6” Flexible AMOLED Integrated with PEDOT Touch Panel

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Abstract

A 6” flexible PEDOT touch panel on a thin PI film was fabricated by invisible patterning process and FlexUp^{TM} technology. On the flexibility test, the resistance change (ΔR/R0) of the PEDOT electrodes was below 1% after 10K cycles bending test. A 6” PEDOT touch panel integrated with AMOLED was successful demonstrated with video exchange, photo exchange, and zoom in/out functions.

1. Introduction

Transparent doped metal oxides such as indium tin-doped oxide (ITO) have been leading candidates for the liquid crystal displays, touch panels, organic light emitting diodes, and solar cells applications. However, the poor flexibility of metal oxide film often results cracks when it is bent or twisted[1]. Various flexible electrode materials have been considered to replace ITO, such as PEDOT: PSS[2], carbon nanotubes[3], graphenes[4], and silver nanowires[5]. Solution-processable conducting polymers, PEDOT, are under intense investigation[6-8] with key advantages over other alternative material including lower haze, relative cheaper, and compatibility with solution-based deposition techniques, e.g. gravure printing, slot die coating, and slit coating. In this paper, high conductive PEDOT as a transparent electrode for flexible touch panel application was investigated including optical properties, reliability and flexibility tests. In addition, the result of PEDOT touch panel integrated with AMOLED was also validated.

2. Methods

2.1 Manufacturing process

A highly conductive PEDOT formulation (from EOC Co., Ltd.) was used as a transparent conductor in this paper. Fig. 1 (a) & (b) show the top and cross section views of PEDOT touch panel structure. FlexUP^{TM} substrate is made by coating a de-bonding layer followed by polyimide varnish. The buffer layer was then deposited on the above substrate by vacuum deposition process. Silver was patterned as bridge and runner. Subsequently, insulator was deposited and patterned as dielectric layer. Conductive polymer was then introduced via spin-coating process and patterned by invisible patterning process[9] to finalize the touch sensor fabrication. The touch sensor was then released by mechanical de-bonding.

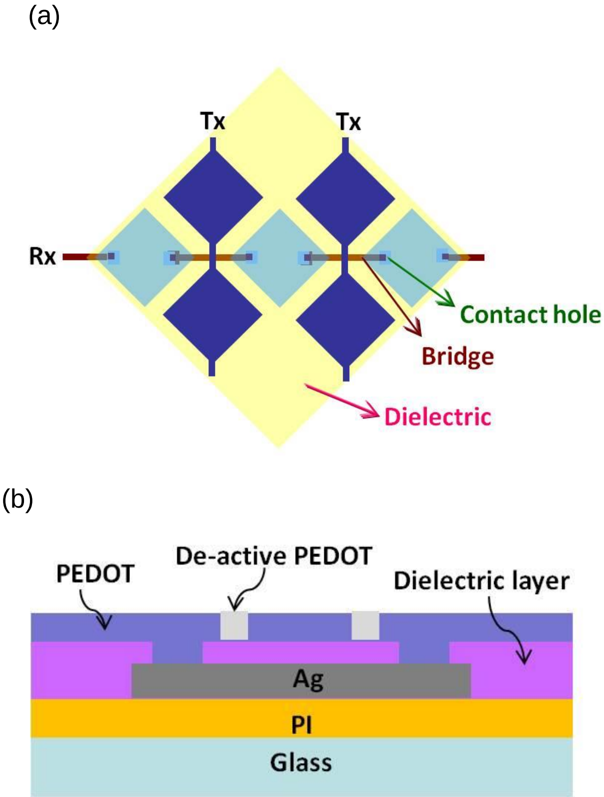


Fig. 1. (a) Top view of flexible PEDOT touch panel; (b) Cross section view of flexible PEDOT touch panel

2.2 Flexibility test

The flexibility of the PEDOT electrodes on the FlexUp^{TM} PI film was evaluated by bending test. In this paper, bending radius, cycle times and bending rate were 5mm, 10K times, and 2sec/time, respectively.

2.3 Integration with AMOLED

The 6” PEDOT touch panel was laminated on a 6” AMOLED with OCA film as shown in Fig. 2. After the lamination process, this integrated module was released from the carrier glass by de-bonding process.

