Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

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Version of record first published: 18 Mar 2009

Mol. Cryst. Liq. Cryst., Vol. 499, pp. 169/[491]–177/[499], 2009

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400802620170

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Hydrogenated amorphous silicon (a-Si:H) thin films, as an active layer of a hydrogenated amorphous silicon thin film transistor (a-Si:H TFT), were deposited with different amounts of hydrogen (H_2) dilutions by plasma enhanced chemical vapor deposition (PECVD). The H_2 atoms in a-Si:H that use an active layer are very important in improving field effect mobility (μ_n) and in controlling the threshold voltage (V_{th}). The μ_n of a-Si:H TFT is an important factor for an active matrix display device. If the μ_n of a-Si:H TFT increases to $1 \sim 2\,cm^2/V \cdot sec$, the TFT-LCD and OLED displays can have a drive IC within the panel. A high resolution display can also be made [1]. Therefore, the H_2 content in a-Si:H is a key factor in the changing V_{th} of TFT. We carried out various studies on the properties of the materials of a-Si:H films that were deposited with a varied H_2 flow rate and found that the V_{th} shifted from 3.6 to 1.4 V with an increase in the H_2 flow rate from 0 to 300 sccm. The μ_n changed also from 0.152 to $0.227\,cm^2/V \cdot sec$.

Keywords: a-Si:H thin film transistor; hydrogen dilution; threshold voltage shift

INTRODUCTION

Nowadays, many kinds of flat panel display (FPD) have been researched to take the place of the cathode ray tube (CRT) that is massive and heavy, liquid crystal display (LCD) and organic light emitting diode (OLED) are the most spotlighted FPDs [2]. These FPDs have many good points to realize the thin model, lightweight, large scale and high definition. The a-Si:H TFT, which is used in many displays as a drive device and TFT-LCD, a FPD, make up a large portion

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of the market [3]. Although a-Si:H TFT has many advantages, its transfer characteristics are unstable against the voltage applied to the gate electrode [4]. In the inverted staggered a-Si:H TFT, this phenomenon causes the movement of V_{th}, which is an essential part of TFT. Moreover, a-Si:H deposited using PECVD has a low μ_n and an instability under light illumination [5]. The a-Si:H, which has H_2 atoms to prevent the dangling bond from building up, has much lower density of states in the band gap than a general one. The low density of states in the gap and low density of band tail states give a high performance a-Si:H TFT.

In this paper, we have investigated the H_2 contents within the a-Si:H thin film deposited with a variation of H_2 flow rate by PECVD. Using these a-Si:H thin films, the a-Si:H TFT was fabricated. We have studied the V_{th} shifts of a-Si:H TFTs that were deposited with various amounts of H_2 dilutions. By measuring C-V characteristic, we have also obtained the changes of μ_n in the channel between the source and drain.

EXPERIMENTAL

Figure 1 shows the process for the fabrication of a-Si:H TFT. NiCr was used as the gate metal and 1500 Å was deposited on 1737 corning glass by a thermal evaporator. After gate patterning, the hydrogenated amorphous silicon nitride (a-SiN:H) thin film was deposited. Using PECVD, a-SiN:H thin film was deposited with a thickness of 2500 Å. The PECVD was performed at 250°C and the total gas flow rate consisted of Ar of 500 sccm, NH_3 of 400 sccm and SiH_4 (diluted in 90% He) of 100 sccm. The working pressure was 750 mTorr and the plasma power was 150 W. Then, the a-Si:H thin film was deposited. The flow rate of SiH_4 was fixed at 100 sccm and we tried an experiment by increasing the H_2 flow rate from 0 to 400 sccm. The thickness of a-Si:H was 2000 Å. The substrate temperature was 250°C, the working pressure was 750 mTorr and the plasma power was 250 W. Then, n+ a-Si:H, as the top layer of three, was deposited by PECVD. The thickness of this layer was 500 Å which was relatively thinner than the two bottom layers. The total gas flow of the n+ a-Si:H layer was SiH_4 of 50 sccm and PH_3 of 50 sccm. For PECVD, there was a substrate temperature of 250°C, a working pressure of 750 mTorr and a plasma power of 150 W. After deposition, thin triple films were patterned for an active area and etched by the reactive ion etch (RIE) method. Plasma etching was executed for 17 minutes with a RF power of 40 W by using 20 sccm of SF_6 gas, and the working pressure was 150 mTorr.

