

The performance of the Co gate electrode formed by using selectively chemical vapor deposition coupled with micro-contact printing

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Abstract

A selective deposition of Co thin films for thin film transistor gate electrode has been carried out by the growth with combination of micro-contact printing and metal organic chemical vapor deposition (MOCVD). This results in the elimination of optical lithography process. MOCVD has been employed to selectively deposit Co films on preformed OTS gate pattern by using micro-contact printing (μ CP). A hydrogenated amorphous silicon TFT with a Co gate selectively formed on SAMs patterned structure exhibited a subthreshold slope of 0.88V/dec, and mobility of $0.35\text{cm}^2/\text{V}\cdot\text{s}$, on/off current ratio of 10^6 , and a threshold voltage of 2.5V, and thus demonstrating the successful application of the novel bottom-up approach into the fabrication of a-Si:H TFTs.

1. Introduction

We have attempted to simplify TFT fabrication process. However, because process using photolithography shows the limit, new method for pattern formation is required.

In this paper, we have successfully developed selective deposition of Co thin films using MOCVD coupled with octadecyltrichlorosilane (OTS) micro-contact printing (μ CP).[1-5]

Selective deposition takes advantage of a different surface state between surface with locally activated and inactive area. We employ μ CP to define pattern by means of stamping which can easily transfer OTS pattern on substrate and repeatedly use stamp.

It is known that OTS is composed of surface group, alkyl group and surface-active head group. μ CP with elastomeric stamps is an effective method to modify the chemistry of surfaces.[6-8] An elastomeric stamp having surface reliefs that are a negative of the desired pattern provides the conveyance for selective placement of OTS on the oxide surface. An

interaction between OTS and oxide (glass) supplied by the PDMS causes the covalent assembly of a monolayer of OTS on the oxide substrate. The OTS is not need anymore other treatment like photolithography and only stamping is all for patterning.

Not only μ CP but also MOCVD is important factor for completely selective deposition. Although OTS monolayer can effectively eliminate absorption of gaseous reactant, selective CVD has narrow window process because the selectivity must be complete, reproducible, and insensitive to changes in reactor operating conditions, substrate type, and cleaning and nature of carrier gas. Therefore, the successful application of selective CVD requires a basic understanding of the mechanism to enable control of selectivity.

We adopt reflectance system to monitor selectivity in-situ during deposition and to comprehend mechanism of deposition as a function of substrate temperature, pressure, carrier gas flow rate and passivation ability of OTS. Also, we employ MOCVD using $\text{Co}_2(\text{CO})_8$ as a precursor. It is possible to deposit on oxide below 100°C due to its high vapor pressure. We have focused the development of the novel fabrication process consisting of the selective CVD of metals coupled with OTS micro-contact printing. The selective deposition of Co at the low temperature, developed for the first time in our group, is able to realize Co gate electrodes formed on patterned SAMs structures. In addition, the material properties and growth mode regarding the Co gate electrode was explored to optimize the process. Finally, the a-Si TFTs with the Co gate were fabricated using the novel process and compared in terms of electrical characteristics.

II. Experiments

A glass has been cleaned by using UV irradiation for 1hr to remove organic material and to provide the activated surface. UV irradiation in the range of

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wavelength from 250 to 380nm can produce oxygen radicals to oxidize and decompose organic compound on the glass surface. Polydimethylsiloxane(PDMS) stamp has been prepared by mixing sylgard A and B, and then pouring it into photoresist(PR) mold, and thus baking it a convection oven at 68°C for 1hr. The separated PDMS stamp from the organized PR has been spun at 3500rpm after dipping into the solution consisting of OTS precursor dissolved in hexadecane. The OTS coated stamp was used to transfer the gate patterns on the glass surface. Then the OTS patterned glass was introduced in a MOCVD reactor, in which Co films was selectively deposited on the uncovered glass surface. The deposition conditions for MOCVD Co include the temp of 50-180°C, the pressure of 0.2-0.6Torr and Ar carrier gas flow rate ratio of 5-10sccm, respectively. The process procedure has been outlined in figure 1. XPS was used to study the decomposition of OTS as a function of UV exposure time. Also the resistivity of metal films was measured by using a four-point probe. The phase and texture of the films was investigated by using an X-ray diffractometer (XRD). The reflectance of Co was examined by using reflectance system.[9-10]

Finally, a-Si TFT was fabricated using a Co gate electrodes and its electrical characteristics measured by using HP 4155A.

III. Results

3.1. Selectivity of MOCVD Co over OTS coated glass

We employ reflectance system in order to examine incubation time for Co nucleation on OTS pattern and glass. Since the incubation time represents the degree of selectivity of each process on various substrates, the measured in-situ reflectivity can be used to identify the time needed for nucleation of Co.

