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PARAMETIC STUDY OF A POSITIVE COLUMN AC PLASMA DISPLAY PANEL CELL.

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Résumé

Les écrans à plasma représentent la technologie la plus prometteuse dans le domaine des écrans plats. Toutefois certaines de leurs caractéristiques nécessitent plus d'améliorations ; à savoir l'efficacité lumineuse. Plusieurs voies s'ouvrent devant les chercheurs afin d'atteindre ce but comme c'est le cas de la décharge à colonne positive. Une étude d'une cellule fonctionnant dans ce régime est effectuée dans ce travail. Le modèle fluide à deux dimensions sur lequel est basée cette étude permet de voir l'effet de la géométrie et des paramètres de la cellule sur l'efficacité lumineuse.

Mots clés: plasma, efficacité lumineuse, distance inter-électrodes, diélectriques.

Abstract

Plasma display panels are becoming one of the major large screens, flat display devices, in spite of their low luminous efficiency, which is about 1 lm/W. Many research works are done to optimize the operation of these panels. A positive column discharge application seems an appreciable solution. A study of a plasma display panel cell functioning in the positive column regime is undertaken. The two-dimensional fluid model on which this work is based shows that the geometry and the physical parameters of the cell play an important role in the limitations of the discharge efficiency. For a sustain electrodes width of 150 µm and a sustain distance (gap) of 566 µm, the efficiency is estimated at more than 46 %.
***Keywords*:** plasma, efficiency, gap, dielectric

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ملخص

إن تلفزيون البلازما يمثل واحد من أهم وسائل التكنولوجيا الحالية نظرا للحجم الكبير للصورة التي يراها المشاهد. نناقش ضمن هذا المقال طرق تحسين الفعالية الضوئية لخلية من التلفزيون و ذلك باستعمال نموذج مائع ثنائي البعد. من اجل ذلك قمنا بدراسة شكل مختلف للخلية و تأثير ذلك على فعالية الغاز في إنتاج الفوتونات فوق البنفسجية و بالتالي على الفعالية الضوئية.
الكلمات المفتاحيـــة :: *البلازما- الفعالية الضوئية- المسرى- السماحية.*

INTRODUCTION

The basic principles of plasma display panels (PDP) were announced in the Sixties at the University of Illinois [1]. Constant progress on materials, processes and electronics allowed the appearance of these panels on the audio-visual market in 1996 [2]. Since then, significant research efforts, both experimental and theoretical, were implemented to optimize the operation and the performances of these plasma display panels and in particular their luminous efficiency. Modeling seems a principal tool to describe the physical phenomena implied in the formation and the extinction of the PDP cell plasma. We have access then to quantities, which are not easily measurable because of the size of the cells and the speed of the phenomena. Various models were employed: 1D, 2D and more recently 3D models [3-8]. The results presented in this work are based on a two dimensional fluid model [9].

One way to increase the discharge efficiency of a PDP is to change the cell geometry and/or the electrodes design as in the case T electrode shape [10] or auxiliary electrodes PDP [11]. The simulation results show that in order to have high discharge efficiency it is necessary to make either a wider positive column discharge (i.e. to favorite the formation of the positive column plasma) or to enlarge the anode region as compared to the cathode region. One simple way is to increase the gap between the sustain electrodes. The positive column AC PDP regime has been described by Weber [12] and by simulation [13-18].

An electric discharge contains primarily two distinct luminous regions; the negative glow where plasma exists with an excess of ions and the positive column where plasma marks a balance between the ions and the electrons. While the alternative plasma panels commercialized until now function in the mode of glow discharge producing the major part of its light from the negative glow, the positive column did not have any application in this field in spite of the impressive results given in the fluorescent lamps. The use of a discharge for a cell of plasma display panel functioning in this mode is currently an appreciable solution in order to improve the efficiency of the plasma panels. In this type of discharge, the distance separating the sustain electrodes is 5 to 6 times larger than that of the standard plasma display panels. Both of experiments and simulations indicate an efficiency of the positive column discharge twice more than that of the standard panels.