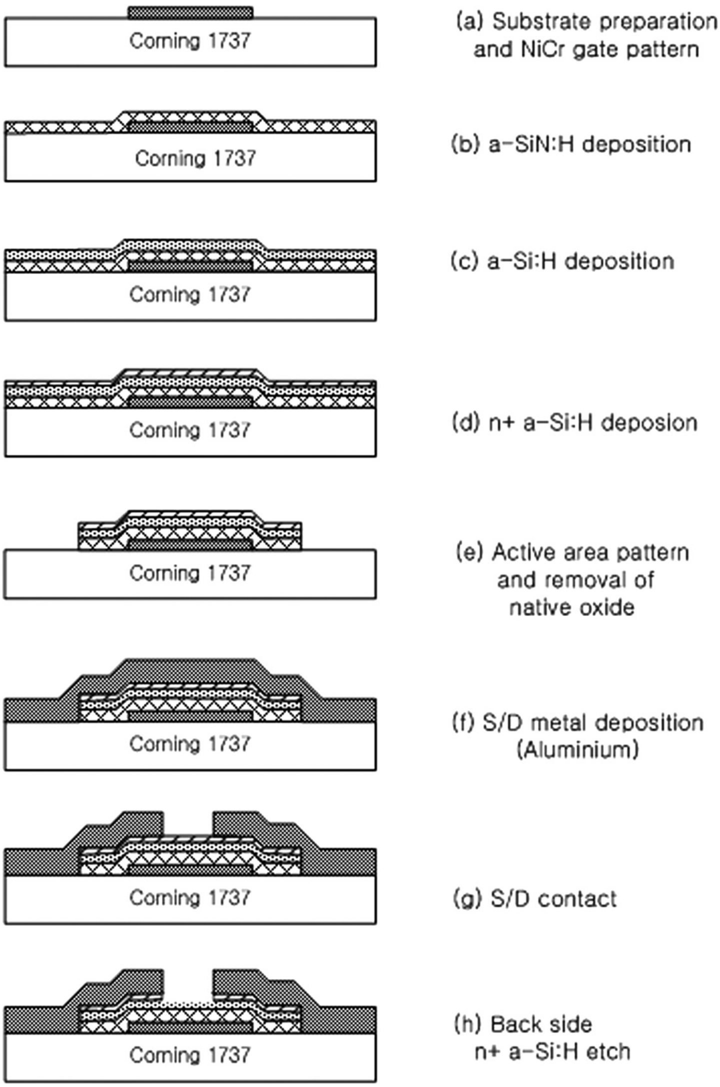

FIGURE 1 A process flow chart of a-Si:H TFT fabrication.

Al was used as a source-drain metal and 2000 Å were deposited by a thermal evaporator. Source-drain contacts were defined by using photolithography. After Al patterning by Al etchant, the back channel between the source and drain electrode was etched by a RIE. The conditions of back channel etching were 45 seconds with a RF power of

20 W by using 20 sccm of SF_6 gas, and the working pressure was 150 mTorr.

RESULTS AND DISCUSSION

The operation of a-Si:H TFT is divided into two areas, linear region and saturation region. In a linear region, the basic current-voltage characteristics can apply to the gradual channel approximation. This condition shown in Figure 2 means that transverse field form the channel and longitudinal field transfer the drain current (I_d) [6,7]. As the gate voltage (V_g) increases, more electron charge is induced in the channel and, therefore, the channel becomes more conducting. The I_D initially increases linearly with the drain bias (V_d). Once the V_D is increased to the point that $(V_g - V_d) = V_{th}$, the threshold is barely maintained near the drain end, and the channel is said to be pinched off. Now, the I_D is said to be in the saturation region because it does not increase with the drain bias significantly. Then I_D is given by [8]

$$I_d = C_i \, \mu_n W/(2L)(V_g - V_{th})^2 \tag{1}$$

To investigate the H_2 contents within a-Si:H thin film, the fourier transform infrared spectrometer (FTIR) measurement was used. FTIR was used to calculate the quantitative and qualitative analysis

