The Low Resistivity Gate Metals Formation of Thin Film Transistors by Selective CVD

S.J. Park, N.J. Bae, S.H. Kim (APEX Co.) H.K. Shin(UP Chem.),
J.S.Choi(HongIk Univ.), J.G.Yee, S.Y. Choi(Kyungpook Nat'l Univ.)

Abstract

Copper and aluminum selective deposition using (hfac)Cu(VTMS) and DMEAA precursors were performed in a warm-wall low pressure chemical vapour deposition reactor. The films of Cu and Al deposited on Corning 7059 glass and quartz with pattern of Cr seed metal. Selective deposition can be achieved at a pressure range of from 10^{-1} to 10 torr and substrate temperature range of 150-250 ℃. Selective deposition of Cu and Al by CVD is one of candidate for gate material formation of larger area and high resolution plat panel displays.

Introduction

Recently, large area flat panel display including thin films transistor liquid crystal display (TFT-LCD) is the most progress field in electronic industry. The fabrication of large, high resolution TFT-LCDs will require several improvements to traditional array processing. As screen sizes grow larger, the limitations of conventional amorphous silicon technology become more readily apparent, as do the problems of gate line delay and photolithographic groundrules. Typical gate metals used for TFT devices include Cr, Mo and Mo-Ta alloy. The resistivities of these materials are too high to be used in large area and high resolution displays. Ultimately, the choice of gate metals is limited to Al and Cu.(1) The low resistivity of copper (1.7 μΩ.cm at 25℃) and Aluminum(2.65 μΩ.cm at 25℃) are its prime advantage in replacing Cr, Mo, Ta and its alloys for gate metal. Aluminum can suffer from problems, most notably hillock formation during high temperature PE(plasma enhanced)CVD(chemical vapor deposition steps. Cu is very low resistivity, no hillock formation and high electromigration resistance. Recently sputtered Al, Cu and its alloys have been given much consideration as gate metals.(2) Now, the fabrication process of Al and Cu deposition commonly is sputtering. But the sputtered Al and Cu films needs one additional photolithography step because of the lack of adhesion to glass of Al and Cu films. Therefore, one of reasonable deposition methods for gate metal is selective MO(metal organic)CVD. In selective Al and Cu CVD, at least one additional photolithography step need not.

Selective processes cannot apply to semiconductor manufacture because of the lack of reasonable process controllability and selective deposition theory. We can observe selective deposition of Cu and Al onto metallic surfaces for the application of TFT gate metals. The purpose of this work was explored experimentally by developing low resistivity gate metals by selective copper and aluminum CVD.

Experiments

Cu and Al CVD system is shown in a schematic diagram in fig. 1. The system consists of three main parts : (1) source delivery part, (2) reactor chamber and (3) vacuum components. The Cu and Al source were a liquid metalorganic compound, hexafluoropentanedione Copper vinyltrimethylsilane (hafc)Cu(VTMS) and dimethylethylamine alane (DMEAA, $(CH_3)_2C_2H_5N:AlH_3$) which were contained in a stainless steel container with heater. To avoid decomposition and condensation of the sources in the delivery line, chamber wall and vacuum line was heated to 70℃ for (hfac)Cu(VTMS) source and 50℃ for DMEAA using heating tapes. Ar gas carried the vapor into the warm wall CVD reactor. The reactor chamber has a resistive heated substrate holder and temperature controlled showerhead. The basic specification of Cu and Al MOCVD processes in the study was known values of parameter in previous reports.(5,6)

The processes are summarized in fig.2. The Cr seed metal of 2500Å was grown on the 1.1mm quartz and Corning 7059F glass. Cr film by thermal evaporation was seed metal for selective CVD. Cr film was then patterned and wet etched using Cr etchant-7. The reasons using Cr films for seed materials in the inverted staggered TFT are properties of good adhesion to glass, black color and low oxidation rate. Selective Cu and Al films were deposited using (hfac)Cu(VTMS) for Cu precursor and DMEAA for Al precursor on the Cr patterned glass wafers. The films thickness was measured by stylus method and SEM(scanning electron microscope). AES (Auger electron spectroscopy) was used to analyze the impurities.

Results and Discussion

A selective Cu and Al deposition using seed metals on glass substrate may bring to the low resistivity gate metal formation for the inverted staggered TFT-LCD of large area and very fine pixel. However, an inherent danger of any selective process is loss of selectivity before the end of the deposition step. A selectivity in the metal-CVD depends on substrate materials, precursors chemistries, deposition temperature, source residual times, working pressure and deposition rate.