A coplanar plasma display panel cell working at a positive column regime is studied in this paper. The cell is defined by the intersection of an electrode known as a column and two parallel electrodes, known as lines. The electrodes are deposited on two glass plates representing the two panel faces. These two plates are placed at approximately 100 µm of each other. The parallel sustain electrodes deposited on the front plate are covered with a dielectric layer and a protective coating of oxide of magnesium (MgO). Dielectric barriers separate the electrode columns in order to minimize the electrical and optical interactions between the close cells. The space between the two plates is filled with a mixture of rare gases, xenon and neon (or helium) with a pressure of about 300 to 500 torr. The UV radiation emitted by the gas mixture will be converted into visible radiation by excitation of phosphors deposited in each cell.

The description of the physical model used in this work is presented in Sec.II. In Sec.III. the computation results are given. Finally the cell geometry and technology effects on the efficiency are discussed.

II. DESCRIPTION OF THE MODEL

A. Physical model

We have used the discharge modeling software SIPDP-AC [9]. It is a two-dimensional physical model describing the cell similar to the one used in Refs. [4, 19]. It is based on the continuity and the simplified momentum-transfer equations for electrons and ions, coupled with Poisson's equation for the electric field:

$$\frac{\partial \mathrm{n_e}}{\partial t} + \nabla.\left(n_e \bar{v}_e\right) = S_e \quad (1)$$

$$n_e \bar{v}_e = -n_e \mu_e E - D_e \nabla n_e \quad (2)$$

$$\frac{\partial \mathrm{n_p}}{\partial t} + \nabla.\left(n_p \bar{v}_p\right) = S_p \quad (3)$$

$$n_p \bar{v}_p = n_p \mu_p E - D_p \nabla n_p \quad (4)$$

$$\nabla \varepsilon_r \ \mathrm{E} = \frac{|\,\mathrm{e}\,|}{\varepsilon_0}\left(n_p - n_e\right) \quad (5)$$

where ne is the electron density, np the positive ion density. The index p in the equations refers to xenon or neon ions. $\bar{v}_e$ and $\bar{v}_p$ represent the mean velocity for electrons and ions, respectively. Se(r, t) and Sp(r, t) are the production rates for electrons and ions respectively. The mobilities µe and µp are function of the reduced electric field E/p. De and Dp are respectively the electrons and ions diffusion coefficients. The D/µ are set to constant values. εr is the relative permittivity and e is the unit charge. Equations (1) and (3) are the electron and positive-ion continuity equations, Eq. (2) and (4) are the simplified momentum-transfer equation for electrons and ions, and Eq. (5) is Poisson's equation.

These equations 1-5 describe all the regions of the discharge, i.e. the positive column and the sheath. There are discredit zed by the scharfetter and Gummel scheme [20, 21] and are integrated in time to determine the space-time evolution of the variables and the derived quantities.

Boundary conditions

The boundary conditions on the sides of the simulation are as follows:
The charged particle flux to a dielectric surface is written,

$$\varphi = a\, n_{e,p}\, W_{e,p} + n_{e,p}\, V_{th\, e,p}/4 \qquad (6)$$

Where ne, p is the charged particle density (electron or ion) at the surface, We, p the drift velocity perpendicular to the wall (We, p= ± μe, p E) and Vth e, p the thermal velocity (electron or ion). The parameter 'a' is set to 1 if the drift velocity is directed toward the wall and is otherwise set to zero.
In order to take account the charges accumulated in the interface Dielectric-gas, the condition on the charged density is written as:

$$\sigma = [\varepsilon_0 E_0 - \varepsilon_1 E_1]\, n_s \qquad (7)$$

Where E0 and E1 are the electric fields in the gas and in the dielectric respectively at the interface gas-dielectric, ε0 and ε1 are the permittivity of the gas and the dielectric respectively, and ns is a vector normal to the surface and directed to the gaseous space
The final boundary condition needed to fully define the problem is the relation between the electron current leaving the cathode and the incident ion current. These quantities are related through the secondary electron emission coefficient, γ, as follows:

$$\varphi_e\,(\text{cathode}) = \Sigma_k\, \gamma_k\, \varphi_k\,(\text{cathode}) \qquad (8)$$

Where the sum is over all ion species, γk is the secondary electron emission coefficient due to the kth type of ion incident on the cathode, and φk is the flux of the kth type of ion to the cathode.