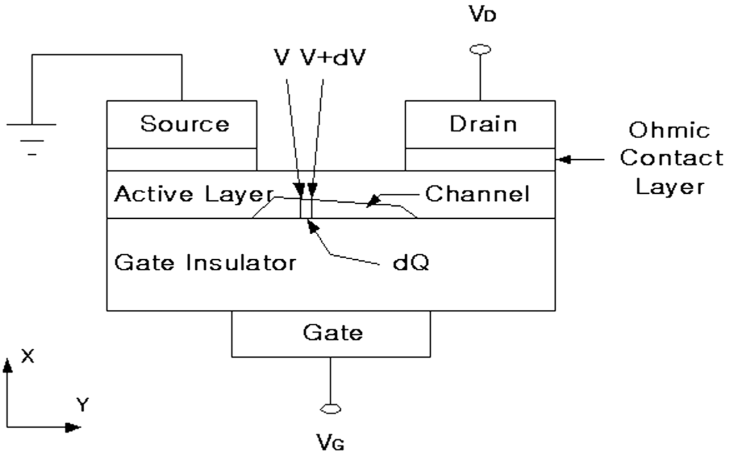

FIGURE 2 A schematic diagram of the inverted staggered a-Si:H TFT.

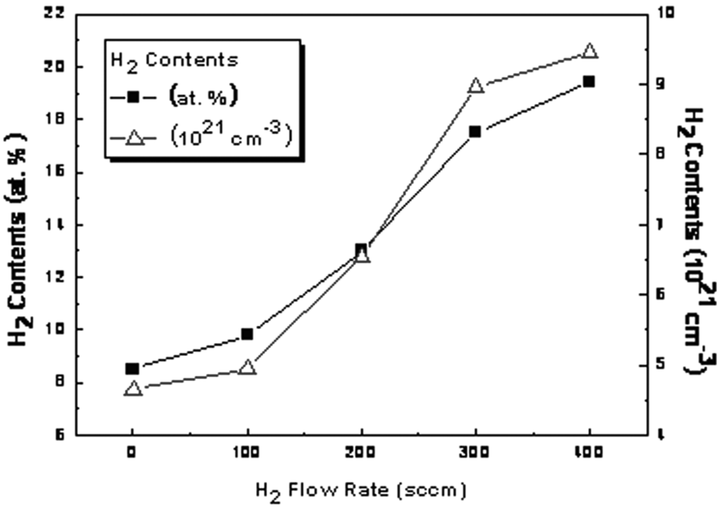

FIGURE 3 The H_2 contents within a-Si:H thin film with a variation of H_2 flow rate.

of a-Si:H thin film. Figure 3 shows the H_2 contents within a-Si:H thin film deposited with the variation of the H_2 flow rate. In the variation of H_2 flow rate, the H_2 contents were increased from

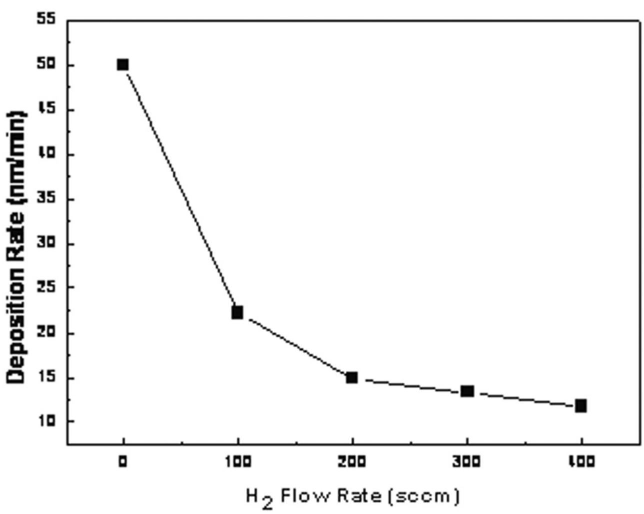

FIGURE 4 The deposition rate of a-Si:H thin film with a variation of H_2 flow rate.

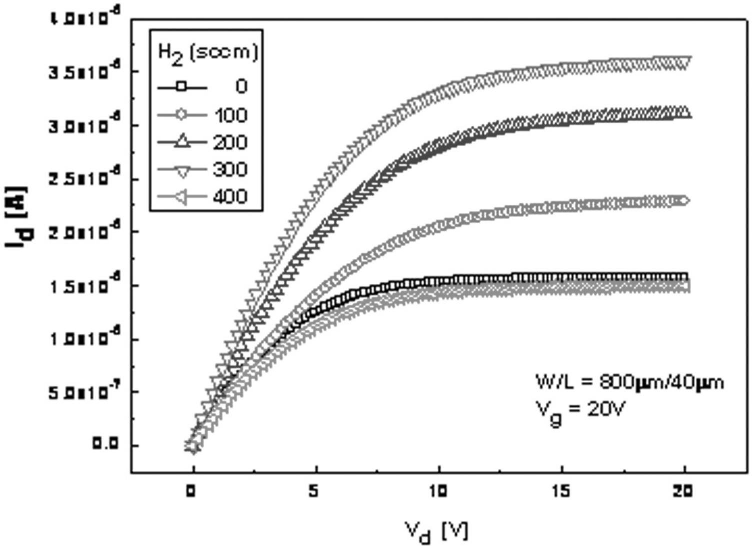

FIGURE 5 The output characteristics of TFT, where a-Si:H layers were deposited with a variation of the H_2 flow rate.

