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Selective Chemical Vapor Deposition of Cu on Octadecyltrisilane (OTS)-Patterned Indium Tin Oxide (ITO) Substrates and the Evaluation of Contact Resistance of Cu-ITO Interfaces Using a Transmission Line Model (TLM) Technique

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A simple process to achieve the selective chemical vapor deposition of Cu on octadecyltrichlorosilane (OTS)-patterned indium tin oxide (ITO) substrates has been realized in this study. A microcontact printing method was employed to transfer the OTS patterns on the ITO surfaces and subsequently a Cu thin film was selectively deposited onto the OTS-free ITO surface areas by metal organic chemical vapor deposition (MOCVD). The selectively formed Cu on the pre-patterned ITO substrates resulted in the Transmission Line Model (TLM) test patterns, giving the low specific contact resistance of Cu-ITO interfaces.

Keyword: OTS, selective Cu deposition, contact resistance

1. INTRODUCTION

Self-assembled organic monolayers (SAMs) have considerable attentions in recent years because of their wide range of applications including chemical and electrical surface passivation, and biosensors, organic electronics,[1-3] and soft lithography patterning.[4,5] In addition, the soft lithography patterning coupled with selective deposition provides a new paradigm for the fabrication of nano- and microstructures with complex shapes.

We have fabricated the simple transmission line model (TLM) test structures,[6] which were designed to measure the specific contact resistance of the Cu-indium tin oxide (ITO) contacts, widely employed in TFT-LCDs, by using the soft lithography technique coupled with selective growth of Cu. OTS was microcontact printed on the ITO substrate, and then Cu was selectively deposited on the OTS-free regions. This leads to the TLM structures, which provided a specific contact resistance of Cu-ITO interfaces.

2. EXPERIMENTAL

The glass substrates were cleaned by dipping them into a cleaning solution (H_2O: NH_4OH: H_2O_2 = 5: 1: 1) at 80°C for 15 min, rinsing them with deionized (DI) water. The cleaned glasses were loaded into a sputter chamber, where ITO was deposited on them. Subsequently, the ITO-coated glass substrates were microcontact printed by OTS-inked polydimethylsiloxane (PDMS) stamp. OTS-patterned substrates were loaded into CVD chamber, where Cu were selectively deposited on the OTS-free region using hacxafluoroacetylacetonate copper dimethyl-1-butene (hfac)-Cu-(DMB) as a precursor at a temperature of 110°C, the working pressure of 0.2 Torr, and an Ar flow rate of 7 sccm for 5 min. The metal-organic precursor was loaded into a bubbler and heated to 30°C, at which the equilibrium vapor pressure of (hfac) Cu(DMB) was approximately 1.5 Torr. The gas delivery line was maintained at 50°C. A copper MOCVD system consisting of a cold-wall reactor with a halogen lamp heating system and a mechanical pump was equipped with laser reflectance (λ = 632.8 nm), which was used to monitor the in-situ reflectivity from the substrate surface during the deposition process, which indicated the variation of the surface roughness that was caused by the initial growth of metals on the surface, and showed the relative induction period needed to nucleate the metal. The selectively deposited Cu on the OTS-free areas formed TLM patterns consisting of 6 contact pads (40 μm (width) × 80 μm (length)) having different contact spacings. The fabrication sequence is shown in Fig. 1. The fabricated TLM structures were electrically characterized using the TLM technique with a KEITHLEY 2400A to provide a specific contact resistance of Cu/ITO structures. In addition, the selectivity for the deposition of Cu in the presence of OTS monolayer was evaluated using optical microscopy. The thickness of the deposited Cu was measured by a

