

Flexible top emission organic light emitting diode on paper substrate

Chan-Jae Lee, Dae-Gyu Moon, Jeong-In Han

Information display research center, #68, Yatap, Bundang, Seongnam, Gyeonggi, 463-816, Korea

Sung-Hoon Choi, Myung-Hwan Oh

School of Electrical, Electronics and computer Engineering, Dankook, University, Seoul, Korea

Abstract

We fabricated an efficient top emission organic light emitting diode (FTEOLED) on paper substrates. For water proof and surface planarization, parylene of 5mm thick has been coated on copy paper substrate by vapor polymerization. As use this coating layer, fabrication of device was possible by photolithography and wet etching. Because paper is not transparent, we adapted top emission structure with transparent cathode and reflective anode. The FTOLED on paper showed the excellent electrical characteristic, 109cd/m², 2.3cd/A at 10V.

Accordingly a barrier layer such as polymer and inorganic oxide is demanded. In order to improve the device performance, we used parylene as barrier layer. The parylene layer provides not only low moisture permeation but also flatness of paper surface. Therefore, the parylene coating is one of the necessary fabrication process for flexible OLED on paper substrate.

In this paper, we fabricated top emission organic light emitting diodes on paper substrate. In order to improve device performance, paper was coated with parylene that plays an important role in surface flatness and water proof. The device with polymer layer was advanced in electrical and optical characteristics.

1. Introduction

Generally, glass substrate has been used in flat panel displays, such as LCD, EL and PDP. However due to properties of glass, these devices have physical limitations such as easy fragile, fixed shape and volume. To improve these, recently many researchers have developed display on flexible substrate such as plastic film or thin metal foil [1-2]. As usage of flexible substrate, display could be deformed to bend and roll. Therefore flexible display has been expected application of new concept, such as wearable display for next generation.

One of the trends in the flexible display is to develop low-cost disposable electronics. To realize low-cost of commercial products, these may require the utilization of economical substrate. Particularly paper is one of inexpensive, renewable and abundant materials. Flexible display using the paper substrate has been investigated [3-5]. However compare to other flexible substrate, the paper is easily moistened during wet process also the surface characteristic of paper substrate is rough. Finally the properties of flexible OLED on paper are unsatisfactory.

2. Experimentals

Substrate used was a commercial paper. Since paper is easily wet in solution and DI-water and has a rough surface, parylene was coated on both sides of a paper in vacuum by parylene coater at the same time. The parylene was deposited by the vapor polymerization method. The pressure for the polymerization process was 10 mtorr, and the parylene dimer was vaporized over 110 °C. The vaporized dimer molecules were decomposed into bi-radical monomer gases from 690 °C in the pyrolyzer zone. The bi-radical monomer gases were condensed and reactivated on the surfaces of the FOLED and finally form the polymer at room temperature.

For top emission OLED, Nickel metal was selected as an anode material. Ni was deposited by magnetron sputter and patterned by photolithography and wet etching. After the definition of anode patterns followed by the pre-cleaning of substrate with D.I. water, substrates were cleaned with alkali cleaner and D.I. water in an ultrasonic bath before loading into

evaporator. Organic layers were deposited in the following sequence: 15nm of 2TNATA (4,4',4''-tris[*N*-(1-naphthyl)-*N*-phenylamino]-triphenylamine), 50nm of α -NPD (4,4' [N-(1-naphthyl)-*N*-phenyl-amino]biphenyl), 35nm of Alq₃ (tris(8-hydroxyquinoline)aluminum) with 1% C6 (3-(2-benzothiazolyl)-7-(diethylamino)-2H-1-benzopyran-2-one) and 10nm BCP (2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline) as shown in Fig. 1. And later thin metal cathode, LiF(0.5nm)/Al(10nm) was deposited with a shadow mask by evaporation. Organic layer and transparent metal cathode are deposited sequentially by thermal evaporation at below 2×10^{-6} Torr with 0.5 - 2 Å/s.

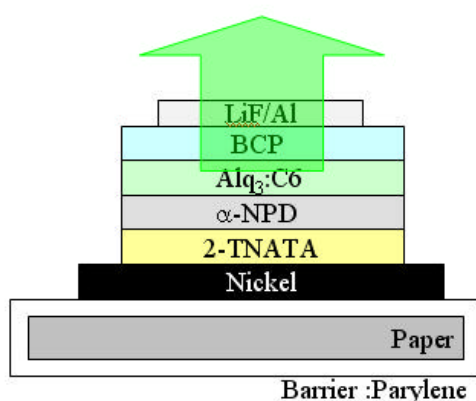


Fig. 1 Schematic structure of flexible top-emitting organic light emitting diode on paper substrate

The luminance-voltage and current density-voltage curves were measured by Keithley 2400 source/measure units with brightness-calibrated photodiodes.