The composition of the deposited Cu was determined by AES, and contaminants of carbon, fluorine, and oxygen was not found in deposited Cu films. The contamination level in Cu films is lower value than detectable limits. But the composition of the Al films was found with oxygen impurity because of the lack of ultra high vacuum in the reactor.

Fig.3. showed selective Cu (Fig.3a) and Al (Fig.3b) CVD on glass substrate with patterned Cr metal. The present study clearly demonstrate that (hfac)Cu(VTMS) and DMEAA deposited Cu and Al films readily on a metallic Cr surface, but not on Corning 7059 glass and quartz. It is very interesting that in the boundary between metal and glass, not only Al growing on the Cr upper surface, but also abnormal Al growing on the side area of Cr pattern. The deposition of Al using DMEAA showed strong dependance on profile of seed metal compared with Cu using (hfac)Cu(VTMS).

In order to clarify the mechanism of abnormal Al growing in the side area of Cr pattern, fig.4 showed surface growing morphology on the Cr pattern and glass of dependance on deposition time. The deposition was performed at constant pressure of 1 torr, flow rate of 200 sccm, and substrate temperature of 150℃. In early stage, DMEAA deposited Al readily on the side surface area of Cr pattern, but not on the glass and Cr upper surface in Fig. 4(a). After deposition time for 1 minute, Al films were grown on both the side and upper surface of Cr pattern. It is a matter of course that Al films on the side area were grown continuously. It is very interesting that growth morphology of deposited Al films on the side area of Cr pattern was lateral columnar structure. Although the mechanism of abnormal Al growth phenomena using DMEAA at initial selective deposition on the side area of Cr pattern has not been investigated, the decomposition mechanism may be relation to distribution of electrons density and/or electron energy states in the Cr pattern. In view of this, we can explain the abnormal Al growth on the side area especially, a corner of Cr pattern. Fig. 5(b) was the demonstration data of above explanation for the abnormal Al growth on a corner of Cr pattern. Similar observations in previously reported CVD Al using DMEAA due to the flux of growing species at edges of the growing films on metal was grater than the flux impinging on the upper surface of metal pattern.(5)

Fig.5(a) showed deposited Al films on glass with patterned Cr metal with nearly perfect selectivity. Selectivity was eventually diminished at longer time. More dramatic was the effect increasing the wafer temperature of above 200 ℃.

Cu selective depositions were shown to be across a narrow temperature range of 150-250 ℃ with growth rates of about 200-500Å at a pressure of 1 torr using (hfac)Cu(VTMS) with Ar carrier. To apply the Cu selective deposition for gate metal in TFT-LCD must develop Cu source and processes with high deposition rate, wide range deposition temperature and low deposition pressure.

Conclusions

Selective Cu and Al films for the gate metal of TFT on the glass with Cr pattern have been deposited by a typical thermal CVD. Selective Al using DMEAA showed abnormal lateral growth on the side area surface of Cr pattern at a growth initial stage. These phenomena are obstacle to TFT gate formation processes. Selective Cu using (hfac)Cu(VTMS) can apply to the gate metal formation of TFT. But for reasonable selective deposition applicable to TFT must be research about precursor and processes including high deposition rate and wide processes window. Although selective Cu and Al for the gate metal has many problems, selective CVD is one of candidate for low resistivity gate metal formation

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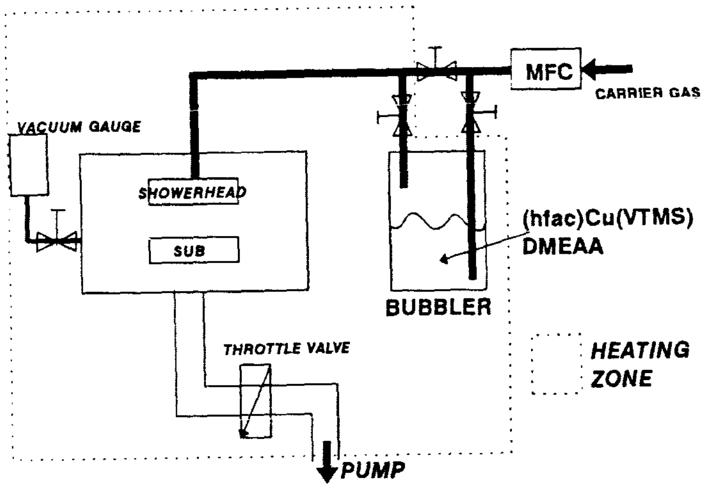


Fig.1. Schematic diagram of CVD with bubbler.

