2009년도 대한전기학회 하계학술대회 논문집 2009. 7. 14 - 17

선택적 표면처리와 딥코팅 방법을 이용한 고해상도 금속 패턴 형성연구

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Patterning of high resolution metal electrodes using selective surface treatment and dip casting for printed electronics

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Abstract - In this report, high-resolution metal electrode patterning is demonstrated by using selective surface treatment and dip casting for low-cost printed electronic applications. On hydrophobic octadecyltrichlorosilane treated SiO_2 surface, deep UV irradiation was performed through a patterned quartz photomask to selectively control the surface energy of the SiO_2 layer. The deep UV irradiated region becomes hydrophilic and by dipping into Ag nano-ink, Ag patterns were formed on the surface. Using this patterning technique, line patterns and dot arrays having less than 10 ㎛ pitch were fabricated.

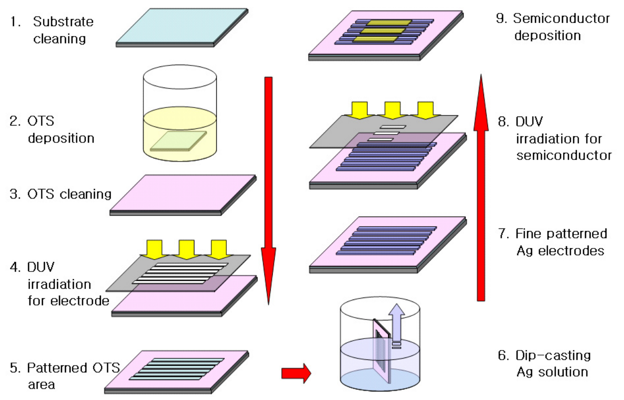
1. Introduction

Recently, direct printing technologies are becoming more important in the field of electronic devices due to their fast, easy, and low-cost manufacturing. Several approaches, such as, nano-scale imprinting[1], soft-lithography[2], self formation[3], ink-jet printing[4], and barrier-like structure with photoresist layer[5] have been introduced and showed promising results. However, there still remains several problems in applying these technologies to low-cost roll-to-roll process due to the process complexity and necessity of conventional photolithography process. In this report, we demonstrate simple and easy fabrication process for building fine patterned metal electrodes and organic semiconductors which can be easily adopted to roll-to-roll process. This process includes surface patterning of self-assembled monolayer (SAM) by non-relief lithography and simple dip-casting process. By employing these processes, fast and cost effective manufacturing is possible, as well as high resolution patterning of various materials.

2. Results and Discussion

2.1 Fabrication

For the patterning of Ag electrodes for source and drain, hydrophobic octadecyltrichlorosilane (OTS) was coated over the thermally oxidized silicon dioxide by dipping. The samples were dipped into the OTS solution having a concentration of 1 mM in ethanol. Then, deep UV (DUV) radiation was performed through a quartz photomask to generate SAM patterns. The 185 nm exposure results in rapid removal of the OTS SAM layer which has been confirmed by water contact angle measurements. After OTS patterning, the samples were dipped into Ag nano-ink which includes nano-particles with an average diameter of 10 - 20 nm and pulled out to form the electrode patterns (Fig. 1). The sample withdrawal speed was controlled from 1 - 100 mm/min and the viscosity of the Ag nano-ink was varied from 1.0 - 27 mPa-s by adding dilution solvent.

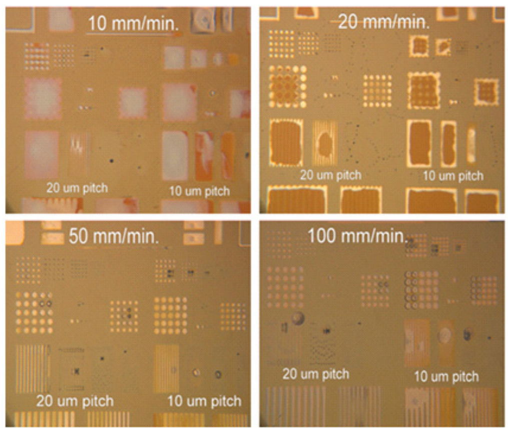


<Figure 1> Process flow of non-relief lithography process for patterning solution processed Ag electrodes and organic semiconductors.

