postech.ac.kr).

Publisher Item Identifier S 0093-3813(01)08845-2.

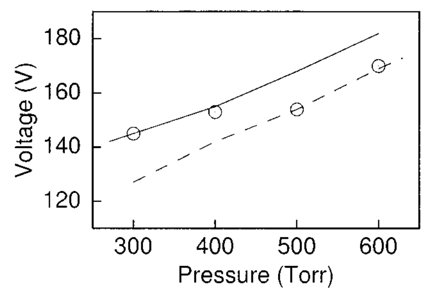

Fig. 1. The experimental data for breakdown voltages (circle) and the Paschen curves from the simulations with $\gamma_{\rm eff} = 0.59$ (solid line) and $\gamma_{\rm eff} = 0.74$ (dashed line) for the pure Ne.

As an indirect method, we estimated $\gamma_{\rm eff}$ by comparing the breakdown curves (Paschen curves) obtained from simulations with the experimental data of breakdown voltages. In the experiment, there exist all the additional effects other than the secondary electrons by the ion-bombardment only. Therefore, the combined effects of ions, excited atoms, photons, and back-scattering are reflected in $\gamma_{\rm eff}$ estimated in this method, though the secondary electrons only by the ion-bombardment were implemented in the simulation code. The details of the simulation code and the code validations are given elsewhere [11], [12]. The breakdown voltages of our simulations agree well with the analytic Paschen theory for a parallel-plate geometry. For example, the theoretical breakdown voltages for pure neon and pure xenon at Pd [torr cm] $= 1$ are 77.4 V and 163.2 V, respectively. We obtained 84.5 V and 160.5 V from the simulation. We also compared the breakdown voltages for two dimensional coplanar PDP obtained from our code and other well-established PDP code [13], [14]. They agree well with our results for the same coplanar geometry, though not published. Although the local field approximation, which is employed in our simulation code, is not appropriate to the cathode fall, the agreement of the Paschen curves makes it believable to measure the $\gamma_{\rm eff}$ using the proposed method. Because of the differences between Ne and Xe in mean free path, inertia and ionization or excitation energy in the cathode fall, the SEEC is different even for the same flux of Ne and Xe. Instead of separate SEECs of Ne and Xe, we focused on $\gamma_{\rm eff}$ since the detailed effects of Ne and Xe in the cathode fall are thought to be reflected in the value of $\gamma_{\rm eff}$ via (1).

II. Results

Fig. 1 shows the experimental breakdown voltages for the pure neon in a coplanar PDP. The simulation breakdown curves with $\gamma_{\rm eff} = 0.59$ and $\gamma_{\rm eff} = 0.74$ in the same geometry are also shown in Fig. 1. The simulation curve with $\gamma_{\rm eff} = 0.59$ fits well with the experimental data for 300 and 400 torr, while $\gamma_{\rm eff} = 0.74$ fits well with the data for 500 and 600 torr. The experiments are not fitted by a simulation curve with a single fixed $\gamma_{\rm eff}$. This is because $\gamma_{\rm eff}$ includes the effects of excited atoms, photo-emission and the electron back-scattering, all of

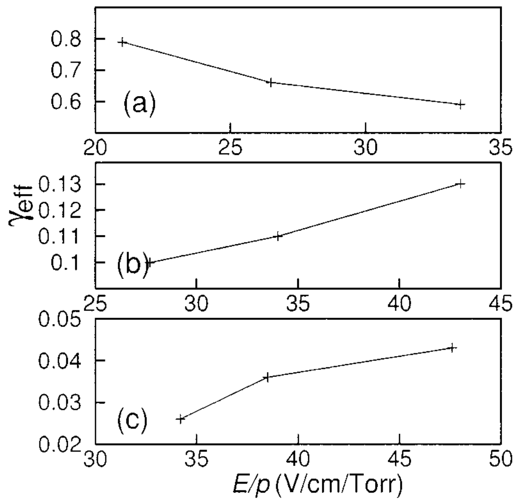

Fig. 2. $\gamma_{\rm eff}$ versus E/p for $p = 500$, 400 and 300 torr. (a) is for the pure Ne, (b) is for the Ne–Xe (96/4) mixture and (c) is for the Ne–Xe (90/10) mixture.