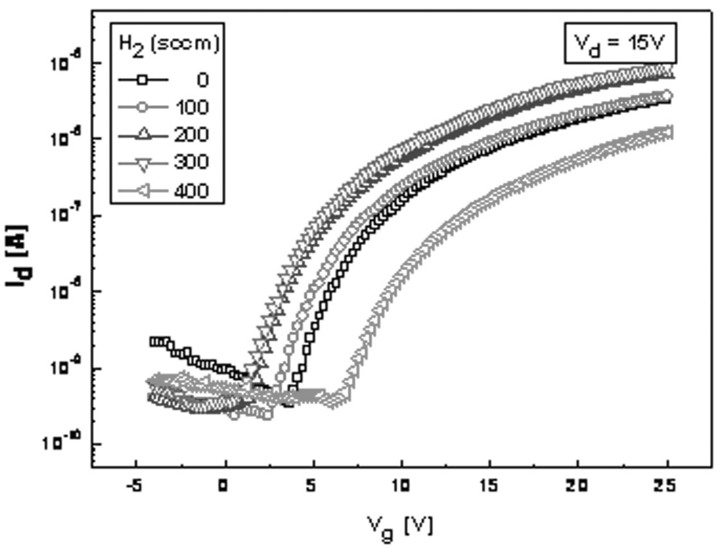

FIGURE 6 The on/off current ratios of TFT, where a-Si:H layers were deposited with a variation of the H_2 flow rate.

8.5 at.% to 19.4 at.% in comparison with the Si contents within a-Si:H thin film. Figure 4 shows the deposition rate of a-Si:H films plotted against the H_2 flow rate. The deposition rate was reduced from 50 nm/min to 11.7 nm/min with an increase in the H_2 flow rate. This is because the H radical in the plasma phase is an etchant for silicon [9,10]. Figure 5 shows the output characteristics of the inverted staggered a-Si:H TFT at the V_g of 20 V, in which a-Si:H films were deposited with a variation of the H_2 flow rate. The on-current of the fabricated device exhibited 3.6 μÅ at the H_2 flow rate of 300 sccm. Figure 6 shows the transfer characteristics of the a-Si:H TFT in which a-Si:H films were deposited using a varied H_2 flow rate. The subthreshold slope and the on/off current ratio obtained from the transfer curve at the V_d of 15 V are 2.5 V/decade and $\sim 10^5$, respectively. The off-state leakage current is about 5×10^{-9} A at the V_d of 15 V and the V_g of -5 V. Figure 7 is $V_g - {I_d}^{1/2}$ curve that $V_d = V_g$ to calculate μ_n. Figure 8 shows the V_{th} of the a-Si:H TFT as a function of the H_2 flow rate. The V_{th} decreased from 3.6 to 1.4 V with an increase in the H_2 flow rate from 0 to 300 sccm. And then it was increased to 5.8 V at the H_2 flow rate of 400 sccm. Substituting the respective values into Eq. 1, we have obtained the μ_n in the channel. Figure 9 shows the changes of μ_n in a-Si:H TFT that was fabriacted with a variation of the H_2 flow rate. The μ_n increased from 0.152 to

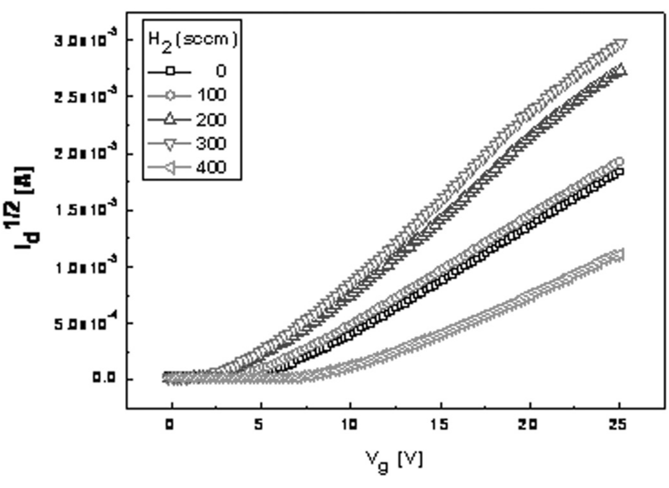

FIGURE 7 The transfer characteristics for saturation region of TFT, where a-Si:H layers were deposited with a variation of the H_2 flow rate.

