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Organic Polymer Thick Film Light Emitting Diodes (PTF-OLED)

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Abstract

A guest-host approach was used to fabricate a 1-layer OLED with performance approaching a typical hetero-junction type device. The thick film ink approach allows the 2-dimension OLED to be processed using traditional methods such as silk-screen printing. The I-V-L characteristics of the PTF-OLED were studied as a function of the device chemical compositions and physical configurations. Different polymers, hole and electron transporters, and emitters at different weight ratios were studied for its composition dependence. Device configuration also plays a significant role on its overall performance. Dependence on film thickness, electrode type, and the usage of additional charge injection layers (CIL) was also investigated. The simplified 1-layer device allows straight-forward interpretation of the charge-transport and recombination phenomena which shed light for future improvement.

Keywords : Polymer thick film inks, organic light emitting diodes, poly(N-vinyl carbazole)

Introduction

Polymer thick film ink is an important element in the building of a hybrid circuitry.[1] Two types of thick film ink are polymer thick film (PTF) and ceramic thick film (CTF) inks. CTF required a high firing temperature (over 300 °C) and has large thermal mismatch with the substrate (usually ceramic). PTF, however, can be applied even at room temperature. It also has excellent compatibility with various types of substrate but usually with a lower tolerance limit. The development of polymeric OLED allows sophisticated components such as diodes, switches, transducers, sensors, photo-cells and other electro-optics to be incorporated into the hybrid structure easily.

In this guest-host approach, the polymer performed as a binder for the other lower molecule weight organic molecules. It also provides improved thermal stability (high Tg polymers), environmental stability (moisture barrier polymers), and interfacial adhesion (low surface energy polymers) for the organic layer. Unlike conductive polymer-based OLED[2], complicated formulation can be achieved without additional chemistry. A typical PTF-OLED composed of: polymer, hole-transporter (HT), electron transporter, emitter/s, sensitizer, and stabilizer, etc. The limitations for the PTF-OLED are common solubility for the different constituents, and maintenance of operation temperature below the lower critical solubility temperature (LCST).

In this report, the construction and performance of a series of polymeric guest-host type OLED will be described. We shall examine the I-V-L properties of OLED as a function of the device configuration (film thickness, electrode, and CIL) and of its compositions (composition, additives, etc.). Data analysis on the various I-V-L regions was performed to determine the overall transport mechanism and critical performance criterion.

Experiemntal

The ITO glass (94 and 72 ohm/sq) is cleansed thoroughly using method described earlier.[3-4] The organic compounds and polymers are synthesized in our lab. or from commercial sources. They are all purified either by re-precipitation or sublimation before used. A reference system consists of poly(N-vinyl carbazole) (PVK) filled with HT, ET, emitter and a range of additives at different weight ratios. A typical HT is an aromatic diamine, N,N'-diphenyl-N,N'-(3-methyl phenyl)-1,1'-biphenyl-4,4'-diamine (TPD) and a typical ET (and emitter) is tris(8-hydroxquinoline) Al(III) complex (Alq_3). The polymer thin film is spun coated on the ITO glass from a chloroform solution and then dried thoroughly. A general OLED cell has the structure ITO(94 ohm/sq)/polymer + HT + EL(1000 Å)/cathode(Ag or Al, 800 Å).

Results and Discussion

(i) Polymer Matrix. A series of engineering plastics with glass transition temperature ranging from 150 to 350 °C and refractive index from 1.6 to 1.7were used. They are poly(N-vinyl carbazole) (PVK), polycarbonate (PC), polyimide (PI), polyetherimide +(PEI), polyamide-imide (PAI), polysulfone (PS), polyethersulfone (PES). The onset voltage was found to depend on the film thickness, polymer types and work function of

