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Fabrication of Au electrodes with photopolymerization of triazine dithiol thin films

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1. Introduction

It has been known that triazine dithiol (DT) derivatives with high thermal stability and reactivity of thiol group could be used for the removal agent of a heavy metal, the bridge construction agent of rubber or a plastic, the adhesives of a metal-plastic or metal-rubber, the metal surface treatment agent (water-repellence, corrosion protection) according to different functional groups, and these films were generally formed by electropolymerization, tribological polymerization or immersion by thermal or photopolymerization by electropolymerization [1-3]. A strong bonding with the chemical linkage of the SiO_2/Si substrate and the Au thin film is enabled to bonding the Au thin film on the SiO_2/Si substrate improves.

In this study, we fabricated electrodes of Au thin films on micropattern poly(DT) thin films photopolymerizated through a photomask This process is easier and environment friendlier than the past process. Furthermore, we also investigated organic thin film transistor (OTFTs) with the Au/poly(DT) electrodes.

2. Experimental

The schematic of the fabrication process of Au electrodes is shown in Fig.1. (1) A heavily n-doped Si substrate acts as the gate electrode with a 300 nm thermally grown SiO_2 layer (Ci ~10 nF/cm^2) as the gate dielectric. 6-[allyl-heptadecafluoro-decyl-amino]-[1,3,5] triazine -2,4-dithiol) (DA) thin films were vacuum-deposited on SiO_2/Si substrate. During deposition, the substrate temperatures were set room temperature (RT) under a base pressure of less than 2×10^{-3} Pa. (2) The deposited DA thin films were UV-irradiated through a photomask at ambient conditions. (3) Au ultrathin films were deposited on the irradiated DA polymer thin films. The line and space of the photomask are 108 μm and 195 μm, respectively. (4) The UV-irradiated films were developed with ethanol to remove unreacted monomers from the substrates. In order to evaluate electrical conductivity of Au/poly(DA) electrodes, DA thin films of various thicknesses were deposited on the SiO_2/Si substrate. Then, the DA thin films were UV irradiated for 20 min at ambient conditions. Finally, Au thin films were deposited on poly(DA) thin films by a shadow mask.

OTFTs were fabricated with Au/poly(DA) electrodes. Pentacene thin films of ca. 100 nm were deposited at RT under a base pressure of less than 2×10^{-3} Pa. All film thicknesses and growth rates were monitored by a thickness and rate monitor (CRTM-6000, ULVAC). Au/poly(DA) micropatterns were observed with optical microscope (KEYENCE VHX-100). R_s of Au/poly(DA) thin electrodes and electrical characteristics of OTFTs were measured using a two-channel voltage current source/monitor system (R6245, ADVANTEST) under ambient laboratory air conditions.

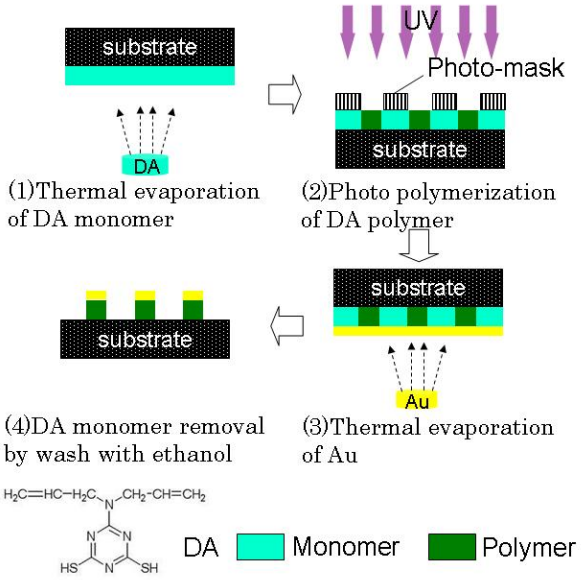

Fig. 1 Schematic of the fabrication process of Au/poly(DA) electrodes with DA thin films UV-irradiated through the photoomask. The molecular structure of DA is also shown.

3. Results and discussion

Figure 2 shows microscopy optical images of Au (ca. 10 nm)/poly(DA)(ca. 40 nm) on SiO_2/Si substrates at various UV-irradiated times. Increasing UV-irradiated time, the width of spaces between Au/poly(DA) electrodes is decreased, and approaches to the line width of photomask, as shown in Fig. 3. On the other hand, the zigzag edges of Au/poly(DA) electrodes in Fig. 2 (a) and (b) are observed due to partial reaction of DA.

Figure 4 shows R_s dependence of Au electrodes on poly(DA) thin film thicknesses. R_s decreases with the film thickness of Au increases, and poly(DA) thin films could improve R_s. When film thickness of poly(DA) is ca. 40 nm,

R_s of 10 nm Au thin films is very low (<20 Ω/□), which is enough to apply to OTFTs.