Energy dissipation in the cell and efficiency

The total electric power is dissipated in the discharge by electrons and ions. A large part of this energy is dissipated by ions-neutral atoms collisions (heating effect). However, from the remaining part of this total power, an important quantity is dissipated by electron impact ionization of xenon and neon. and a small quantity is used to excite xenon atoms. This leads to a low efficiency of the ultra-violet photons production. [15, 22]. The energy balance of a typical PDP discharge is represented in figure.1.

The discharge efficiency of exciting xenon atoms represents the relationship between the energy dissipated by the electrons in the xenon excitation and the total electric power [9, 23-25]. It is defined by the ratio

$$\eta = \frac{E_{\varepsilon,\, Xe^*}}{E_{tot}} \qquad (9)$$

Where the total energy deposited in the discharge is given by:

$$E_{tot} = \int (p_e + p_i)\, d^3r\, dt \qquad (10)$$

where pe and pi are the power densities dissipated by the electrons and the ions respectively.
$p_e = \vec{J}_e . \vec{E}$ and $p_i = \vec{J}_i . \vec{E}$ where Je and Ji are the current densities of the electrons and the ions respectively and E is the electric field.
The energy dissipated by the electrons in the xenon excitation is defined as:

$$E_{\varepsilon,\, Xe^*} = \int_{t_0}^{t} S_{\varepsilon,\, Xe^*}\, dt \qquad (11)$$

t0 being the time start of the impulse.
S ε, Xe * is the power deposited by the electrons in the xenon excitation process. It is equal to:

$$S_{\varepsilon,\, Xe^*} = n_e\, |V_e|\, \delta_{Xe^*} \qquad (12)$$

Where ε is the threshold energy, ne is the electron density, Ve the electron velocity, δXe* is the excitation loss coefficient for xenon which is pre-calculated as a function of E/P (E is the electric field, P is the pressure).

III.Results and discussions

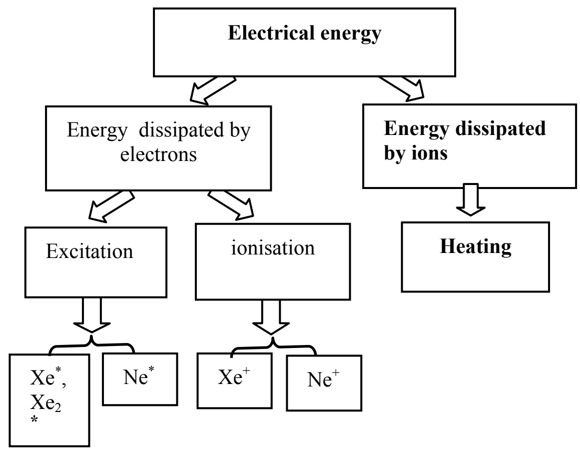


Figure.1. Schematic of the discharge energy deposited in the cell.

The results obtained in this work are those of a coplanar plasma display panel cell working at a positive column regime [13]. Fig.2. shows the simulated operating conditions for the 2D Cartesian geometry. The secondary emission coefficients of xenon and neon are equal to 0.05 and 0.5 respectively. The dielectric covering the sustain electrodes (coplanar) has a relative permittivity of 10. The width of these electrodes is equal to 150 µm. The gas mixture is Xe (10%)-Ne at 500 torr pressure.

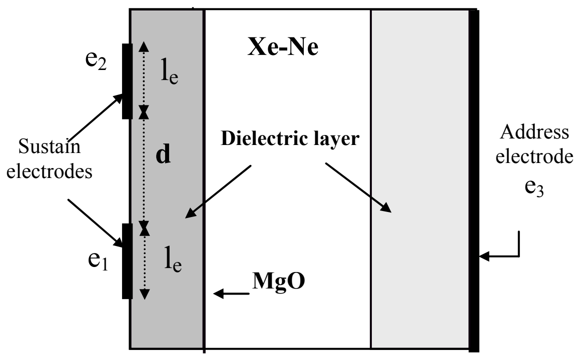


Figure.2. A model of the cell geometry is shown schematically.