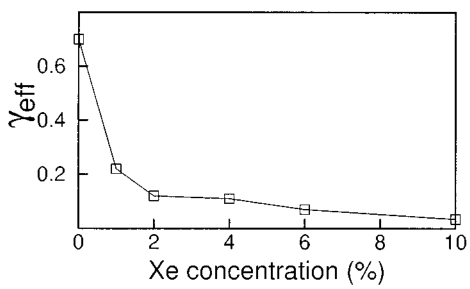

Fig. 3. $\gamma_{\rm eff}$ versus the ratio of xenon concentration, where $\gamma_{\rm eff}$ is averaged over 300, 400, 500, and 600 torr.

which are dependent on pressure. Because of the competition of these terms depending on pressure, the dependence of $\gamma_{\rm eff}$ on pressure is quite different from pure Ne to Ne–Xe mixtures.

The ion flux ($\Gamma_{\rm i}$) is dependent on the ion energy [1]–[7]. Considering the local field approximation [11], it is possible to assume that ion energy is determined by the reduced electric field (E/p), where E is the electric field and p is the pressure. Other terms associated with the excitation collisions and back-scattering [9], [10] are also dependent on E/p. Therefore, it is valuable to describe $\gamma_{\rm eff}$ as a function of E/p. Fig. 2 represents $\gamma_{\rm eff}$ versus E/p for the pure Ne and the Ne–Xe mixtures. Though the electric field is dependent on the position in the coplanar PDP, the E/p in Fig. 2 could be uniquely determined for the following reasons. Near the breakdown voltage, since the discharge starts to produce a small number of plasma particles, there is not much field distortion by the plasma. The discharge is highly concentrated near the cathode edge, since the field is not strong enough to fully extend the discharge in the whole region of PDP. Therefore, the secondary electrons are emitted in the very narrow region near the cathode edge. The values of the electric field were taken in that region. It is observed in Fig. 2 that as E/p increases from 20 to 50 (V/cm/torr), $\gamma_{\rm eff}$ decreases for the pure Ne, while $\gamma_{\rm eff}$ increases for the Ne–Xe mixture. The trend of $\gamma_{\rm eff}$ for the gas mixture can be inferred from the fact that the frequency of back-scattering of the secondary electrons is a monotonically increasing function of E/p [10]. However, the origin of the opposite trend for Ne remains yet to be clarified. The behaviors of $\gamma_{\rm eff}$ are qualitatively consistent with other results [10], [15], although the systems are quite different.

Fig. 3 displays $\gamma_{\rm eff}$ averaged over pressures versus the ratio of xenon concentration. $\gamma_{\rm eff}$ decreases significantly when one percent of Xe is added to the base gas of Ne. Since the collisional cross section of Xe is much larger than that of Ne, a large number of xenon ions are produced even at a low concentration of Xe. As seen in Fig. 4, the xenon ion flux reaching the cathode is much larger than that of Ne. Fig. 4(a) shows the ion fluxes of neon and xenon at an initial stage before the discharge occurs and Fig. 4(b) indicates the fluxes after the discharge yields a peak current. The simulation is carried out for the Ne–Xe (99/1) mixture. Even in the initial stage, the xenon ion flux is over three times larger than the neon ion flux. The SEEC of Xe is known to be much smaller than that of Ne. As a result, $\gamma_{\rm eff}$ which is affected by xenon ion flux is reduced in the mixed gases.

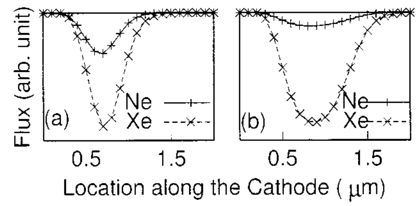

Fig. 4. The neon and xenon fluxes on the cathode (a) early in the discharge and (b) after the discharge yields a peak current for Ne–Xe (99/1) case with 500 torr. The horizontal axis represents the location from the left edge of the cathode. The anode is located on the left side of the cathode.

III. Conclusion

$\gamma_{\rm eff}$ is modified by various effects other than ion-bombardment in the high-pressure discharges as in PDP. We have estimated $\gamma_{\rm eff}$ of MgO for PDP by comparing the Paschen curves from simulations with experimental data for discharge breakdown in PDP. The resultant values are in the range of $0.59 \sim 0.79$ for the pure Ne and $0.1 \sim 0.13$ for the Ne–Xe (96/4) mixture, respectively. For a very high pressure system, it is more appropriate to describe $\gamma_{\rm eff}$ as a function of the reduced electric field E/p, rather than treating it as a function of beam ion energy. We have described the dependence of $\gamma_{\rm eff}$ on E/p and explained its behavior qualitatively, though more exact physical origin remains to be clarified in the future research. We have also observed a sudden decrease in $\gamma_{\rm eff}$ when a small amount of Xe is added. $\gamma_{\rm eff}$ is very important especially in PDP simulation, since the discharge properties of PDP, most of which are very difficult to be diagnosed in the experiments, are mostly determined by this value. Although our method is not predictive of SEEC for different parameters, it should be used more widely for a database of $\gamma_{\rm eff}$ in PDP.

