THIN FILM PC-EL TYPE SYSTEM WITH CHOPPER IN THE PATH OF OPTICAL FEEDBACK

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(Received March 22, 1989; in final form May 1, 1989)

1. INTRODUCTION

Thin film systems of PC-EL type obtained by series connection of a photoconducting element /PC/ with an electroluminescent cell /EL/ are interesting because of their possible application for various kinds of optoelectronic systems.^{1,2}

Particularly interesting are PC-EL systems with optical feedback, which at suitable high values of the feedback coefficient can be of bi-stable character.

High values of the feedback coefficient are technically difficult to obtain. However, at low values of this coefficient, it is possible to obtain a bi-stable system if a chopper is employed in the path of optical feedback.

2. THEORETICAL CONSIDERATIONS

For analysis of properties of thin film PC-EL system with optical feedback, a theoretical model³ developed on the basis of an equivalent circuit shown in Fig. 1 was investigated.

The admittance Y_{EL} of an electroluminescent cell is described by the formula:

$$Y_{EL} = G_{EL} + j\omega C_{EL} \quad (1)$$

FIGURE 1 Equivalent circuit of a PC-EL system.

where $\omega = 2\pi f$, f is the frequency of the alternating exciting sinusoidal voltage, G_{EL} is the leakage conductance of the electroluminescent cell and C_{EL} is the capacitance of the cell.

The admittance Y_{PC} of a photoconductive element is given⁴ by the formula:

$$Y_{PC} = G_0 + g_1 (1 + \omega^2 \tau^2)^{-1} L_{TOT} + j\omega C_{PC} \quad (2)$$

where G_0 is the “dark” conductance of the photoconductive element, g_1 and τ are parameters that are constant for a given photoconductive element, C_{PC} is the capacitance of the element and L_{TOT} is the total illumination of the element.

For a thin film PC-EL system with optical feedback,

$$L_{TOT} = L + \beta B \quad (3)$$

where L is the external illumination, B is the luminance of the light emitted by an electroluminescent cell and β is a constant, determined by geometry and by the degree of spectral overlap of the electroluminescent cell and the photoconductive element.

The instance of the break in the path of optical feedback, the coefficient $\beta = 0$.

To describe the luminance B of the electroluminescent cell, Alfrey and Taylor's⁵ formula was used:

$$B = B_0 \exp\left(\frac{-\gamma\pi}{2\omega}\right) \exp(-b U_{EL}^{-1/2}) \quad (4)$$

where B_0 , γ , and b are constant parameters for a given electroluminescent cell,

$$U_{EL} = \left| \frac{Y_{PC}}{Y_{EL} + Y_{PC}} \right| U_0$$

and U_0 is the amplitude of the applied sinusoidal voltage.

For a real PC-EL system, three additional simplifying assumptions are usually fulfilled:

$$C_{PC} \ll C_{EL}; \quad \omega C_{EL} \gg G_0; \quad \omega C_{EL} \gg G_{EL}.$$

Then the dependence of the average value of the luminance B on the external intensity L of illumination can be expressed as follows:

$$B = B_0 \exp\left(\frac{-\gamma\pi}{2\omega}\right) \exp\left\{ \frac{-b}{\sqrt{U_0}} \left(1 + \left[\frac{\omega C_{EL}}{G_0 + g_1(L + \beta B)(1 + \omega^2 \tau^2)^{-1}} \right]^2 \right)^{1/4} \right\} \quad (5)$$

The characteristics calculated from eq. (5), the dependence of the luminance B on the external illumination L , are shown in Fig. 2 for several values of the feedback coefficient β . It can be seen that for values of β greater than β_{LIM} a thin film PC-EL system with optical feedback has a negative slope and a bi-stable nature.

For the PC-EL system, for which the coefficient $\beta > 0$, in the moment of a break in the path of optical feedback, a transition from the characteristic for $\beta > 0$ to the characteristic for $\beta = 0$ (Fig. 2), takes place.

FIGURE 2 B vs. L theoretical characteristics of a PC-EL system.