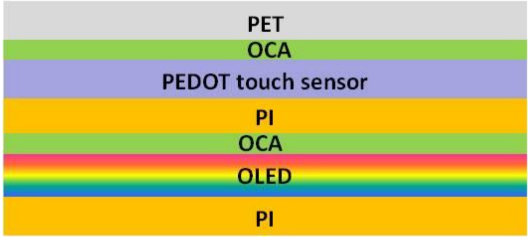


Fig. 2. Diagram of AMOLED integrated with PEDOT touch panel

3. Results & Discussion

Sheet resistance and thickness variations of spin-coated PEDOT films were controlled by tuning the recipe of spin-coating process. Fig. 3 shows the optical properties of PEDOT. The haze value of PEDOT film is satisfactory low (<1%) and stable. The transmittance of red, green, and blue light increased with decreasing sheet resistance. The transmittance was greater than 80% when the sheet resistance was over 70Ω/□. For touch panel application, the sheet resistance and transmittance of PEDOT film were suggested to be controlled at the area of dotted blue region, as shown in Fig. 3.

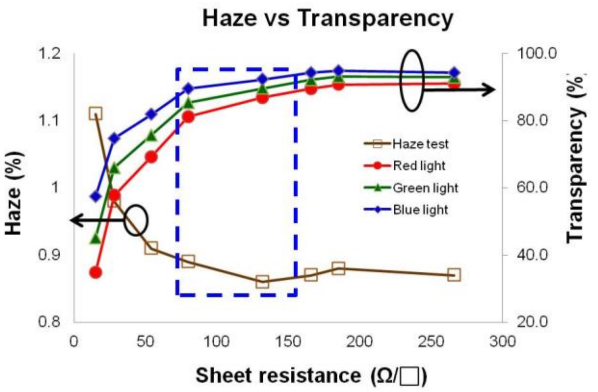


Fig. 3. Relation between sheet resistance of PEDOT film and its optical properties

To identify the minimal line width of PEDOT electrodes, a test key with different line widths was designed for the test. The line widths were 75um, 150um, 200um, 250um, 300um, 350um, 400um, respectively. After de-activation process with PEDOT etchant, the line resistances of PEDOT electrode, where the line width was higher than 200µm, slightly increased with increasing etching time but increased substantially in the fine line design where the line width is smaller than 200µm as shown in Fig. 4. In order to ensure the line resistance of electrodes was lower than 15KΩ, required specification of touch panel IC, the line width of the circuit is suggested to be greater than 200µm.

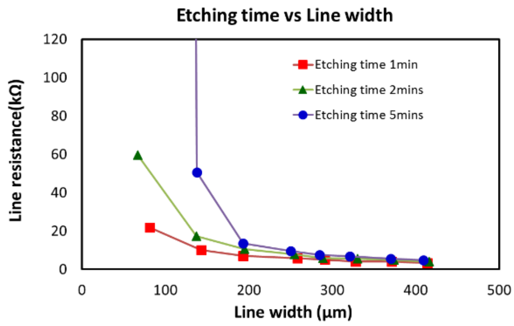


Fig. 4. Relation between sheet resistance of PEDOT film and its line width

In order to examine the flexibility of PEDOT electrodes, a test key of PEDOT electrode was fixed on a bending machine which the bending radius can be programmed from 5 mm to 50 mm by adjusting bending angle and the bending cycle can be counted by a built-in register. Fig. 5 shows the screen captures during the bending test, for example, the bending radius is 5mm as the bending angle is 0 degree. In this flexibility test, the line resistance of PEDOT electrodes will be checked after 10,000 cycle inward/outward bending tests at 5mm radius.

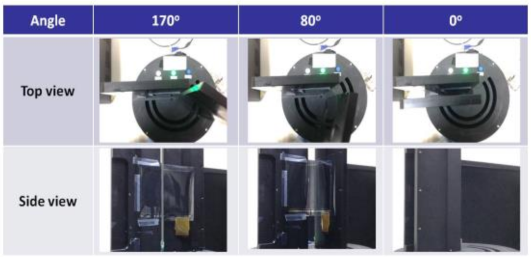


Figure 5. The bending test instrument

Fig. 6 shows the result of inward/outward bending test of PEDOT electrodes. The bending radius is 5mm, the bending times are 10,000 cycles, and the structure of PEDOT test electrode was simulated an actual touch panel structure which PET laminated on PEDOT electrode/PI by OCA film. After 10,000 cycles inward/outward bending test, the resistance variation of each PEDOT electrode was below 1%.