The applied voltage sequences to the cell are represented in the figure.3. To initiate the discharge, i.e. during the address period, it is necessary to apply a voltage superior to the breackdown voltage. According to refs [12,14,17,23] we have estimate an address voltage of 500 V. The second period, which consists of the pulse sequences that follow, corresponds to the sustaining period of the cell. A voltage equal to 280V is then applied alternatively between the coplanar electrodes. The voltage applied to the address electrode during all these pulses is, as shown in Fig.3, biased to zero voltage. The duration of each voltage pulse is 3 µs.

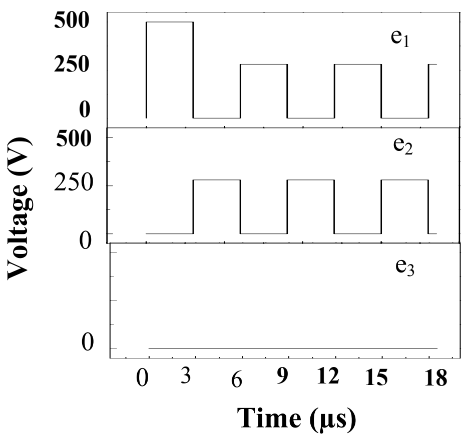


Figure.3. Typical driving voltage sequence applied to the cell electrodes.

Fig.4. shows the temporal variation of the excitation efficiency during several pulses. The duration of each one is 3 µs. The excitation of xenon atoms becomes more significant with each pulse. The discharge efficiency rises from a value of 41 %, at the first sustain pulse, to a value of 45 % at the steady state sustaining regime.

In order to improve the efficiency of the discharge to excite xenon atoms, a parametric study was undertaken by looking at the influence of the geometry and the technology of the cell.

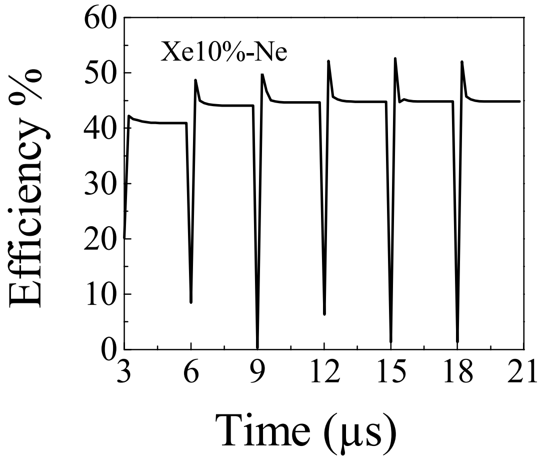


Figure. 4. Temporal evolution of the discharge efficiency

To investigate the effect of the positive column, the discharge efficiency was calculated for various length of the gap (distance between the sustain electrodes). Figure 5 confirms the linear increase of the efficiency with the gap lengths [12, 14]. At first, let say that the electric field is the integral of the potential, which is the sum of the dielectric potential and the gas one. Increasing the distance between the sustain electrodes will reduce their mutual capacitance, and therefore the electric field, which is proortional to capacitance [6]. On the other hand, this reduction of the electric fields due to the increase in the coplanar electrodes gap induces the rise of the electric energy part deposited by xenon excitation. During this discharge regime, the ion dissipation in the sheath is lower and most of the xenon excitation occurs in the plasma column and not in the sheath region, which is close to the sustain electrode, e1. There are the principal reasons why the excitation efficiency is then significantly better for high values of the coplanar electrodes gap.

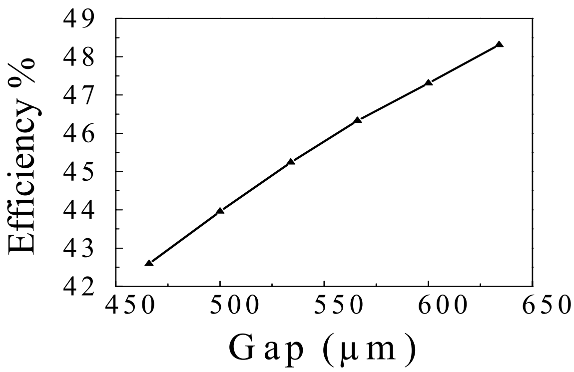


Figure.5. Effect of the coplanar electrodes gap on the discharge efficiency.