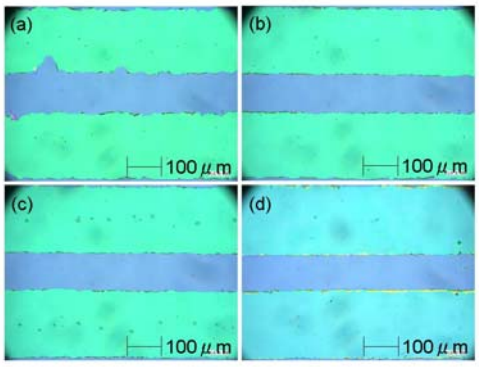

Fig. 2 Microscopy optical images of Au (ca. 10 nm)/poly(DA) (ca. 40 nm) electrodes on the SiO_2/Si substrates with UV-irradiated times: (a) 5 min, (b) 10 min, (c) 20 min, and (d) 30 min

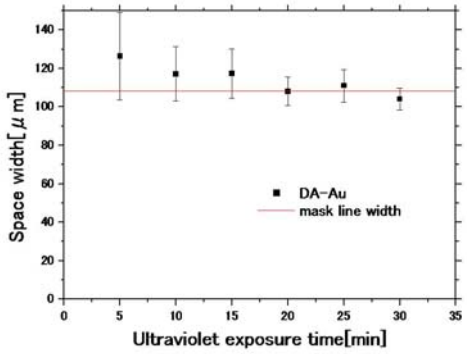

Fig. 3 Space width between Au/ poly(DA) electrodes vs. UV-irradiated time

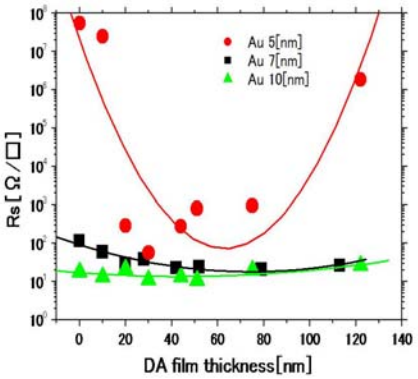

Fig. 4 Plots of R_s of Au thin films vs. poly(DA) thin film thicknesses.

Figure 5 shows the drain current-gate voltage (I_D-V_G) characteristics of OTFTs with Au/poly(DA) electrodes and Au electrodes. The field-effect mobility (μ) and threshold voltage can be extracted using the saturated drain current I_D vs V_G relation:

$$I_D = \frac{W}{2L} C_i \mu (V_G - V_T)^2, \qquad (1)$$

where W, L, and C_i are channel width, channel length, and gate dielectric capacitance per unit area, respectively. From the plots of $|I_D|^{1/2}$ vs V_G, mobilities of these OTFTs using Au(10nm)/poly(DA) electrode and Au electrodes are 1.01×10^{-1} cm^2/Vs and 5.70×10^{-3} cm^2/Vs, respectively. The mobility of OTFTs could be improved to ca. 20 times by poly(DA) thin films.

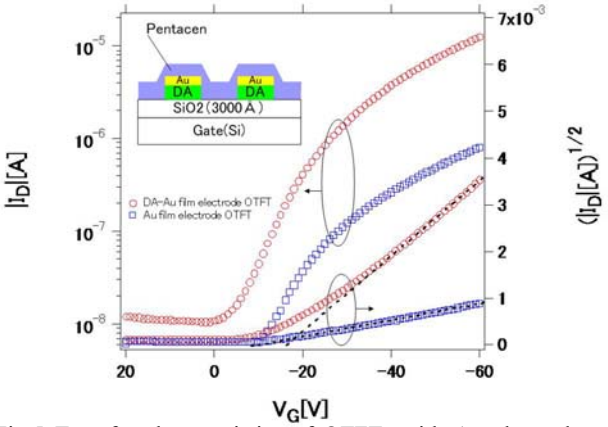

Fig.5 Transfer characteristics of OTFTs with Au electrodes and Au/poly(DA) electrodes. The inset shows structure of OTFT.

3. Conclusions

We have fabricated Au/ploy(DA) electrodes with photopolymerization and measured R_s of ultrathin film Au electrodes deposited on poly(DA). When Au thin films of 10 nm is deposited on DA thin films of ca. 40 nm and UV-irradiated for 20 min, the Au/poly(DA) electrodes were steadily formed with a low R_s (<20 Ω/□). Mobilities of OTFTs using Au thin films (10nm) electrode and Au(10nm)/DA films electrode were 5.70×10^{-3} cm^2/Vs and 1.01×10^{-1} cm^2/Vs, respectively. The electrical performance of OTFTs was improved by using Au/poly(DA) electrodes.

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