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Brightness-Current-Voltage Characteristics of Bilayer Organic Light-Emitting Diodes

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Abstract

The present paper reports the brightness-current-voltage characteristics of bilayer organic light-emitting diodes. The OLEDs work as follows. Electrons and holes are injected in a stack of layers of organic molecular or polymeric semiconducting materials, in which they are transported under the influence of an applied bias voltage and their mutual Coulombic interactions either to the collecting electrode or to each other. When electrons and holes meet, they recombine to form a bound electron-hole pair, called exciton, which can decay radiatively giving rise to the emission of a photon. At low voltage the charge injection process should be from the thermionic emission and it should follow the Richardson-Schottky process of charge carrier injection. For high values of applied voltage, the plot of $\ln(I/V^2)$ versus (1/V) is a straight line with negative slope .This result indicates that, at high voltage the charge injection in OLEDs follows Nordiem fowler equation.

Key words: OLED, Charge injection,Richardson- Schottky equation,Nordeim-Fowler equation.

1. INTRODUCTION

Organic light-emitting diodes (OLEDs) are promising high-efficiency lighting sources having great potential for flat-panel displays and solid state lighting devices [1,2].The OLEDs work as follows. Electrons and holes are injected in a stack of layers of organic molecular or polymeric semiconducting materials, in which they are transported under the influence of an applied bias voltage and their mutual Coulombic interactions either to the collecting electrode or to each other. When electrons and holes meet, they recombine to form a bound electron-hole pair, called exciton, which can decay radiatively giving rise to the emission of a photon. Due to the amorphous nature of the organic materials used, charge carriers are transported by means of hopping between neighboring molecules or segments of a polymer. The energy levels of the hopping sites are assumed to be randomly distributed according to a Gaussian density of states (DOS). In the past, after the investigation of OLEDs having low operating voltage, the theoretical understanding of the transport of charge carriers through this disordered energetic landscape of sites has grown substantially. The further development of a predictive model describing all important electronic processes in OLEDs such as charge-carrier transport, the injection of charge carriers, the recombination of electrons and holes, the formation and motion of excitons and the luminescent decay of excitons, are of profound importance to enhance the efficiency and lifetime of OLEDs. The present paper reports the brightness-current-voltage characteristics of bilayer organic light-emitting diodes

2. THEORY AND EXPERIMENTAL SUPPORT

Tang et al.[3] have studied practically the dependence of current and EL brightness on the applied voltage for undoped and doped organic thin films ,in which the OLED structure was : (a) ITO/diamine/ doped Alq_3/Mg:Ag, (b) ITO/ diamine/Alq/ Mg:Ag. Fig.1 shows the light-current-voltage characteristics for an undoped cell: ITO/diamine (750 Å)/Alq (600Å)/Mg:Ag. It is seen that, both the current and brightness increase with increasing values of the applied voltage.

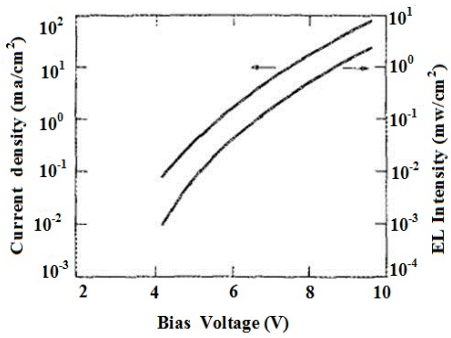

Fig.1. Light-current-voltage characteristics for an undoped cell: ITO/diamine(750Å)/Alq (600Å)/Mg:Ag (after ref. [1]).

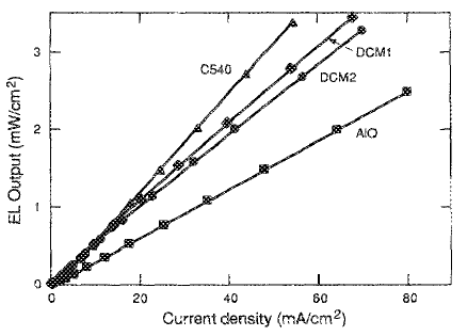

Fig. 2. Brightness-current characteristics for doped and undoped EL cells (after ref. [1]).