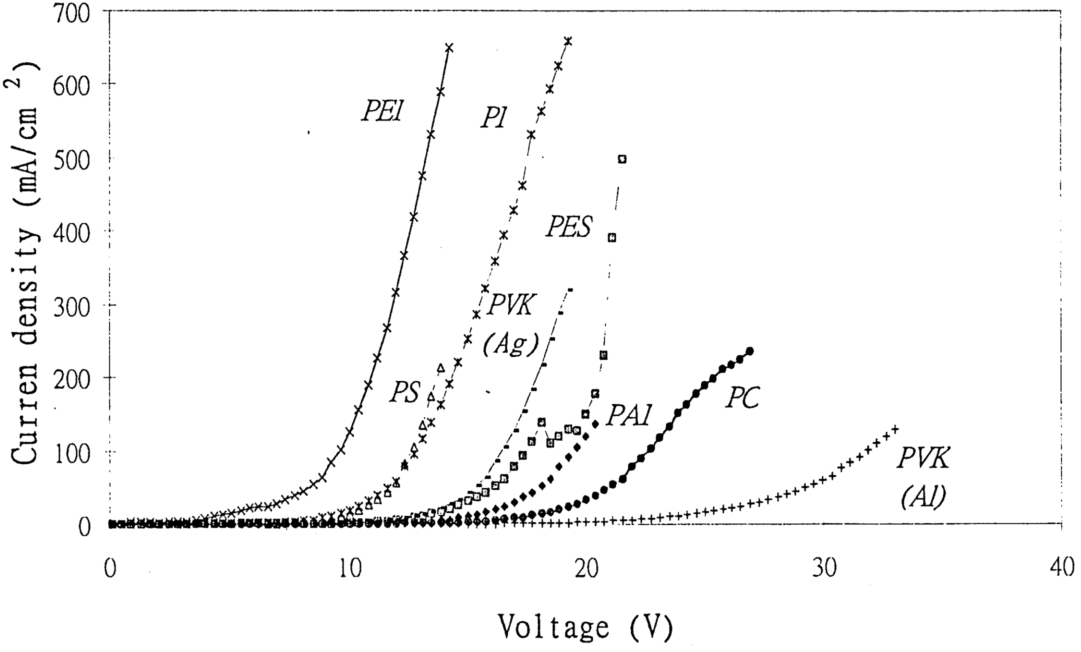

Figure 1 I-V characteristics of PTF-OLEDs using various engineering plastics.
(The cathode is Al except indicated otherwise.)

the cathode. (see Figure 1) Either PC and PVK has the highest luminous efficiency in which both has large energy band gap. The EL spectrum has the characteristic emission of Alq_3, except PI has an additional maximum at 680 nm which was related to the chain rigidity rather than microcavitation[4] or its chemistry. Polyimide with the highest Tg (350 °C) also has the best thermal stability and tolerate up to 150 mA/cm^2.

(ii) Polymer Composition. Using PVK as the reference material, a series of OLED with different polymer to organic ratios were studied. It is found that for less than 50 wt % polymer, the OLED shows sufficient high luminous efficiency (a percolation limit). The onset voltage, however, varied continuously with the polymer composition with no indication of a percolation threshold. (see Figure 2) Maximum brightness is achieved for

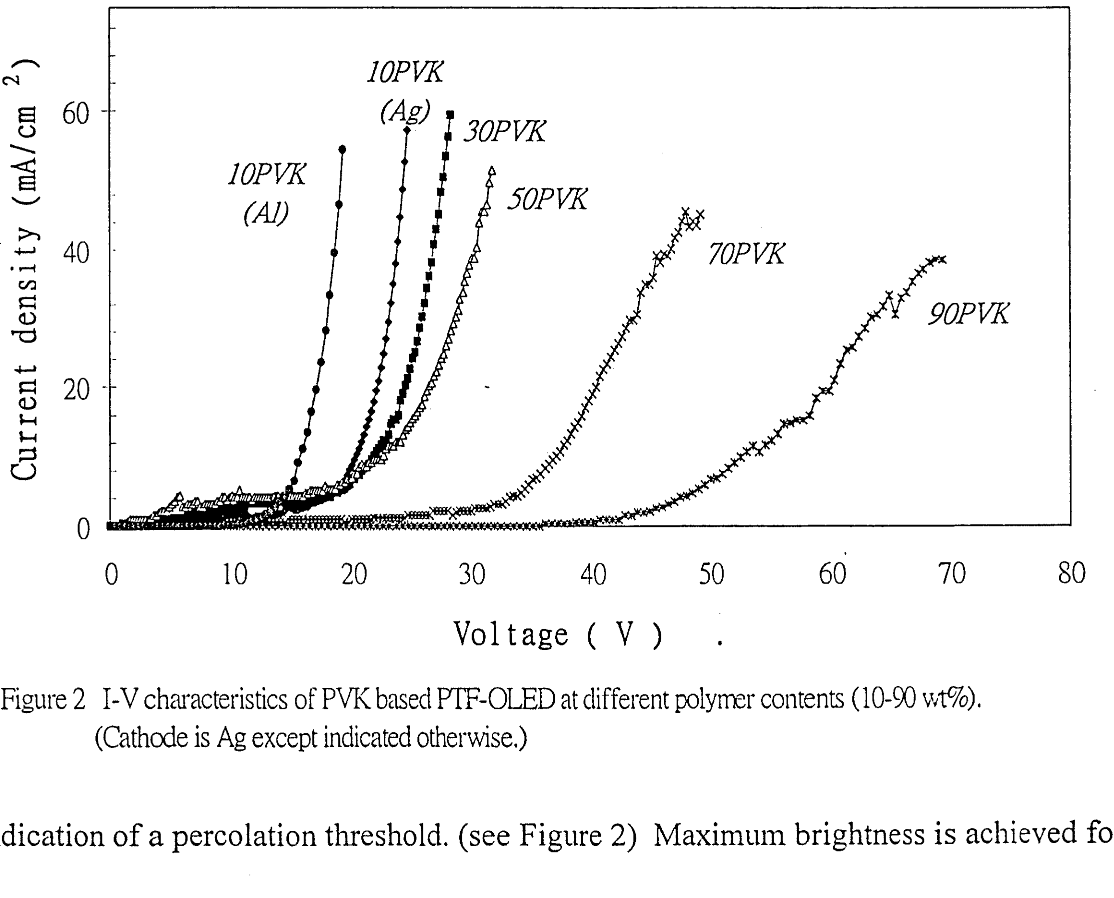

Figure 2 I-V characteristics of PVK based PTF-OLED at different polymer contents (10-90 wt%). (Cathode is Ag except indicated otherwise.)