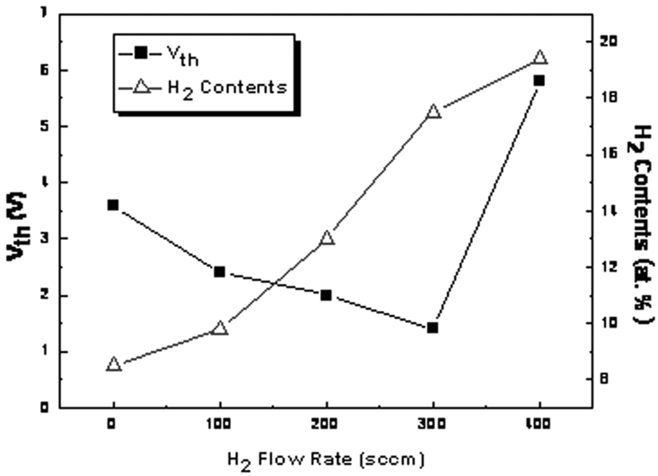

FIGURE 8 The shift of V_{th}, where a-Si:H layers were deposited with a ariation of the H_2 flow rate.

0.227 $cm^2/V \cdot sec$ with an increase in the H_2 flow rate from 0 to 300 sccm. And then it was reduced to 0.186 $cm^2/V \cdot sec$ at the H_2 flow rate of 400 sccm.

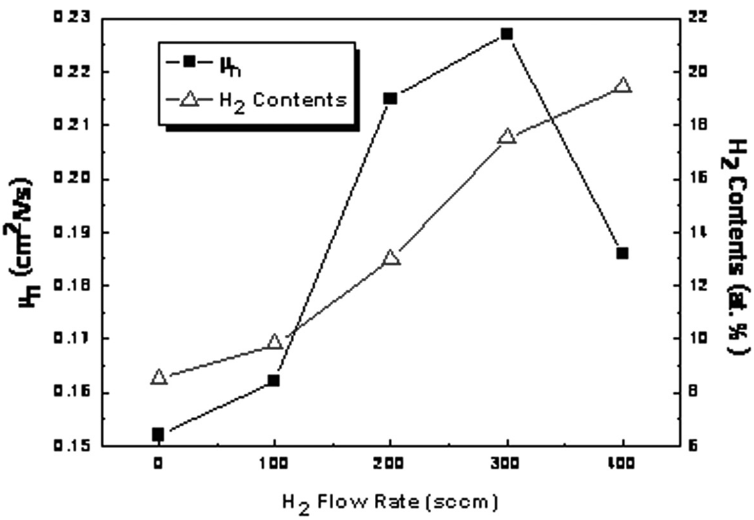

FIGURE 9 The change of μ_n, where a-Si:H layers were deposited with a variation of the H_2 flow rate.

CONCLUSIONS

We have studied the properties of the materials of a-Si:H films deposited via different H_2 dilution rates and found that the V_{th} shifted with the variation in the H_2 flow rate. Moreover, a-Si:H films deposited with a varied H_2 flow rate also exhibited the changes in the μ_n. As the H_2 contents increased within a-Si:H thin film from 8.5 to 17.5 at.%, the V_{th} of the a-Si:H TFT was decreased from 3.6 to 1.4 V and the μ_n was increased from 0.152 to 0.227 $cm^2/V \cdot sec$. This is because the a-Si:H, which has H_2 atoms to prevent the dangling bond from building up, has much lower density of states in the band gap. But the H_2 contents within a-Si:H thin film were 19.4 at.% at the H_2 flow rate of 400 sccm. Because too much H_2 contents within a-Si:H thin film have a bad effect to the electrical characteristic of a-Si:H TFT, the V_{th} and μ_n at the H_2 flow rate of 400 sccm are 5.8 V and 0.186 $cm^2/V \cdot sec$, respectively.

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