Fig.6. shows the effect of the sustain electrodes width on the excitation efficiency. It is noted that the proportion of the total electric power deposited by the electrons in the xenon excitation increases for broader electrodes. The behavior of the efficiency is similar to that observed by S. Rauf et al. [6] in standard PDPs operating at the mode of glow discharge.

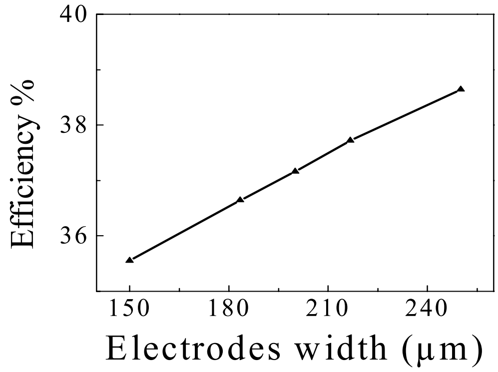


Figure 6. Effect of the coplanar electrodes width on the discharge efficiency.

The variation of the xenon excitation efficiency according to the relative permittivity of the dielectric covering the address electrode, εr2 is shown in the figure 7. As εr is increased, the address dielectric capacitance increases. In this condition it will be difficult to ignite and sustain a discharge between the coplanar electrodes. The current density on the sustain electrodes decreases leading to less xenon excitation. The efficiency is then reduced. Fig.7. shows that, as has suggested Weber [12], in the case of a positive column discharge, the dielectric covering the address electrode must have a low permittivity. In this condition only a small current will flow between the address electrode and the coplanar electrodes, and the corresponding discharge will help to initiate the main discharge between the two coplanar electrodes. This main discharge is more efficient than in standard PDP cells [15, 26-27].

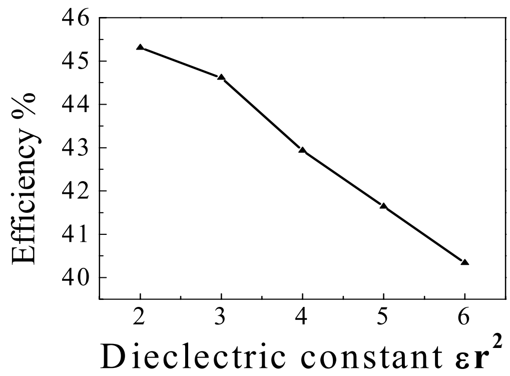


Figure.7. The discharge efficiency as a function of the relative permittivity of the dielectric covering the address electrode.

The excitation efficiency is calculated for various pressures and for two concentrations of the gas mixture (Xe5%-Ne and Xe10%-Ne) as shown in Fig.8. For each concentration of the xenon in the xenon-neon mixture, the efficiency increases with pressure, and it is also more significant for more important values of concentrations leading to a more important UV emission efficiency [28-29].

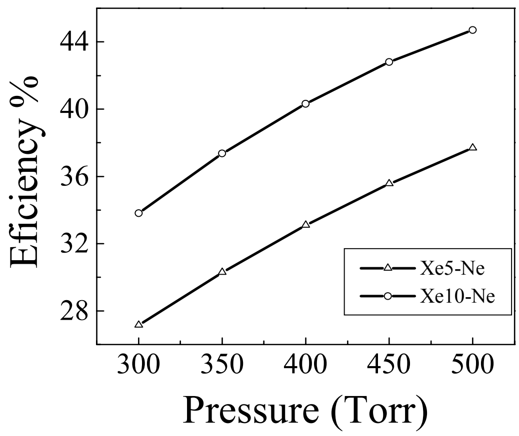
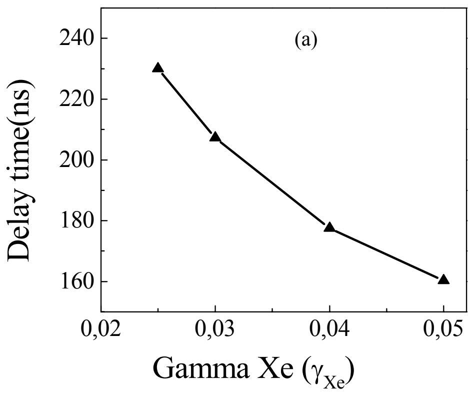


