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3A14: Doped-Polymer Organic Light Emitting Diodes and OLED Device Integration

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Introduction

A long sought goal is a display technology which is energy efficient, flexible, full-color, and rugged. Towards this end, we first describe the optimization of doped polymers for the formation of red, green, and blue OLED's. We then describe the integration of LED's from different organic materials onto a single substrate to make multi-color emitters, followed by the integration of OLED's and amorphous silicon TFT's onto flexible lightweight thin stainless steel foils.

Results and Discussion

In general, the formation of multiple organic layers in polymer LED's is difficult due the dissolution of previously formed layers when depositing later layers. The multiple material functions of electron transport, hole transport, and emitter can be incorporated into a single layer, however, by blending all of these materials together in solution before depositing them together by spin coating [1,2]. We have concentrated on doped polymers based on PVK as a backbone and hole transporter which were doped with the small organic molecules PBD or Alq as an electron transporter along with either coumarin 47 (blue), coumarin 6 (green), or nile red (orange-red) as emission centers. OLED's were formed by depositing these layers on anode layers (typically ITO-coated glass) by spin coating, followed by the evaporation of a MgAg/Ag bilayer cathode contact. Because of the efficient carrier transfer between the transport materials and the emission centers, only a low concentration (~1 % by weight) of the dye materials is required for optimum devices [3]. With optimum electrodes and compositions (typically 100:40:1 PVK:electron tranport agent:dye by weight), turn-on voltages of about 3V and external quantum efficiencies of about 1% can be achieved, with brightnesses of 100 cd/m^2 at ~10V for all colors (Fig. 1).

Achieving high efficiency color displays will involve fabricating optimized red, green, and blue devices on a single substrate. We have chosen the approach of using three different organic layers in three separate devices. Fabricating such devices requires dry processing due to the sensitivity or the organic layers to water and many solvents. We realized such patterning of the organic layers using plasma etching and a patterned silicon nitride layer on the ITO to render the edge of the device electrically inactive (Fig. 2). Using this technique and three separate spin-coating steps for three organic layers, one can achieve devices of three colors on a single substrate, with the performance of each device unaltered from that of isolated devices [4]. The plasma etching is masked by metal layers deposited by evaporation which form the device anodes.

To achieve lightweight flexible displays, one can choose either plastic substrates or very thin metal foils. We have adopted the later approach since stainless steel foils (75 - 200 um thickness) are more compatible with the fabrication of amorphous silicon TFT's, which generally require a substrate temperature of 300 °C. The integration of TFT's is required for active matrix displays, in which TFT's at each pixel control the brightness of the OLED. To demonstrate such integration, we fabricated a top-emitting OLED (using a transparent top cathode and a Pt anode) along with a TFT on a steel foil (Fig. 3) [5]. The performance of the TFT is similar to that of conventional devices made on glass plates (Fig. 4, [6]). The TFT can be used to control the OLED (Fig. 5), with lower switching voltages expected with improved top-emitting OLED's.

In summary, doped-polymer OLED's, dry processing, and stainless steel foils offer a route for achieving full-color, rugged, and flexible active matrix displays.

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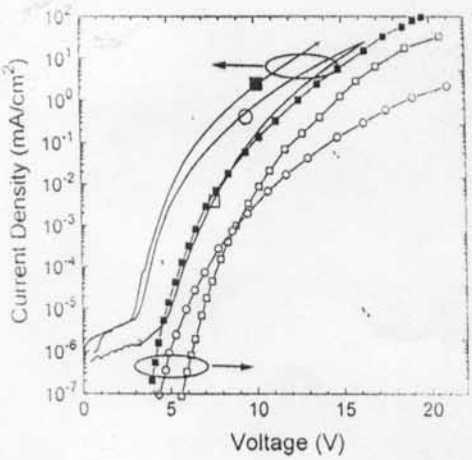

Fig. 1. Current voltage and light-voltage characteristics of single-layer doped polymer LED's with compositions PVK:PBD:C47 (blue, open circle); PVK:PBD:C6 (green, solid square); and PVK:Alq:nile red (orange, open square). Cathodes are MgAg:Ag in all cases.

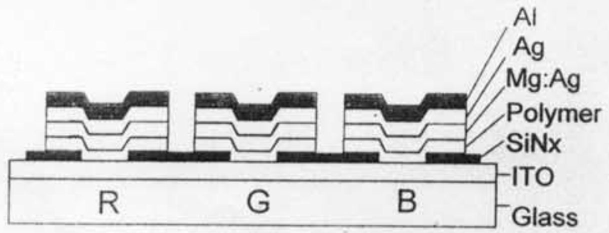

Fig. 2. Cross section of integrated three-color devices using plasma-etching to pattern organic layers on top of substrate with patterned silicon nitride.

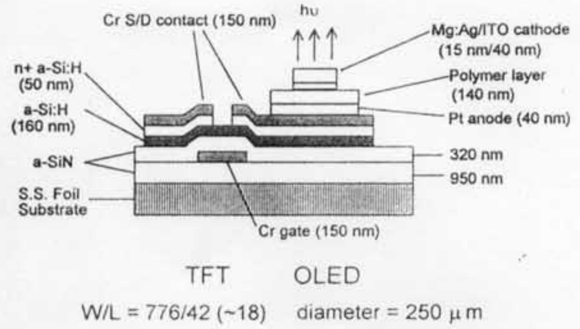

Fig. 3. Cross section of integrated amorphous silicon and top-emitting OLED.

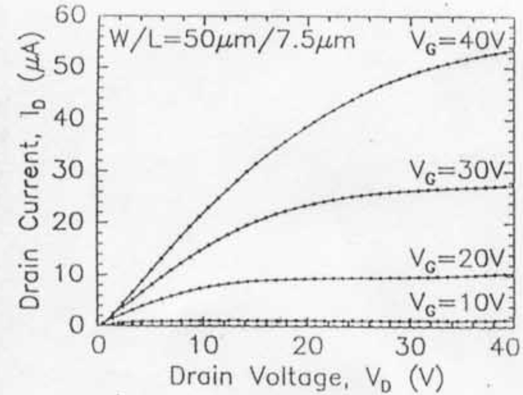

Fig. 4. Amorphous Si TFT characteristics on thin stainless steel foils.

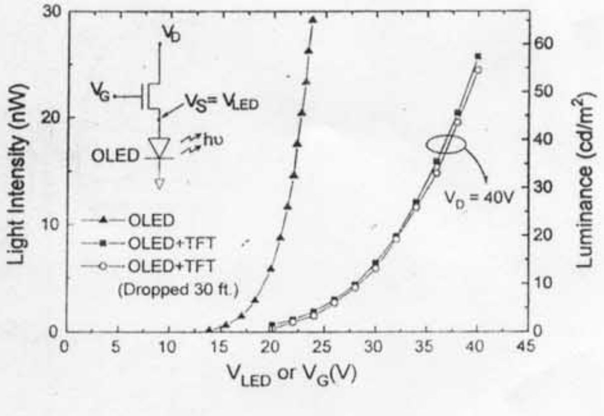

Fig. 5. Light-voltage characteristics of isolated LED (V_{LED}, triangles) and of TFT/OLED circuit (V_G, $V_D = 40V$) on stainless steel foils before and after dropping 10 m onto concrete.