2.2 Results

The printing quality or the line/dot pitch of the patterns was significantly affected by the withdrawal speed of the sample and also the viscosity of the Ag nano-ink. With the withdrawal speed of 20 mm/min, electrode line pitch of 100 ㎛ has been obtained. By increasing the withdrawal speed to 50 mm/min, electrode line pitch of 5 - 10 ㎛ was obtained. However, further increase of the withdrawal speed to 100 mm/min reduced the printing resolution of the electrode patterns.

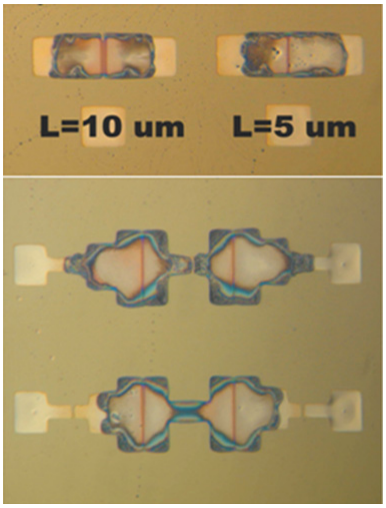
By optimizing the dip-casting parameters such as withdrawal speed and the viscosity of the Ag nano-ink,, electrode pitch of 5 - 10 ㎛ were easily achieved as shown in Fig. 2.



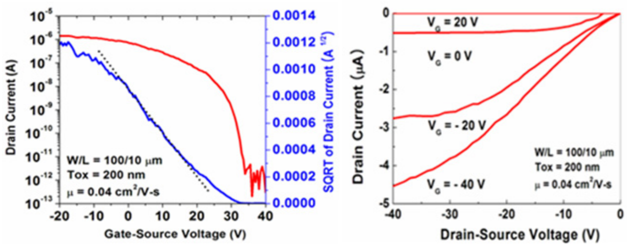
<Figure 2> Optical micrographs of patterned Ag electrodes with variation of withdrawal speed (Viscosity : 1.37 mPa-s)

Furthermore, to achieve high molecular ordering and fine patterning of organic semiconductors, another DUV exposure was performed with quartz mask, resulting in a new barrier structure for confining organic solution. Finally, TIPS-pentacene from 2 wt% chlorobenzene solution was ink-jetted over the pre-patterned barrier-like structure. As shown in figure 3(a), dropped TIPS-pentacene ink was automatically confined within the patterned OTS area.

Figure 3(b) shows I_D and $\log(I_D)$ versus V_{GS} characteristics for VS = -40 V, and I_D versus V_{DS} characteristics for the TIPS-pentacene organic thin-film trnasistor (OTFT) with a surface energy patterned source-drain electrode and active layer deposited from a 2wt% chlorobenzene solution. The device had a channel length of 10 ㎛, a channel width of 100 ㎛, and a 200 nm-thick silicon dioxide gate dielectric. The devices typically had extracted field-effect mobility of about 0.03 - 0.06 $cm^2/V{\cdot}s$ with on/off current ratios $>10^6$, and subthreshold slope < 0.7 V/decade. The typical performance of all printed OTFTs fabricated from the surface patterning and dip-casting process was similar to that of OTFTs from ink-jet printed semiconductors and photolithographically patterned electrodes [4].



(a)



(b)

<Figure 3> (a) Optical micrographs of ink-jet printed TIPS-pentacene on patterned Ag electrodes, and (b) electrical characteristics of all printed TIPS-pentacene OTFT (I_D-V_{GS} and $\log(I_D)$-V_{GS} (V_{DS}=-40 V), I_D-V_{DS})

3. Conclusion

High-resolution Ag electrode patterning was demonstrated by using selective surface treatment and dip casting for low-cost printed electronic applications. Ag line and dot patterns having pitches less than 10 ㎛ were successfully patterned on SiO_2 surface. With the patterned electrodes as S/D electrodes, TIPS pentacene OTFTs were fabricated and showed similar electrical performance compared to that fabricated by conventional photolithography.

[References]

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