Figure 2 shows the in-situ reflectance of MOCVD Co over the bare glass and the OTS-coated glass substrates, respectively. It is clearly seen that MOCVD Co shows the much increased incubation time over OTS-coated glass, compared with the glass surface at the temperature of 60 to 90°C. Figure 3 reveals AFM images of selectively deposited Co thin films under the conditions of the temperature of 60°C, the pressure of 0.2Torr for 1min. Completely selective deposition of 250Å-thick Co film on the OTS patterned glass was obtained. It is also noted that the Co films shows excellent surface morphology with

the rms of 25Å. The Co film has been successfully produced on glass without a photolithography step, revealing the remarkable surface morphology of Co with the rms of 25Å.

3.2 The removal of OTS after forming the Co pattern

The cleaning of OTS is essential to the electrical characteristics of a-Si TFT, frequently affected by the silicon nitride quality, which can be influenced by the presence of OTS. Therefore, the residual OTS has to be removed from the glass to reduce its effects on silicon nitride quality. UV cleaning was employed to eliminate OTS layer. The decomposition of OTS was investigated by using XPS as a function of UV exposure time. Figure 4 exhibits the variation of C1s peak with the UV exposure time. The intensity C1s coming from decreases as the exposure time increases and then drastically reduced to that of the bare glass in 2hr. Moreover, no damage on Co films can be seen in terms of resistivity.

3.3. Resistivity of Co films

The variation of the resistivity of the dicobalt octacarbonyl ($\text{Co}_2(\text{CO})_8$) films deposited on glass as a function of deposition temperature is shown in figure 5. The resistivity of MOCVD Co on glass abruptly decreases as the deposition temperature, up to 70°C, which is attributed to decomposition for heterogeneous reaction, continuously grain growth and surface reaction limit of $\text{Co}_2(\text{CO})_8$ as a precursor. We consider that selective deposition should be successfully achieved in range from 50°C to 80°C dependant on surface reaction and obtained lowest resistivity of Co thin film. AES depth profiling was employed in investigate the impurity distribution in the deposited Co films. Figure 6 shows AES depth profile of a pure MOCVD Co deposited at 60°C. This low impurity such as oxygen and a concentration of carbon let to low resistivity in MOCVD Co films.

3.4. a-Si TFT fabrication using selectively deposited Co gate electrode

We fabricated an a-Si TFT, using the selectively deposited Co films, to investigate the feasibility of

OTS micro-contact printing coupled MOCVD. Figure 7 shows the transfer characteristics a-Si TFT for a selectively deposited Co gate. The subthreshold slope and on/off current ratio obtained from the transfer curve at a drain voltage of $V_d = 9V$ are $0.88V/dec$ and about 10^6 , respectively. The electron field-effect mobility at saturation was $0.35 \text{ cm}^2/V_s$ for $V_d = 9V$. The threshold voltage, V_T , defined as the linear intercept of the curve at $V_d = 9V$ with the V_g axis, was $2.6V$. The off-state leakage current was below 10^{-12} A at $V_d = 9V$.

IV. Conclusion

The selective deposition of Co has been achieved by using OTS microcontact printing coupled with MOCVD. Consequently, the selectively deposited Co films can be applied as gate electrode in large-area, high resolution, TFT/LCDs, resulting in a reduction in the process step.

References

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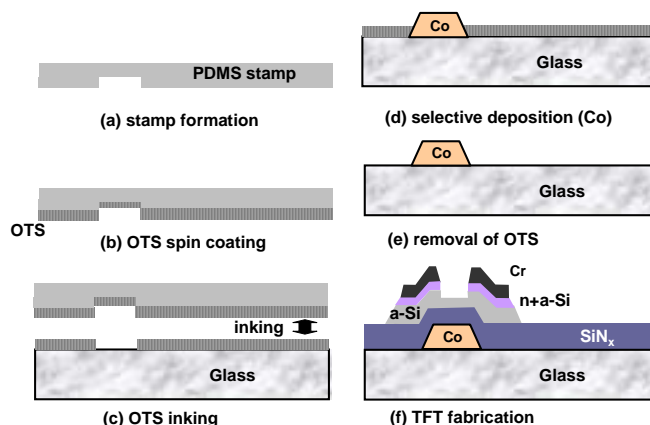


Fig. 1. A schematic of TFT fabrication using micro-contact printing coupled MOCVD.

