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Fabrication of flexible EPD panel using the solution processable OTFT

Myung Won Lee, Mi young Lee, Jae Cheol Choi, Jong seung Park and Chung Kun Song

[1]Dept. of Electronics Eng., media device lab, Dong-A University, Busan, Korea
840 Hadan2-dong, Saha-gu, Busan, Korea
Phone: +81-51-200-7366 E-mail: mwlee@dau.ac.kr

1. Introduction

Electrophoretic display(EPD) is attracting much attention as a display for electronic books because of its paper-like appearance, flexibility and low power consumption. Bute EPD does not have threshold voltage for rotating micro-capsule, it should be controlled by a switch with threshold voltage such as TFTs in order to implement a display panel. Among the various TFT, organic TFT have drawn much attention due to their low production cost, processing flexibility, and possible openings for new applications. Recently, there have been numerous reports about OTFTs based on solution processing using various printing techniques, such as screen, micro-contact, gravure, and inkjet printing. As for screen printing, it is hard to achieve fine resolution below than 100μm, and this makes it difficult in defining the gate or channel length of OTFTs. Micro-contact printing provides high resolution if combined with photolithography process, but it also has limitation in transferring uniformity on substrate and obtaining accurate alignment. Meanwhile, inkjet printing eliminates the use of photomasks and also enables simple fabrication with high accuracy and resolution.

In this paper, we presented results of enhancement conductivity of PEDOT film treated with organic compound for Source/Drain electrodes of OTFT. We also presented about process of plasma technique combining ink jet printing technique to obtain high resolution and high performance OTFT in a very simple and efficient way. Finally we fabricated solution processable OTFT-backplanes on flexible substrate. It worked successfully and demonstrated to display some patterns

2. Experiment

We used polycarbonate substrate with thickness of 125um, plastic substrate was purchased from DuPont Teijin. Particle contamination was minimized by cleaning the substrate before depositing the materials in class 1000 clean room. The plastic substrate was also pre-annealed for reduction of polymer shrinkage because it causes serious problem in adjusting alignment for fabrication.

The OTFT-backplane were employed bottom contact structure, containing 1 OTFT and 1 capacitance in each pixel. The fabrication process of OTFT-backplane included the following :

Ag ink was used for gate electrode which was made by screen printing. PVP was used for gate dielectric made by spincoating and PEDOT:PSS was used for Source/Drain electrodes made by ink-jet printing. In order to use source/drain electrodes instead of Au in OTFT, especially, it should have similar work-function between semiconductor and electrode of OTFT. We chose PEDOT:PSS and tried to enhance conductivity. Here we applied different concentrations of glycerol into PEDOT:PSS to make modified PEDOT:PSS solutions. Thin films were made by spincoating and curing them on the substrate at different temperatures. And then the sheet resistance was measured and compared. Results showed that, while the sheet resistance of pure PEDOT:PSS is 1.5MΩ, that of modified PEDOT:PSS is found to be decreased by three orders of magnitudes(fig. 1) This result showed that electrical performance of OTFT used modified PEDOT:PSS was superior to OTFT used pure PEDOT:PSS. Fig. 2 compared OTFT characteristics using modified PEDOT:PSS and pure PEDOT:PSS for S/D electrodes.

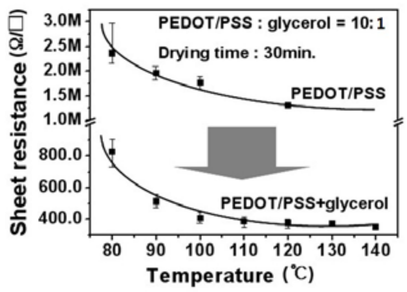


Fig 1. Comparison of sheet resistance of PEDOT:PSS according to drying temperature