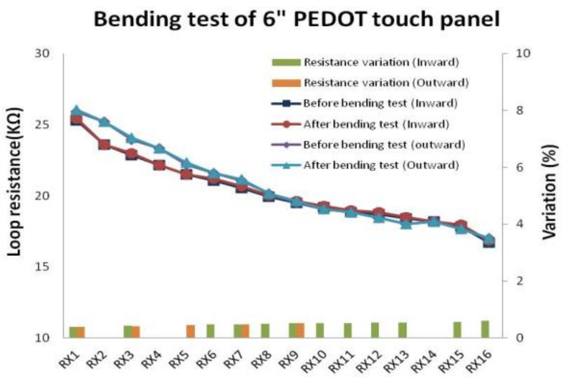
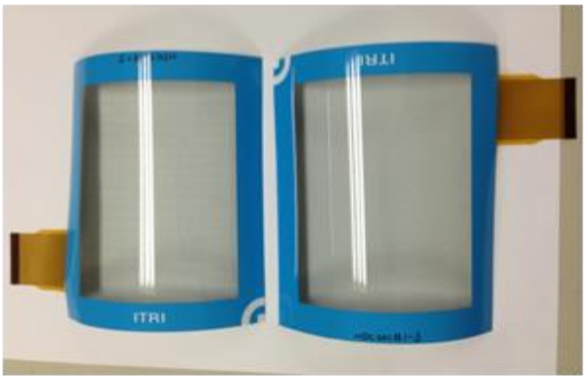


Fig. 6. Resistance variations of electrodes on a PEDOT

test key pattern after 10000 cycles bending test.

Focaltech FT6306 touch IC incorporated its designed pattern was applied to investigate functions of PEDOT touch sensor. Fig. 7(a) shows the PEDOT touch panel laminated with a decoration PET film. This decoration film was used to improve the mechanical strength of PEDOT touch panel which was built on a 15μm PI film. Fig. 7(b) shows driving test results of a 6” curved PEDOT touch panel. The 6” PEDOT touch panel bonded with FPC was conformed on a curved carrier. The 6” curved PEDOT touch panel was successfully demonstrated with sketching, photo exchange, zoom in/out and rotation functions.

(a)



(b)

Fig. 7. (a) The photograph of the 6’ PEDOT touch sensor; (b) 6” PEDOT touch panel function test

Fig. 8 shows driving test results of a 6” flexible AMOLED integrated with PEDOT touch panel. The above device was conformed on a curved wearable carrier. This 6” PEDOT TP-integrated AMOLED was successfully demonstrated with video exchange, photo exchange, and zoom in/out functions.

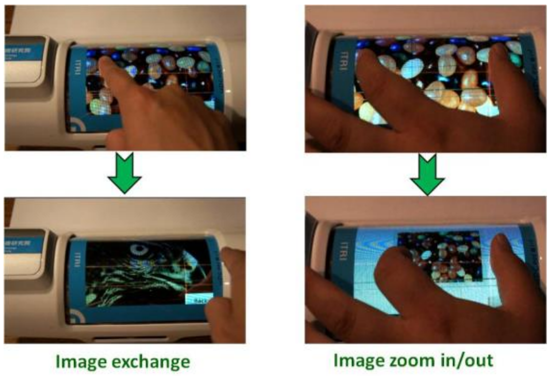


Fig. 8. Function tests of 6” flexible AMOLED integration with PEDOT touch panel.

4. Conclusions

A 6” flexible PEDOT touch panel was fabricated by PEDOT patterning process and FlexUp™ technology. Integrating with AMOLED module, it was successfully demonstrated with sketching, 5 point multi-touch and zoom in/out functions. After 10,000 cycles inward/outward bending test at 5mm radius, the resistance variation of each PEDOT electrode was below 1%. According to the above results, PEDOT, a transparent and high conductive polymer, shed light on opportunity to be used for flexible touch panel application.

References

1. B. G. Lewis and D. C. Paine, MRS Bull. , Vol. 25, p. 22 (2000).
2. A. Kumar and C. Zhou, ACS Nano, Vol. 4, p. 11 (2010).
3. D. S. Hecht and L. Hu, G. Irvin, Adv. Mater. , Vol. 23, p. 1482 (2011).
4. D. R. Cairns, R. P. Witte II, D. K. Sparacin, S. M. Sachsman, D. C. Paine and G. P. Crawford, App. Phys. Lett. , Vol. 76, p. 1425(2000)
5. M. Vosgueritchian, D. J. Lipomi and Z. N. Bao, Adv. Funct. Mater. , Vol. 22, p. 421 (2012).
6. J. G. Tait, B. J. Worfolk, A. A. Maloney, T. C. Hauger, A. L. Elias, J. M. Buriak and K. D. Harris, Sol. Energy Mater. Sol. Cells, Vol. 110, p. 98 (2013)
7. S. Xiao, L. Chen, L. Tan, L. Huang, F. Wu and Y. Chen, J. Phys. Chem. C, vol. 119 (4), p. 1943 (2015)
8. T. B. Song, N. Li, Electronics, Vol. 3, p. 190(2014)
9. Guntermann U, Gaiser D, “Method for producing layer structures by treatment with organic etchants and layer structures obtainable therefrom”. Patent application WO002012062446” (2011)

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