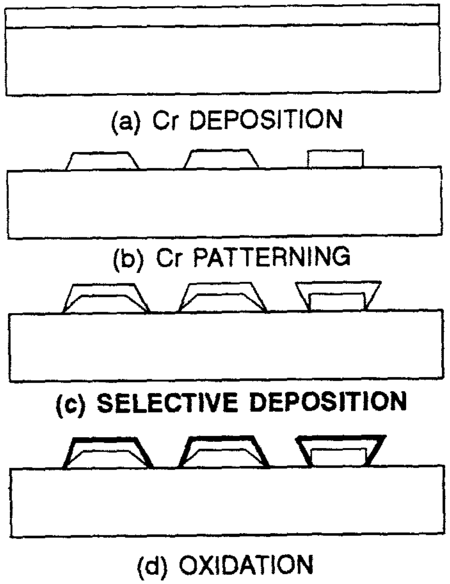
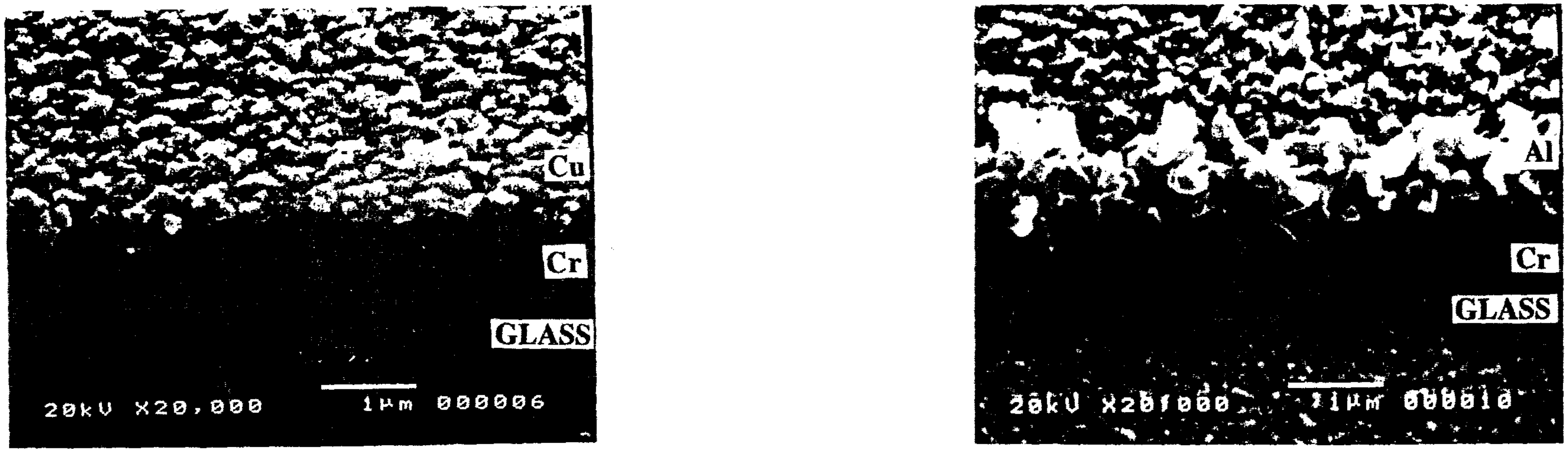