3. Results & Discussion

Since paper has very rough surface, for fabrication of OLED, surface morphology make to be smooth. Especially, OLEDs that were made on rough surface are known to have poor electrical properties and short life-time [5]. Therefore we estimated surface morphology of paper with parylene. Fig. 2 shows the atomic force microscopy (AFM) image of paper

substrate with surface treatment. The surface root-mean-square (RMS) roughness of the bare paper is about 34 nm as shown in Fig. 2(a). The poor surface characteristic of bare paper leads to 1) the reason of degradation and dark spot formation and 2) the reduction of hole injection from anode electrode. Therefore improvement of surface characteristics should be considered to achieve high-performed device. The AFM image of a parylene coated paper substrate is relatively smooth with rms roughness of 5nm. Above all the surface roughness has been greatly reduced from 34nm to 5nm after surface treatment of paper surface. Parylene makes tissue of paper surface to fill and flat, so it provided enough flat substrate to make device.

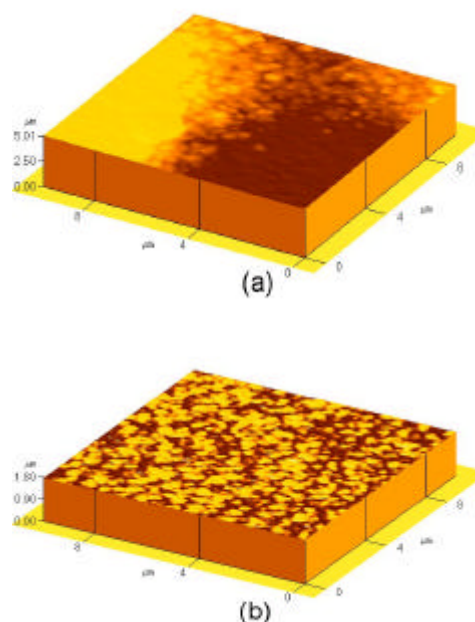
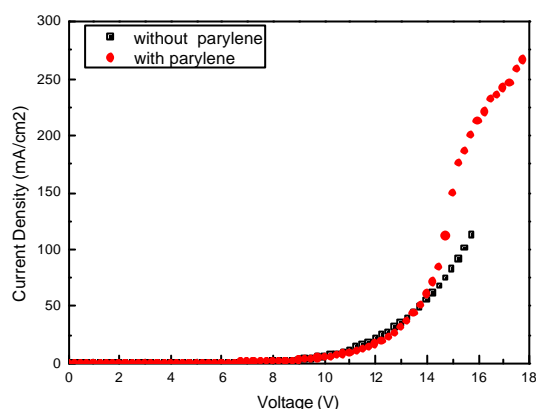


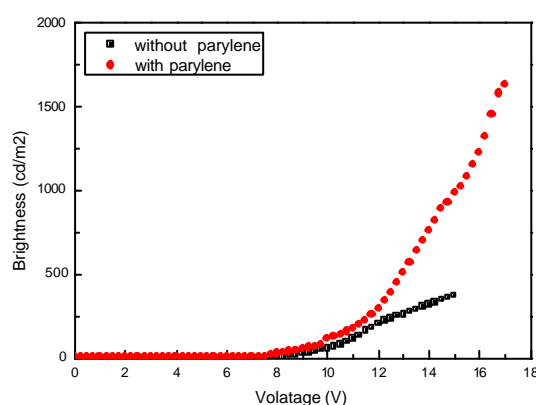
Fig. 2 AFM image on paper substrate (a) bare paper (b) parylene coated paper

In order to investigate the influence of the surface roughness on the FTOLED performance, we have also measured the electrical and the optical properties. Figure 3 shows current density-voltage and luminance-voltage characteristic of the devices with and without parylene layer. The higher electrical and optical properties were obtained from the device fabricated on paper substrate with parylene barrier layer. The voltage of device with parylene was 7.6V for 10mA/cm² but device without parylene was 8.4V.

At the same voltage, 10V, brightness and efficiency of device with parylene that were 109cd/m^2 and 2.3cd/A were better than device without parylene 55cd/m^2 and 1.0cd/A , respectively. Device without parylene was burn out over 17V.



(a)



(b)

Fig. 3 Electrical and optical properties of OLED on paper substrate (a) current density-voltage (b) brightness-voltage

Paper morphology affects the formation and roughness of anode and that was relative to device characteristics. First of all, tissue of paper was composed fiber and very different from glass. Therefore the improved properties were mainly

attributed to the improvement of surface roughness. Since device with parylene was better properties than without, parylene on paper substrate played a role as planarization layer.

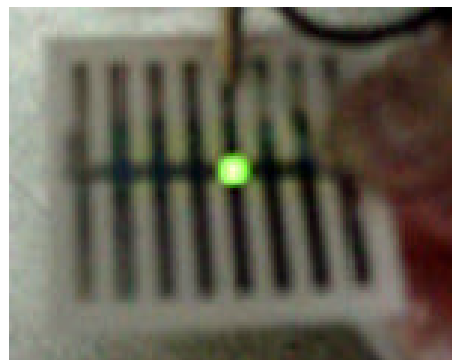


Fig. 4 Photograph of the fabricated devices on paper substrate.

4. Conclusions

We fabricated novel device, FTOLED on commercial paper. Paper is weak against water and has rough tissue, but this obstacle problem was overcome by coating parylene. By using these substrates, we fabricated top emission OLED. and estimated electrical properties as a function of substrate coating layer. Device with parylene showed 109cd/m^2 , 2.3cd/A at 10V. So, display on paper is expected to realize a new concept for the next generation display.

5. Acknowledgements

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5. References

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