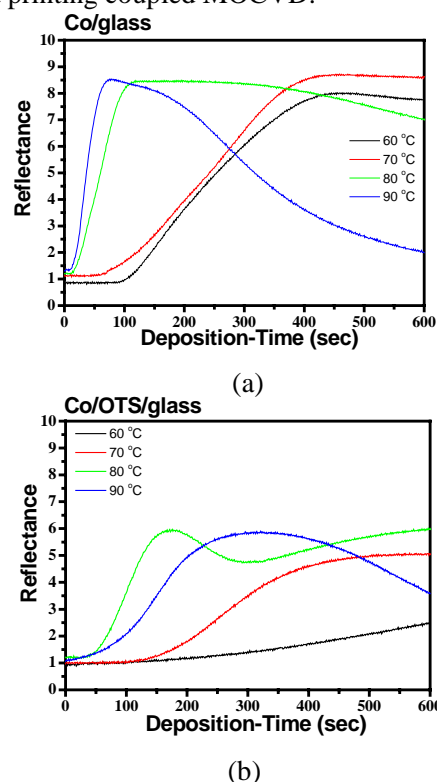


Fig. 2. The reflectance of MOCVD Co over (a) the bare glass and (b) the OTS-coated glass substrates.

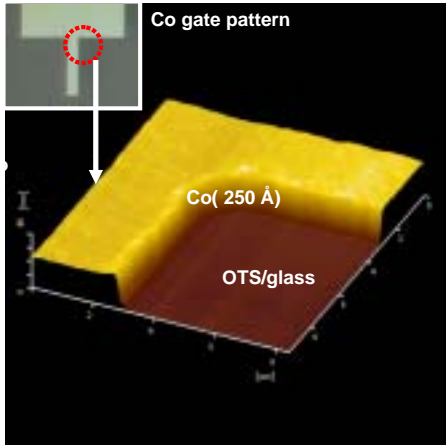


Fig. 3. The AFM images of selectively deposited Co thin films.

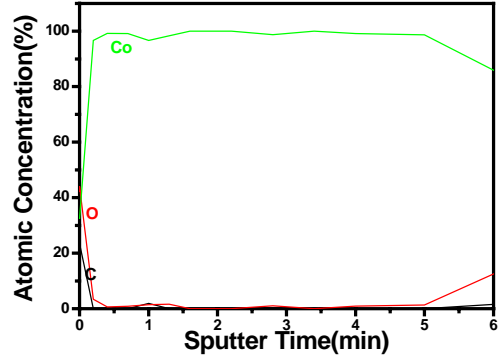


Fig. 6. AES depth profile of Co films.

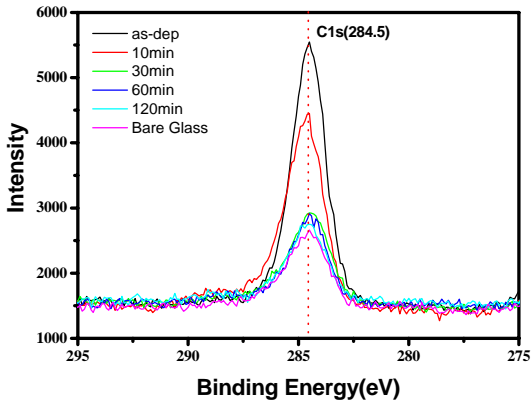


Fig. 4. C1s XPS lines as a function of UV exposure time.

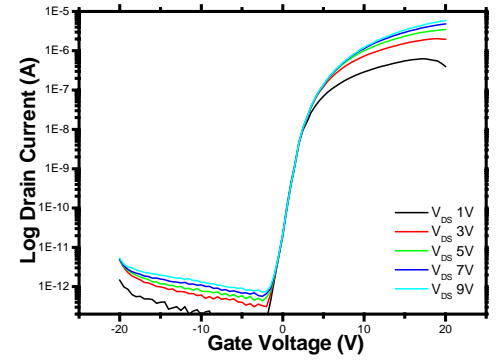


Fig. 7. The transfer characteristics of a-Si TFT for a selectively deposited Co gate.

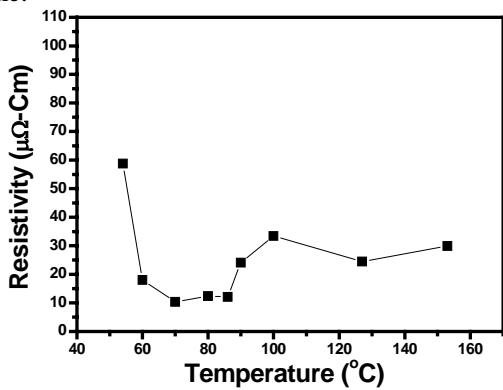


Fig. 5. Resistivity of Co films deposited on glass.