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Overshoot Effect in Organic Light Emitting Diodes: A Theoretical Approach

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Abstract **- Over the past decades organic light emitting diode (OLED) has been the focus of intense scientific interest, which led to great advances regarding materials, device fabrication and device performance. Transient electroluminescence (EL) from the pulsed OLED can provide much information on the distribution of charge carriers and the internal field, which is dominated by the electro-optical conversion process of charge. One of the transient EL characteristics of OLED under pulsed voltage is the occurrence of a spike at the switch-off. Present paper discusses the theoretical aspects of overshoot effect in organic light emitting diode.**

Keywords **- Organic light emitting diode; electroluminescence ; overshoot; radiative recombination; electro-optical conversion.**

I. INTRODUCTION

It is observed that overshoot effect is present only in the systems that have been prepared by spin coating and in which internal energy barriers exist for the passage of both holes and electrons1. It is assumed that the back flow of the charge accumulation that occur in the transient layer is responsible for electroluminescence (EL) overshoot. A similar assumption was proposed for the low molecular OLED, showing that upon the removal of the bias, the accumulated charges in the interface layer recombined, yielding the spike. As the voltage is turned off, the interfacial space charges will recombine under the action of their mutual electric field. In many cases overshoots are associated with large currents or even sparking and occur directly after switching off the voltage.

When the voltage is turned off, the holes are sucked back into the anode as the parallel plate capacitor discharges with the characteristic RC time constant2. Some majority carriers remain trapped at the metal/polymer interface, whereas some minority carriers are still trapped in the bulk of the device after turn off. The field inside the OLED then approaches zero, and holes migrate back to the anode and recombine with electrons they meet on the way. As luminescence is quenched within 10 nm of the metal, the de trapped charge carriers have to migrate a certain distance before radiative recombination can occur. This is the origin of the delayed luminescence peak. Since the delay itself is governed by the diffusion of holes, the temporal position of the delayed luminescence peak does not depend on the pulse length or bias at $t < 0$. The absence of a bias dependence suggests that injection effects are not relevant to the overshoot process.

II. THEORY

The electroluminescence (EL) signal of a bilayer organic light emitting diode (OLED) upon application of rectangular voltage pulses of variable duration, under forward bias conditions (Figure 1). Under reverse bias condition no emission was observed2. The emission starts after a delay time of about 1 ms and approaches a steady state value for $t >> 10$ ms. At the end of voltage pulse there is EL overshoot whose peak amplitude increases with increasing duration of the applied voltage pulse. Upon addressing the OLED with a voltage pulse, a positive and a negative space charge layer will be established at the opposite faces of interfacial layer. Charge recombination will preferentially occur with the incoming flux of injected carriers of opposite polarity. As the voltage is turned off, the interfacial space charges will recombine under the action of their mutual electric field. This is due to the fact that after turning off the external voltage, electron stored at the interface next to the anodic cell compartment will experience an electric field directed towards the positive space charge, which acts as electron sink. By this token, the probability for electrons to recombine rather than migrate towards the anode and get discharged increases non radiatively, which may be the explanation for overshoot effect.

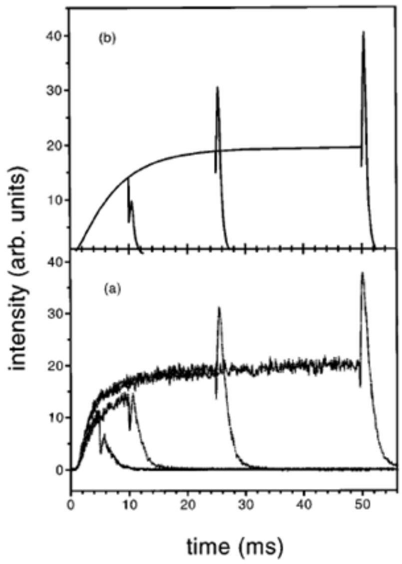

Figure 1. Transient electroluminescence from an ITO/DPOP-PPV/PVK/PBD-PS/Al upon application of a rectangular voltage pulse of variable duration

The phenomenon of EL overshoot was observed in single layer organic light emitting diode previously3.Two features control the operation of a single layer LED after the end of a positive voltage pulse. First, the presence of a thin insulating aluminum oxide layer between the polymer and the metal leads to significant accumulation of holes at the cathode. When the bias is reversed, those holes migrate back to the anode and recombine with electrons they meet on their way. Second, as luminescence is effectively quenched within l ≈ 10 nm of the metal, the holes have to migrate a certain distance l before radiative recombination can occur . This is the origin of the EL spike .

A device with a structure of ITO/α-NPD/DSB/LiF/Al was used for application of trapezoid pulse of 18 V4 . Results revealed that with increase in transition time of the applied voltage pulse, the magnitude of EL spikes is reduced and their duration at switch off is prolonged. It is associated with the charge accumulation in the interfacial layer. By taking the integral of the EL intensity over the duration of EL spikes, the accumulated charge in the interfacial layer can be directly estimated. Due to the accumulated charge in the interfacial layer, EL spikes will last up to the time when the external electric field is less than the internal buildup field, which is closely related to the thickness of the organic layer and the accumulated charges at the interface.

III. CONCLUSIONS

Important conclusions drawn from the theoretical studies on the overshoot effect in pulse excited organic light emitting diodes are as follows. After switching-off of the applied voltage pulse, EL overshoot appears after1-2 µs, which strongly depend on temperature. Lowering the temperature increases the EL spike amplitude. EL overshoot also depends on the pulse duration of applied voltage. It was observed that as the pulse duration is increased with constant voltage amplitude, height of the EL peak goes on increasing. The overshoot effect in transient electroluminescence is attributed to an accumulation and trapping of holes at the polymer/metal interface. EL overshoot effect is observed only with the systems, which are prepared by using spin coating method for its preparation, this effect is not present in the systems or devices which are prepared using vapour deposition technique for its construction. Another reason for the EL overshoot at turn-off of voltage pulse is that, when the field is turned off, the polarization of the medium relaxes exponentially. The de trapped charge carriers move under the influence of the field associated with this residual polarization and recombine leading to the EL overshoot.

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