UV-Ozone Effect of the Organic Thin Film Transistor with PVP Gate Dielectric in Low Temperature

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1. Introduction

Organic thin film transistors (OTFTs) are of great interest owing to the possibility for low cost, flexible and the large area electronic applications such as smart card, radio frequency identification (RFID) tags and flat panel displays (FPD). Many reports on OTFTs showing high electrical performance have been obtained by using Si substrate as a gate contact, an inorganic material as a gate dielectric, and a noble metal as a source and drain contacts with only an organic material as channel. However, to fabricate low-cost and low-temperature process for OTFTs, it is crucial that all components of TFTs have to be altered by organic materials. Especially, the use of an organic gate dielectric is one of the key-factors in the development of the all-organic transistors because it strongly affects the reliable characteristic of OTFTs [1-3]. In this paper, we fabricate OTFTs with PVP gate dielectric in low-temperature using UV-Ozone (UVO) exposure.

2. Experiments

The process flow of experiment is summarized in Figure 1. A 600 nm Aluminum (Al) was first thermally evaporated on a pre-cleaned glass substrate as the gate electrode. The polymer dielectric layer was obtained from a poly[4-vinylphenol] (PVP) precursor (8 wt%), methylated poly[melamine-co-formaldehyde] (MMF) (1.6 wt%), and a photo-initiator[1-phenyl-2-hydroxy-2-methylpropane-1-one, Darocur1173@Ciba] (PI) (2.4 wt%) in a propylene glycol monomethyl ether acetate (PGMEA) solvent. The insulator layer of PVP was spin-coated and baked at 90 °C for 90 sec to remove the solvent and then exposed to 254 nm UVO irradiation (17.1 mW/cm²) for 0 or 10 minute to catalyze the cross-linking reaction. Then, surface of the PVP gate dielectric treatment using hexamethyldisilazan (HMDS). And these films were hardened through the additional baking at 90 °C or 180 °C during 60min. A 300 Å thick pentacene active layer was deposited by thermal evaporation under base pressure of 3.0×10⁻¹¹ Torr. Finally, silver source/drain electrodes were deposited by the thermal evaporation with a shadow mask; giving TFTs with a channel length of 100 um and a channel width of 2 mm.

3. Results and discussion

Figure 2 shows the leakage current density of the MIM capacitors as function of PVP insulator and various UVO exposure time. In the figure 2-(a), the device which doesn't exposure UVO measured the leakage current density of 1.57 nA /cm² (@2MV/cm). The more the UVO-Ozone treatment time longer, the leakage current was decreased. When UVO exposure 10min, the leakage current density of 60 pA /cm² (@2MV/cm). We have known that UVO exposure helps cross-linking of PVP.

Figure 3 shows the electrical transfer characteristic of OTFTs as function of the kind of PVP gate dielectric and annealing temperature. The electrical properties of 90 °C process devices are better than 180 °C process devices. As for the OTFT made into the gate dielectric with current process temperature (180 °C), the field effect mobility was 0.13-0.30 cm²/V.s. In the case of OTFTs with the low temperature (90 °C+UVO) gate process dielectric, the mobility was improved to 0.45-0.62. Moreover, other electrical characteristics including the hysteresis, sub-threshold slope (SS) and on/off current ratio were improved. It is well known that the hysteresis and leakage current is reduced by additive adding into the PVP. But mobility and on-current are slightly decreased. Our results agree with previous results [4-5].

Figure 4 shows the electrical output characteristic of OTFTs with PVP gate dielectric formed by different annealing temperature. It is well formed ohmic contact. But in the figure 4-(b), 180 °C PVP gate dielectric processes, come out leakage current.

Figure 5 shows the FTIR spectra analysis of the PVP gate dielectric films with various UVO exposure time. The peak stretch reflected on the 3600-3200 wavelength vicinity shows the -OH group. It is widely known that the -OH group can be trap sites or mobile ions in OTFTs and has a bad influence on carrier transport in gate dielectric [6-7]. We believe that the -OH group was reduced by more cross-linking of PVP and this reduction improved the electrical properties of the OTFTs.

4. Conclusion

In summary, we fabricated the low temperature OTFTs device using UVO exposure. We found that the UVO ex-
posure helps to cross-link PVP and reduce –OH group. The low-temperature OTFTs show the device performance with field effect mobility of the 0.45 /V·s, sub-threshold slope of 0.6 V/decade, hysteresis of 0.2 V and on/off current ratio of 3.3 x 10^6 at −40 V gate bias. These results shows the possibility of using PVP as gate dielectric for OTFTs, where the various application with low temperature and large area deposition.

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References

Fig. 1. Process flow for experiments.

Fig. 2. Leakage current density of the MIM capacitors with PVP insulator (a) PVP, (b)PVP+MMF+PI as function of the UV-Ozone exposure time.

Fig. 3. Electrical characteristic of Fig. 4. Electrical output characteristic of OTFTs with PVP gate dielectric for a 90 °C annealing (b) 180 °C annealing dielectric and annealing temperature.

Table 1. Characteristics of the OTFTs.

<table>
<thead>
<tr>
<th>Process Temperature [°C]</th>
<th>PVP</th>
<th>PVP+MMF+PI</th>
</tr>
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<tbody>
<tr>
<td>Capacitance [uF/cm²]</td>
<td>16.61</td>
<td>11.55</td>
</tr>
<tr>
<td>K (Permittivity)</td>
<td>3.86</td>
<td>3.82</td>
</tr>
<tr>
<td>Channel Width [mm]</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Channel Length [µm]</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Subthreshold Slope [V/dec]</td>
<td>-15.9</td>
<td>-21.3</td>
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<tr>
<td>On / Off Current Ratio</td>
<td>3.4 x 10⁷</td>
<td>3.3 x 10⁷</td>
</tr>
<tr>
<td>Mobility (cm²/V·sec)</td>
<td>0.62</td>
<td>0.45</td>
</tr>
<tr>
<td>Hysteresis [V]</td>
<td>0.2</td>
<td>0.8</td>
</tr>
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Fig. 5. Fourier-transform infrared (FTIR) spectroscopy of the PVP gate dielectric films as function of the UV-Ozone exposure time.