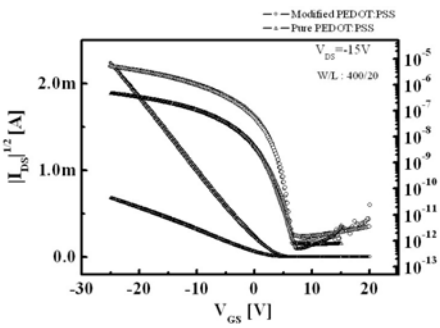
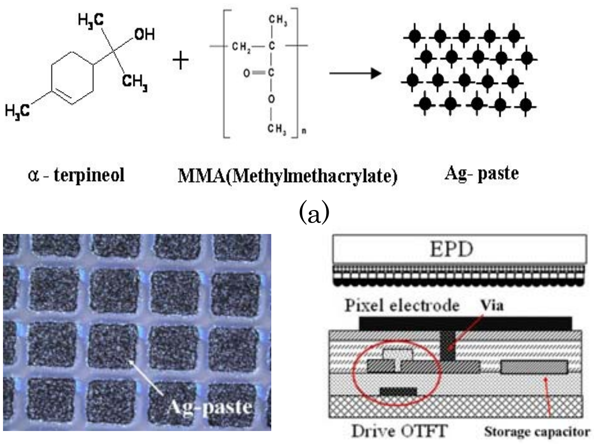


Fig 2. Comparison of transfer characteristics using modified PEDOT:PSS and pure PEDOT:PSS for S/D electrodes.

In fabricating OTFTs on plastic substrate, PEDOT should be deposited at room temperature due to possible shrinkage of the substrate by heating. However, without heating fine patterns are hard to obtain. Alternatively, we have adopted O_2 plasma treatment on the electrode surface of PEDOT:PSS. Through the treatment, we are able to obtain OTFTs having high resolution and performance on plastic substrate without the need of heating. Resulting OTFTs exhibit an improvement in overall performances, with mobility of 0.22 cm^2/v.sec, off-state current of 0.002 pA/um, threshold voltage of 1.5 V, sub-threshold slope of 0.64, and on/off current ratio of ~10^6. The performance of OTFT was sufficient for operating EPD panel. Although modified PEDOT:PSS increased performance of OTFT, it was not suitable for data line of backplane because of low electrical conductivity of PEDOT:PSS. So we made data line of hybrid type which was applied Ag ink with ink jet printing technic to compensate conductivity of PEDOT:PSS in backplane.

In order to control EPD, OTFTs should have to interlayer dielectric(ILD) layer between backplane and EPD panel. It is important to make a good ILD because ILD is required not to give a serious damage to the lower OTFT and also protect it from upper EPD panel lamination process. The pixel electrode pads, which were directly contacted to EPD panel and applied voltage to pixel, were connected to drain electrode of OTFT through via holes formed in ILD. Pixel electrode pads were deposited by screen printing. Ag-paste for pixel electrode was made from acryl resin because of normal Ag-paste dissolved ILD and cured high temperature. So we designed to low curing temperature(90^{o}C) process to minimizing damage below OTFT. In fig. 3 schematic depiction of Ag-paste formation from acryl resin and its incorporation as pixel electrode.

Finally, we fabricated OTFT-EPD panel which worked successfully and demonstrated to display some patterns which showed in fig. 4



(b) (c)

Fig 3. (a)schematic depiction of Ag-paste formation from arcryl resin (b) image of pixel electrode using screen printing (c) the cross-section of a pixel consisting of OTFT and EPD.

Fig 4. The image displayed on flexible OTFT-EPD panel

3. Conclusions

We fabricated flexible OTFT-backplanes for the electrophoretic display(EPD) on plastic substrate. The active area size of backplane was 6" in diagonal direction and consisted of 192 x 150 pixels, containing 1 OTFT and 1 capacitance in each pixel. The OTFTs employed bottom contact structure and used the cross-linked polyvinylphenol for gate insulator, PEDOT:PSS treated with organic compound for Source/Drain electrodes, pentacene for active layer. Here we present high performance in OTFTs made of plasma modification followed by inkjet printing without heating on plastic substrate.

We used PVA/Acryl double layers for passivation of backplane as well as for ILD between backplane and EPD panel. And also we formulated Ag ink to use pixel electrode of backplane with screen printing. We could replace the vacuum process with solution process. Finally we fabricated OTFT-EPD panel which worked successfully and demonstrated to display some patterns.

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