The dynamic properties of thin film PC-EL system with optical feedback can be described as developed in an earlier work³ using three equations:

$$\frac{d}{dt}\Delta n = \alpha\eta[L + \beta B(t)] - \frac{\Delta n}{\tau_1} \quad (6)$$

where Δn is the density of excess carriers, α is the light absorption coefficient, η is the quantum yield and τ_1 is the photoconductivity rise time,

$$\begin{aligned} C_{EL} \frac{d}{dt} U_{EL}(t) + U_{EL}(t) [G_{EL} + G_0 + g_1 \Delta n] \\ = C_{PC} \frac{d}{dt} U_e + [G_0 + g_1 \Delta n] U_e \end{aligned} \quad (7)$$

where g_1 is a constant parameter and U_e is the instantaneous value of the exciting voltage of a PC-EL system, and

FIGURE 3 The arrangement of the thin film PC-EL system with optical feedback.

$$B(t) = B_0 \exp(-\gamma t) \exp[-b|U_{\text{EL}}(t)|^{-1/2}] \quad (8)$$

The dependence of the luminance $B(t)$ on the time can be calculated by using equations (6), (7) and (8) for values of coefficient $\beta > 0$ and $\beta = 0$.

3. EXPERIMENTAL DETAILS AND RESULTS

The photoconductive element and electroluminescent cell (Fig. 3) were prepared as a sandwich-type system on a glass substrate. A cadmium sulphide thin film photoconductive element and a zinc sulphide thin film electroluminescent cell were prepared by vacuum evaporation.³

A sinusoidal voltage of fixed amplitude and frequency was applied to the PC-EL system. The luminance B of the electroluminescent cell was measured for various intensities L of illumination of the photoconductive layer and for values of $\beta < \beta_{\text{LIM}}$. The results were compared with values computed using the above theoretical model.

Based on the measurements of the dependence of luminance B on the illumination intensity L , for $\beta > 0$ as well as for $\beta = 0$, the dependence

FIGURE 4 Dependence of ΔB on the illumination intensity for the frequency of 100, 200, 500 and 1000 Hz / $\beta = 0.7 \text{ lx.m}^2.\text{cd}$.

$\Delta B = B_{(\beta>0)} - B_{(\beta=0)}$ on illumination intensity was calculated. The measurements were carried out for the frequencies of 100, 200, 500 and 1000 Hz of the voltage applied to the PC-EL system. The dependences of ΔB from L are shown in Fig. 4.

As can be seen from this figure, the curve $\Delta B(L)$ reveals a maximum. The position of this maximum on the curve shifts with frequency towards higher values of luminance. The highest value ΔB was found for the frequency 200 Hz, at 2 lx of the intensity of luminance.

For fixed values of illumination intensity $L = 5 \text{ lx}$ and frequency 500 Hz, the dependence of the luminance B on time for a PC-EL system with optical feedback ($\beta = 0.7 \text{ lx.m}^2.\text{cd}^{-1}$), and for this system in the moment of a break in the path of optical feedback ($\beta = 0$), was measured. A break in the path of optical feedback was obtained using a rotating disk with cut-out sectors (chopper), with the frequency of the breaks considerably lower than the frequency of the voltage supplying the PC-EL system. The obtained characteristic is presented in Fig. 5.

FIGURE 5 Dependence of the luminance B on time for $f = 500$ Hz (— experimental results, --- values calculated using the theoretical model).

4. CONCLUSIONS

From experimental measurements and theoretical considerations, a thin film PC-EL system with optical feedback can be a bi-stable system, even for low values of feedback coefficient, upon use of a chopper in the path of optical feedback.

The output signal of the PC-EL system in the form of the luminance B of the light emitted from the electroluminescent cell assumes two different values for the same luminance intensity constituting the input signal. The first is a signal of the PC-EL system with optical feedback [$\beta > 0$], and the second a signal of the system without feedback [break in the path of optical feedback, $\beta = 0$].

The difference of these two values, ΔB , depends on the frequency of the voltage supplying the system and on the luminance intensity.

The obtained characteristics show a good agreement with the curves calculated on the base of proposed theoretical model.

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