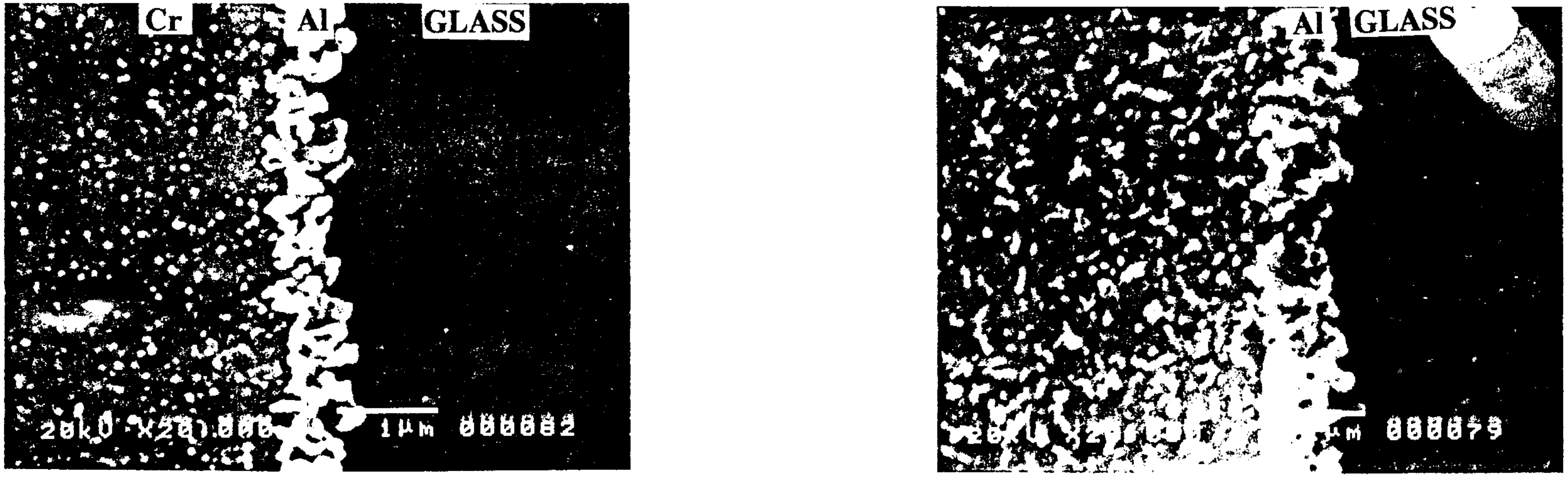
Fig.2. Process procedure of selective CVD.



(a)

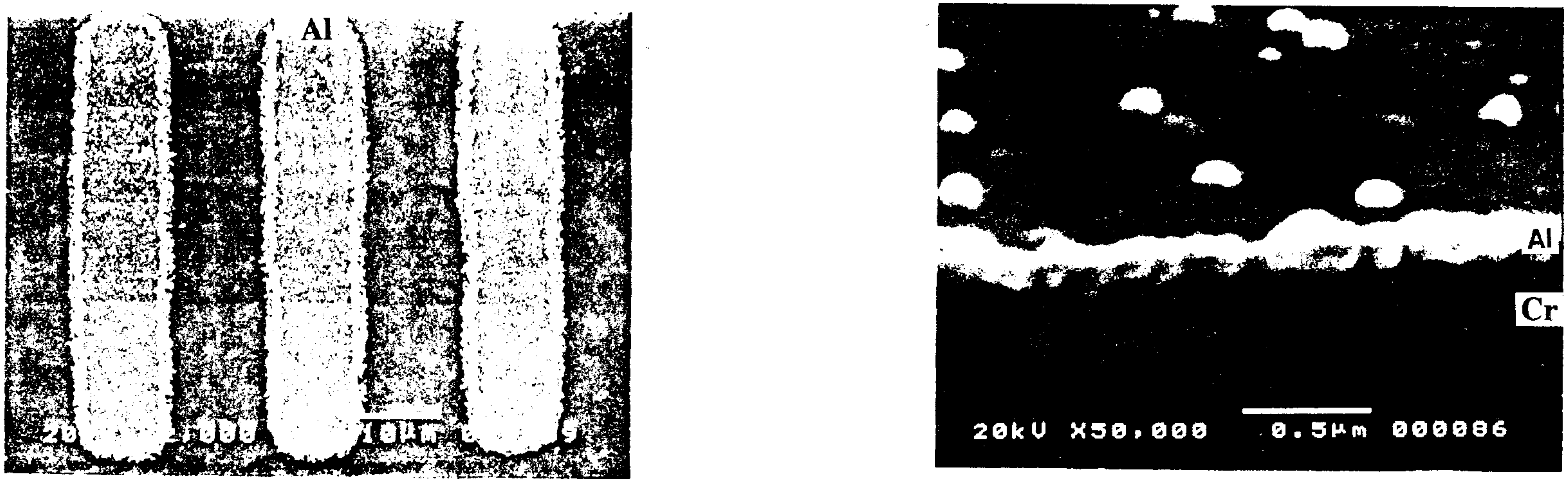
(b)

Fig.3. SEM photography of selective Cu films(a) and Al films(b) on the glass substrate with pattern of Cr seed metal.



(a) (b)

Fig.4. SEM photography of CVD Al films dependance on a deposition time of (a) 0.5min and (b) 1min...



(a) (b)

Fig.5. Demonstration of nearly perfect selective Al(a), photography of the initial deposited Al films (b).