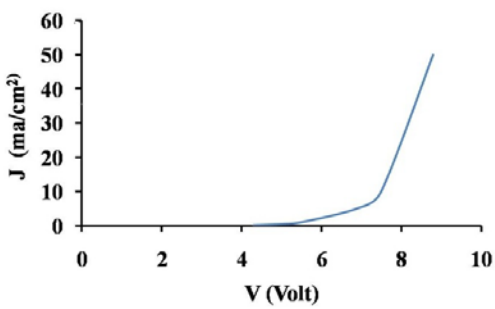

Fig. 3. Dependence of Current density on the applied voltage for Al/Diamine/Alq_3/Mg:Ag OLED.

Fig.1.shows the light-current-voltage characteristics for an undoped cell: ITO/diamine(750Å)/Alq (600Å)/Mg:Ag (after ref. [1]).

Fig. 2.shows the dependence of EL brightness on the current flowing through the OLED. It is evident that the EL brightness increases linearly with the current flowing through the OLED. This fact clearly indicates that the charge carrier recombination is respc

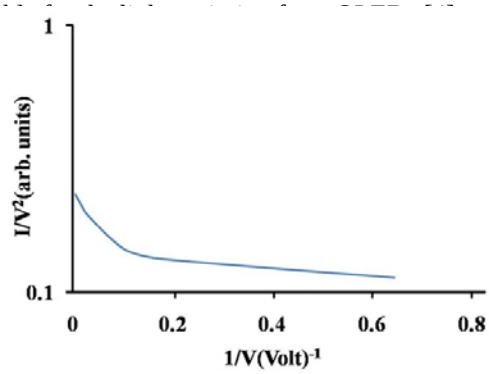

Fig. 4. Semilog plot of I/V^2 versus 1/V for Al/Diamine /Alq_3/Mg:Ag OLED.

Fig. 3. Illustrates the dependence of the current flowing through the OLEDs on the applied voltage. It is seen that, initially the current increases linearly with applied voltage and for the higher values of applied voltage the current increases nonlinearly with the applied voltage. This fact indicates that, for low values of applied voltage the current-voltage relation is ohmic: however, for higher values of applied voltage the current-voltage relation is non-ohmic. Thus it seems that, at low voltage the charge injection process should be from the thermionic emission and it should follow the Richardson-Schottky process of charge carrier injection.

Fig. 4. shows that for high values of applied voltage, the plot of $\ln(I/V^2)$ versus (1/V) is a straight line with negative slope .This result indicates that, at high voltage the charge injection in OLEDs follows Nordeim Fowler equation.

In fact, there are following four types of carrier injection mechanisms in OLEDs [5]:

(i) Field-assisted thermionic injection over the image force barrier: strong gradient of J_x (x)

In this case, the dependence of J on F is given by

$$J = AF^{3/4}\exp(a_s F^{1/2}) \qquad (1)$$

where $a_s = \left(\frac{q}{kT}\right)\left(\frac{q}{4\pi\varepsilon\varepsilon_0}\right)^{1/2}$ and A is the constant

(ii) Field assisted thermionic injection over the image force barrier :the one-dimensional Onsager model.

In this case, the relation between J and F can be expressed as

$$J = A_0 F^{3/2} \exp(a_s F^{1/2}) \quad (2)$$

where A_0 is a constant

(iii) Cold emission: tunneling through the triangular barrier

In this case, the dependence of J on F is given by

$$J = BF^2 \exp\left(-\frac{b'}{F}\right) \quad (3)$$

where B and b' are constants

(iv) Cold emission :primary carrier penetration over image force barriers

In this case, the relation between J and F is given by:

$$J = J_0 \exp\left(-\frac{C}{F^2}\right) \quad (4)$$

where J and C are constants.

3. CONCLUSION

In the ITO/Diamine/Alq_3/Mg:Ag OLED, at lower fields, Richardson-Schottky thermionic emission model is applicable for the charge carrier injection; however, at higher field , the field dependence of current follows Fowler-Nordeim formula for the charge carrier injection.,

References :

1. J. Shinar, Organic Light-Emitting Diodes, Springer Berlin, (2004).
2. F. So, (ed.), Organic Electronics-Materials, Processing, Devices and Applications; CRC Press: Boca Raton,

   FL, 2010.
3. C. W. Tang, S. A. VanSlyke, and C. H. Chen, J. Appl. Phys. 65 (1989) 3610-3616.
4. V. K. Chandra and B.P. Chandra, Organic Electronics13(2012)329-334.
5. J.Kalinowski, J. Phys. D: Appl. Phys., 32, (1999)R179-R250