Acknowledgment

The authors wish to thank Y. K. Shin, W. T. Kim, and J. H. Ryu of LG Electronics for the experimental data and S. J. Kim and S. S. Yang for the computational supports.

References

[1] K. Yoshida, H. Uchiike, and M. Sawa, "Fundamental characteristics of MgO film and their influence in operation of plasma displays," in *Proc. IDW'98*, 1998, pp. 515–518.

[2] A. Shiokawa, Y. Takada, R. Murai, and H. Tanaka, "A γ coefficient measurement of MgO on plasma display panel," in *Proc. IDW'98*, 1998, pp. 519–522.

[3] E. H. Choi, H. J. Oh, Y. G. Kim, J. J. Ko, J. Y. Lim, J. G. Kim, D. I. Kim, G. Cho, and S. O. Kang, "Measurement of secondary electron emission coefficient (γ) of MgO protective layer with various crystallinities," *Jpn. J. Appl. Phys.*, vol. 37, pp. 7015–7018, Dec. 1998.

[4] M. Ishimoto, S. Hidaka, K. Betsui, and T. Shinoda, "Secondary-electron-emission analysis of MgO films in AC plasma displays," in *Proc. Society for Information Display Symp.'99 SID Dig. 1999*, 1999, pp. 552–555.

[5] J. Y. Lim *et al.*, "Influence of gas mixing ratio on the secondary electron emission coefficient (γ) of MgO single crystals with different orientation and MgO protective layer in surface discharge AC-PDPS," in *Proc. IDW'99*, 1999, pp. 639–642.

[6] K. S. Moon, J. H. Lee, and K. W. Whang, "Electron ejection from MgO thin films by low energy noble gas ions: Energy dependence and initial instability of the secondary electron emission coefficient," *J. Appl. Phys.*, vol. 86, pp. 4049–4051, Oct. 1999.

[7] S. J. Yoon, I. Lee, J. W. Lee, and B. Oh, "A theoretical study of the secondary electron emission from MgO surface," in *Proc. IDW'99*, 1999, pp. 643–646.

[8] Y. K. Shin, J. K. Lee, C. H. Shon, and W. Kim, "Ion energy distribution on alternating-current plasma display panel cell," *Jpn. J. Appl. Phys.*, vol. 38, pp. L174–L177, Feb. 1999.

[9] O. Sahni and C. Lanza, "Importance of the dependence of the secondary electron emission coefficient on E/p_0 for Paschen breakdown curves in AC plasma panels," *J. Appl. Phys.*, vol. 47, pp. 1337–1340, Apr. 1976.

[10] Y. Murakami and H. Matsuzaki, "Monte carlo simulation on the effective secondary electron yield γ of a cathode for plasma display panel," in *Proc. Int. Workshop on Basic Aspects of Non-equilibrium Plasmas Interacting With Surfaces*, 1999, pp. 38–38.

[11] Y. K. Shin, C. H. Shon, W. Kim, and J. K. Lee, "The voltage-pulsing effects in AC plasma display panel," *IEEE Trans. Plasma Sci.*, vol. 27, pp. 1366–1371, Oct. 1999.

[12] Y. K. Shin, J. K. Lee, and C. H. Shon, "Two-dimensional breakdown characteristics of PDP cells for varying geometry," *IEEE Trans. Plasma Sci.*, vol. 27, pp. 14–15, Feb. 1999.

[13] C. Punset, S. Cany, and J. P. Boeuf, "Addressing and sustaining in alternating current coplanar plasma display panels," *J. Appl. Phys.*, vol. 86, pp. 124–133, July 1999.

[14] S. Rauf and M. J. Kushner, "Dynamics of a coplanar-electrode plasma display panel cell. I. Basic operation," *J. Appl. Phys.*, vol. 85, pp. 3460–3469, Apr. 1999.

[15] G. Auday, P. Guillot, J. Galy, and H. Brunet, "Experimental study of the effective secondary emission coefficient for rare gases and copper electrodes," *J. Appl. Phys.*, vol. 83, pp. 5917–5921, June 1998.