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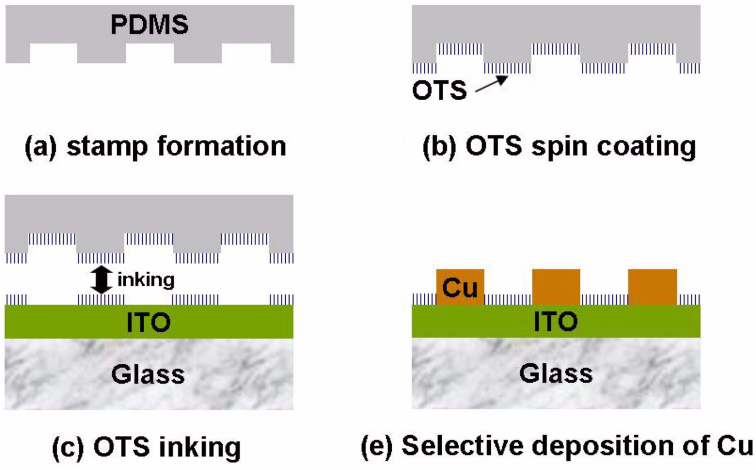

Fig. 1. The procedure sequence for selective deposition of Cu on OTS-patterned ITO surfaces.

surface profilometer. The formed SAMs on ITO was confirmed by measuring the wet contact angle and showed an equilibrium contact angle of 110°.

3. RESULTS AND DISCUSSION

The in-situ reflectivity of the substrate surface was monitored by laser reflectance to determine the apparent induction period on either OTS-coated glass substrate or glass substrate.

Figure 2 shows the changes in reflectance during the deposition of Cu on the OTS monolayer and glass surface, respectively. For the deposition on glass surface, the reflectance slightly decreases and then rapidly increases approximately in 70s after the onset of the deposition. This is in contrast with the deposition of Cu on the OTS monolayer, where the reflectance remains constant for a deposition time of 600 s and more, showing the existence of long induction period for Cu nucleation on the OTS. The significant difference in the apparent induction period between on the OTS and glass possibly indicates that the deposition condition at the temperature of 110°C and the time less than 300s is adequate for obtaining the selectivity in the presence of OTS monolayer.

Figure 3 shows the TLM test structures which consists of differently spaced Cu grid contacts selectively formed on the OTS-free ITO surface. There are clearly seen Cu contact pads selectively formed on the OTS patterned ITO substrate, indicating that MOCVD Cu shows the excellent selectivity over OTS monolayer. The methodology consists of injecting a current (I) between the contacts and measuring the corresponding reduction in voltage (V). A plot of the total resistance, R_C (= V/I) versus the grid contact spacing (d) was generated as shown in Fig. 4 and linear fitting of the measured data was carried out. The excellent linear fitting can be seen at the short spacing, for example of 2.5 um, 5.0 um, 15 um, however, slight deviation is seen at the distance of 30 um and likely increases as the distance increase to 55 μm. We believe the deviation seen at the long distance is due to the edge current effects, which increases as the d/W increases. The linear curve was extrapolated to give the intercept ($2R_C$ = 2 V/I) on the Y-axis. The slope (R_S/W = Vd/I d) of the this curve gave the sheet resistance (R_s) of the ITO thin films, where W is the contact width, d is the distance between the contacts, and Vd is the corresponding voltage drop. As a result, the calculated contact resistance of the Cu-ITO interfaces was 2.23×10^{-5} Ω-cm^2 and the resistivity 65 μΩ-cm. This specific contact resistance is low enough for its application into thin film devices.

4. CONCLUSIONS

Microcontact printing was used to produce OTS patterns on ITO surfaces, which passivated the ITO regions and thus inhibited the deposition of Cu on it. Compared with that, much less induction period for the Cu deposition was seen