OLED with 30 % PVK which maybe due to self-quenching at higher dye concentration as well as efficiency in energy transfer from PVK to the emitter.

(iii) Film thickness. With 30 wt % PVK, a series of PTF-OLED with different film thickness were prepared by adjustment on the spin coating RPM and solution concentration. The film thickness was measured by a profilometer. A maximum in luminous intensity as a function of the film thickness is determined at around 1000 Å. The maximum is related to the diffusion length of the exciton^5 (lower intensity at smaller thickness) and absorptivity (lower intensity at high thickness) of the matrix. (see Figure 3). The optimal film thickness also indicate the hole-electron recombination occurs within a depth in the organic matrix.

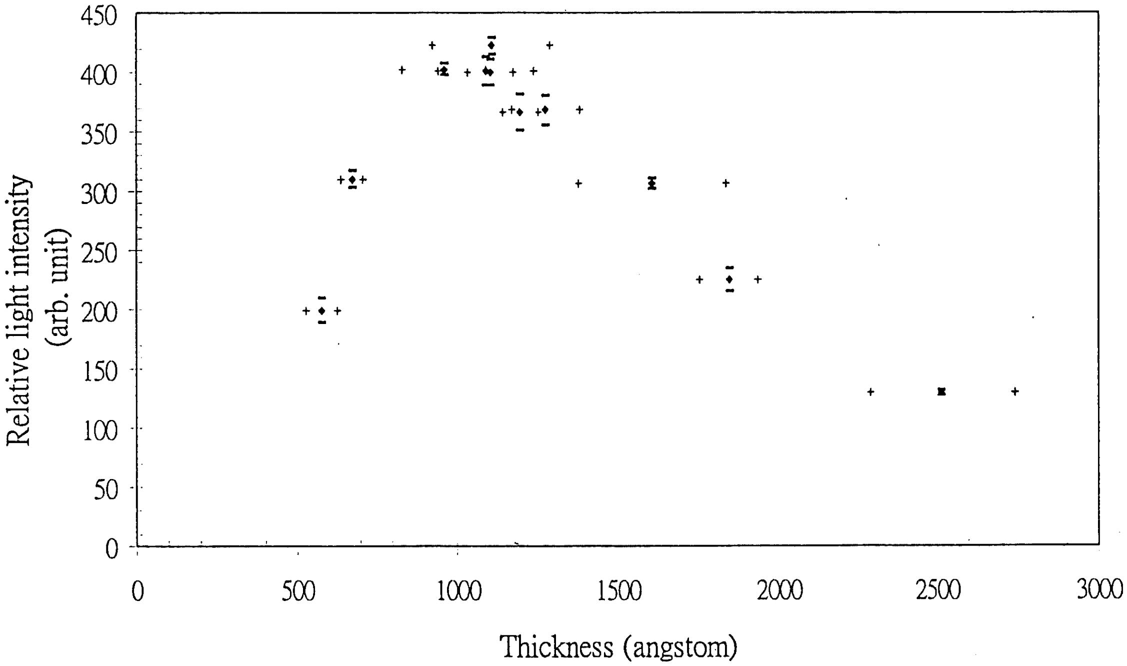

Figure 3 Light intensity vs film thickness for a 30wt% PVK based PTF-OLED operated at 40mA/cm^2.
(The cathode is Ag, and error bars are provided.)

(iv) Other Additives. Additional additives such as sensitizer, dyes, stabilizers were studied and eventually the formulation for a PTF-OLED with high efficiency was established.

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References

(1) Louis M. Leung and K.T. Chung, “Flexible Epoxy Polymer Thick Film Inks", Proceedings of the NEPCON East (Boston, USA), 525-533(1987).
(2) Y. Yang, “Polymer Eectroluminescent Devices”, MRS Bulletin, June issue, 31-38(1997).
(3) S.K. So, W.K. Choi, C.H. Cheng, L.M. Leung and C.F. Kwong, “Surface Preparation and Characterization of Indium Tin Oxide Substrates for Organic Electroluminescent Devices”, Appl Phys., A **68**, 447-450(1999).
(4) S.K. So, W.K. Choi, L.M. Leung and K. Neyts, “Interference effects in bilayer organic light-emitting diodes”, J. Appl. Phys. Lett., **74**(14), 1939-1941(1999).
(5) C.W. Tang, S.A. Van Slkye, and C.H. Chen, “Electroluminescent of doped organic thin films”, J. Appl. Phys, **65**, 3610-3616(1989).

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