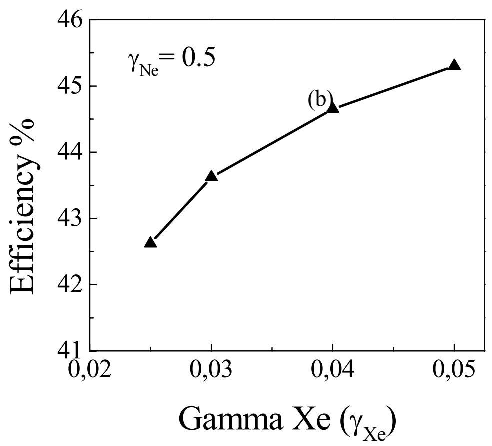
Figure..8. The discharge efficiency as a function of the total pressure for two mixtures of gas; Xe5%- Ne and Xe10%-Ne.

In order to study, the effect of the secondary electron emission due to ions impact, we plotted in figures 9 and 10 the breakdown delay time and the discharge efficiency for xenon and neon respectively. The breakdown time depends strongly on the secondary electron emission as shown in figure 9-a and figure 10-a (the breakdown time is defined as the time when the current density reaches 10% of its maximum value). When the flow of electrons extracted from the MgO increases as layer compared to that of the incident ions (xenon or neon), the current density grows in the plasma and the plasma formation time decreases. From Figs. 9-b and 10-b it appears clearly that the discharge efficiency is very sensible to the secondary emission due to xenon and neon ions.

Figure.9. Variation according to the xenon secondary emission coefficient. of :

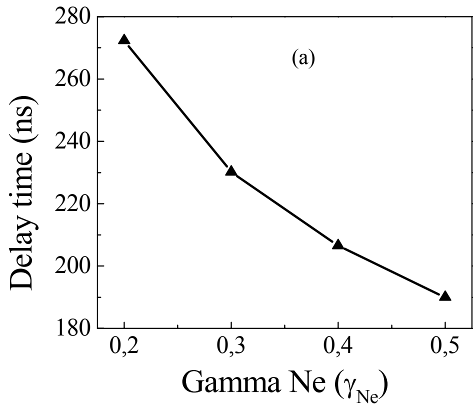


a) the delay time.

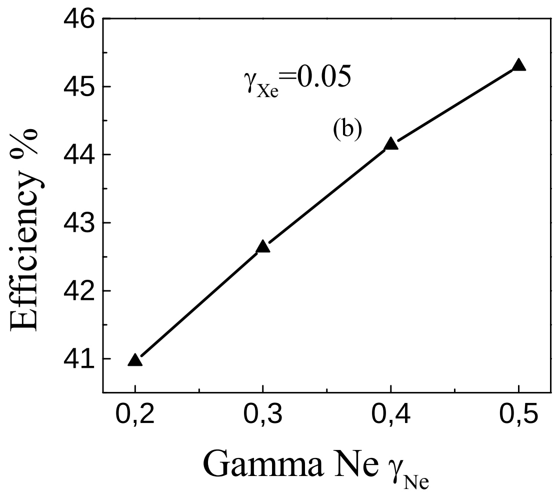


b) the xenon excitation efficiency. The sustain voltage is equal to 290 V. The neon gamma is equal to 0.5.

Figure. 10. Variation according to the neon secondary emission coefficient of:



a) the delay time.



b) the efficiency. The xenon gamma is equal to 0.05.

CONCLUSION

A coplanar plasma display panel cell working at a positive column regime has been analyzed for a variety of operating conditions and cell dimensions.
The plasma display panel cell will be more efficient for sustain electrodes broader and/or more distant from each other. For a sustain electrodes width of 150 µm and a sustain distance (gap) of 566 µm, the efficiency is estimated at more than 46 %. This study also illustrates that a low permittivity of the dielectric covering the address electrode allows a significant excitation of xenon and thus a great light emission. The use of materials having important secondary emission coefficients for xenon and neon is essential to improve the PDP luminous efficiency. Finally, the results show that the geometry and the physical parameters of the cell play an important role in the limitations of the discharge efficiency, and it is necessary to operate at large gap lengths.

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