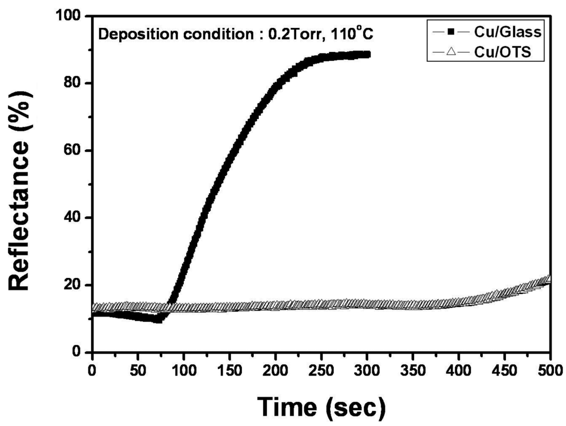

Fig. 2. The variation of reflectance with time during Cu deposition on (a) glass substrate, and (b) OTS-coated glass substrate, respectively.

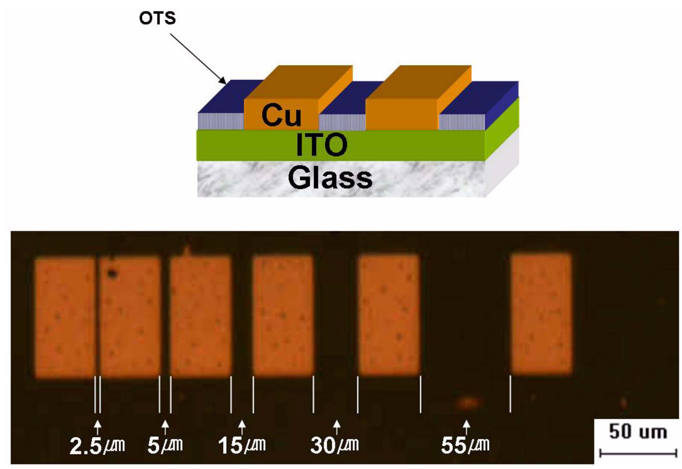

Fig. 3. The optical image of TLM pattern consisting of selectively deposited Cu on OTS-patterned ITO surface.

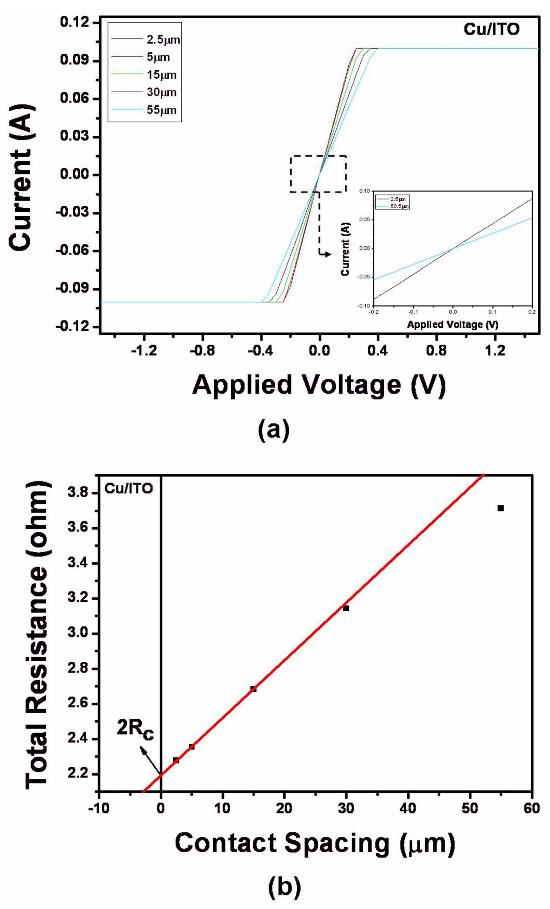

Fig. 4. The I-V characteristics for the different spacings between the contact pads for the (a) ohmic conduction, and (b) the curve fitting of the measured data using the TLM technique for measuring the specific contact resistance.

on the ITO surface. This results in excellent selective deposition of Cu on ITO in the presence of OTS monolayer. The fabricated TLM structures using the soft lithography combined with the selective growth of Cu shows the low specific contact resistance of Cu/ITO interfaces.

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