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Organic Thin Film TransistorsWith Tailored Liquid Sources of HfO_2 as High-κ Insulator

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1. Introduction

Organic thin film transistors (OTFTs) are actively studied for application of displays and RFID module. To improve OTFT characteristics, higher dielectric permittivity (κ) material was effective for gate insulator. Especially, HfO_2 and HfO_2-based materials are intensely studied because they combine good dielectric properties with lower leakage current.[1)] And solution-processed these material system to the OTFT was reported.[2)] For fabrication of solution-processed HfO_2 insulator, a tailored liquid sources is one of the best system to obtain lower process temperature, good insulating characteristics and smoother surface roughness because of the tailored controlled system.[3,4)] In this study, we have studied OTFTs with the tailored liquid sources of HfO_2 as high-κ insulator with varied UV irradiation conditions and with double-layered HfO_2/fluorinated resin as gate insulator.

2. Experimental Methods

Figure 1 shows a fabrication process of OTFT. A fusion-formed aluminosilicate glass (Corning 1737) was used for substrate . First, gate electrode of Ta (300 Å) was sputtered on a glass substrate and was patterned using reactive-ion-etching (RIE, CF_4 10 sccm at 3.8 mTorr.) apparatus. Second, insulating material was formed using the tailored liquid sources of HfO_2. Three times repetition of spin coating, baking (200℃ for 10 min), ultraviolet light (UV) irradiation (high-pressure mercury lamp (ML: 350 W, USHIO) and deep UV lamp (DUV: 500 W, USHIO) for 30 min, annealing (250℃ for 10min) were carried out. Thickness of the insulator was about 400 Å. The tailored liquid sources was blended using hafnium isopropoxide $Hf(O\text{-}i\text{-}Pr)_4$/ ethylene glycol monomethyl ether (EGMME) with 1 eq. diethanolamine (DEA) (0.1 mol/L). For optimizing condition, obtained κ of HfO_2 was 20 and flatness of the HfO_2 was as small as 0.13 nm on silicon/ thin SiO_2 substrate. For the case of double-insulator OTFT, fluorinated resin Cytop (600 Å, Asahi-kasei) was used. Third, organic semiconductor of pentacene (500 Å) was evaporated. Finally, source and drain electrodes of Au (500 Å) was evaporated. A manual prober (Micronics 705A-6) and a parameter analyzer (HP 4155B) were used to measure electrical characteristics.

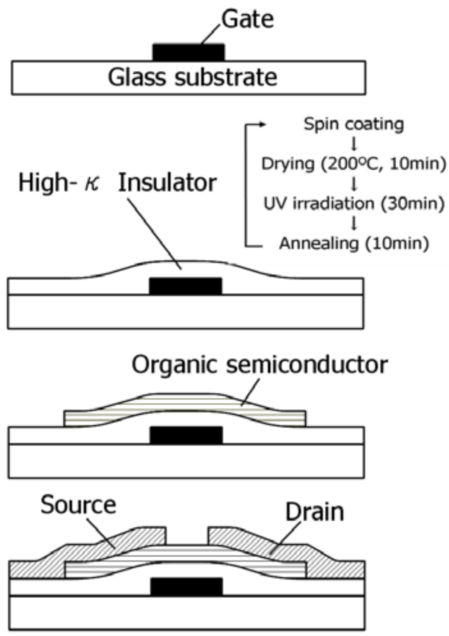

Fig. 1 Fabrication process of OTFT.

3. Results and Discussions

To investigate an effect of UV irradiation, two types of light source were tested and resultant OTFT characteristics were evaluated. Surface energy above insulator was largely influenced on the grain growth of pentacene. Measured contact angles of water were 52° and 80° using ML and DUV irradiations, respectively. Therefore, larger grain growth will be expected under DUV irradiation.

Static transistor characteristics were evaluated. Figure 2 shows drain voltage (V_D) vs drain current (I_D) characteristics of OTFT with HfO_2 gate insulator fabricated using DUV irradiation. Channel length L and width W were 0.25 and 2 mm, respectively. The p-channel mode operation was obtained and estimated field-effect mobility (μ_{FE}) was 0.16 cm^2/Vs from curve fitting. While, the mobility of OTFT fabricated using ML irradiation was 0.05 cm^2/Vs. Therefore, superior performance could be obtained for the case of DUV irradiation. This is due to the better HfO_2 film formation decomposed from $Hf(O\text{-}i\text{-}Pr)_4$. Figure 3 shows gate voltage (V_G) vs I_D characteristics. The on/off ratio was 2.9×10^3, threshold voltage was -1.8 V and subthreshold slope was 1.1 V/decade. Where, threshold voltage was relatively shifted to minus several volts. There exist some positive charges at insulator itself and/or insulator /semiconductor interfaces. In order to improve OTFT characteristics, double-insulator of HfO_2/Cytop was evaluated. Figures 4 show V_D vs I_D characteristics of HfO_2/Cytop OTFT fabricated using DUV irradiation. The L and W were 0.25 and 2 mm, respectively. Estimated μ_{FE} value was 0.25 cm^2/Vs. The on/off ratio was 9.4×10^3. Main reason of the improvement of OTFT performance was smaller surface energy of Cytop, where, the contact angle of water was imcreased to 83°.

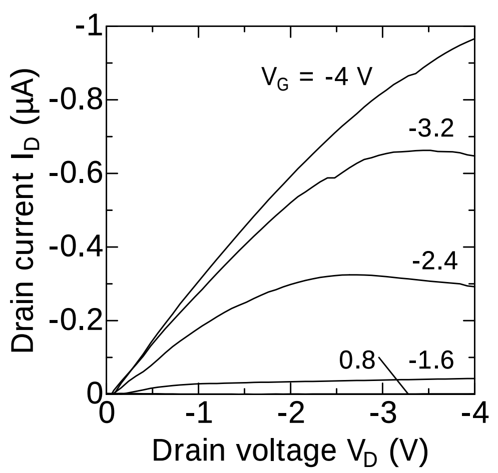

Fig. 2 Drain voltage vs drain current characteristics of HfO_2OTFT using deep UV irradiation.

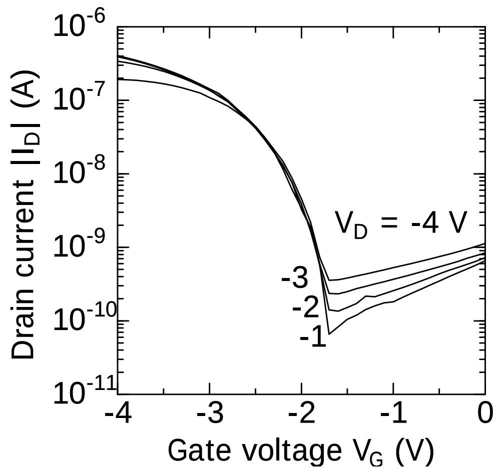

Fig. 3 Gate voltage vs drain current characteristics of HfO_2OTFT using deep UV irradiation.

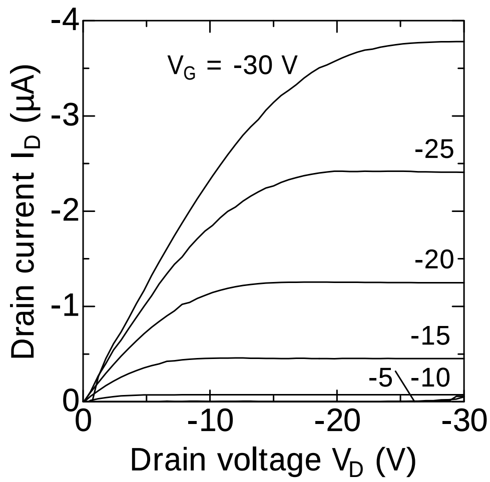

Fig. 4 Drain voltage vs drain current characteristics of HfO_2/Cytop OTFT used deep UV irradiation.

4. Conclusions

We had investigated the OTFT using tailorec liquid sources of HfO_2. The OTFT using deep UV iradiation and with double-insulator of HfO_2/Cytop, superior performances were obtained. This high-κ HfO_2 system will be promising for higher device performance without vacuum process for insulator formation.

Acknowledgemnt

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