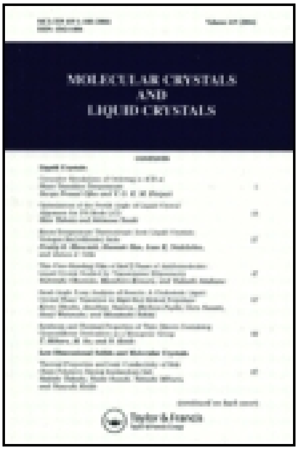

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Effect of a-SiN:H Thin Film Deposited by PE/RACVD on a-Si:H Thin Film Transistor

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Version of record first published: 31 Jan 2007

To cite this article: Jae Wook Kang, Kyung Won Park, Byung Nam Park, Kyo Ho Moon, Sie Young Choi & Young Soo Sohn (2006): Effect of a-SiN:H Thin Film Deposited by PE/RACVD on a-Si:H Thin Film Transistor, Molecular Crystals and Liquid Crystals, 459:1, 157/[437]-165/[445]

To link to this article: http://dx.doi.org/10.1080/15421400600930136

Mol. Cryst. Liq. Cryst., Vol. 459, pp. 157/[437]–165/[445], 2006

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400600930136

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Electron mobility of a hydrogenated amorphous silicon thin film transistor (a-Si:H TFT) a is important factor for a active matrix display device. The electron mobility of a-Si:H TFT is about 0.5 $cm^2/V{\cdot}sec$ in current technology. If the electron mobility the of a-Si:H TFT increases to 1 ~ 2 $cm^2/V{\cdot}sec$, TFT-LCD and OLED display can have drive IC within the panel. High-resolution display also can be made. Hydrogenated amorphous silicon nitride (a-SiN:H) thin films, as dielectric layer of hydrogenated amorphous silicon thin film transistor (a-Si:H TFT), were deposited by radical assisted chemical vapor deposition (RACVD) and plasma enhanced chemical vapor deposition (PECVD). Interface roughness between a-SiN:H and a-Si:H is important to improve electron mobility in a-Si:H TFT. We compared surface roughness of a-SiN:H thin films deposited by RACVD and PECVD and investigated field effect mobility of a-Si:H TFTs using a-SiN:H thin film deposited by RACVD and PECVD.

Keywords: AFM; a-SiN:H thin film; a-Si:H Thin film transistor; RACVD; remote PECVD

INTRODUCTION

Nowadays, a-Si:H TFTs have been used in many displays as switching device [1]. Although a-Si:H TFTs have many advantages, their

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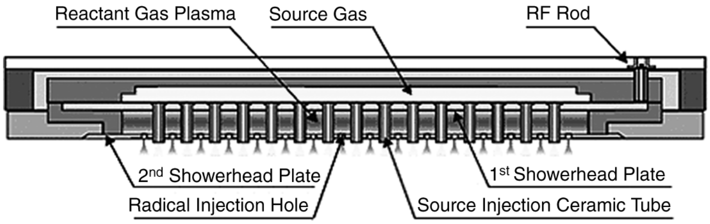

FIGURE 1 Cross section of the showerhead of RACVD.

electron mobility is very lower than that of poly-Si TFTs. If the electron mobility of the a-Si:H TFT increase to $1 \sim 2\,cm^2/V{\cdot}sec$, TFT-LCD and OLED display can have drive IC within the panel. It can reduce unnecessary panel size. High-resolution display also can be made [2]. In the inverted staggered TFTs, the interface roughness between the a-Si:H and the a-SiN:H affects the electron mobility [3]. Interface treatment of a-Si:H/a-SiN:H is a key factor of changing electrical characteristics of TFTs. In this paper, we investigated surface morphology of the a-SiN:H thin film deposited by RACVD and PECVD. RACVD is a new technology of thin film deposition. It uses radical energy and thermal energy. The showerhead of RACVD has dual structure to turn on plasma in it. The mechanism of RACVD is similar to remote PECVD [4]. RACVD has good uniformity, plasma damage free, low temperature deposition, and good film quality [5,6]. Figure 1 shows cross section of the showerhead of RACVD.

EXPERIMENTAL

Figure 2 shows the process flow for fabricating the a-Si:H TFT used in this experiment. Cr was used as gate metal and deposited on 1737 corning glass by sputtering method. After gate patterning, a-SiN:H thin film was deposited. The a-SiN:H thin film of 2500 Å thickness was deposited by PECVD for reference. The a-SiN:H thin film was deposited by 2-step growing using PE/RACVD. PE/RACVD means one reactor with two deposition way. First a-SiN:H thin film was deposited thickness of 2000 Å by PECVD, and then deposited 500 Å by RACVD. Both RACVD and PECVD performed at 250°C and gas flow rate including 100 sccm of Ar, with 45 sccm of NH_3 and 30 sccm of SiH_4 (89.5% He) [6]. The reactor pressure was 700 mTorr, and the r.f. power (radio frequency) was 200 W both PECVD and RACVD. Both a-Si:H and n^+ a-Si:H thin films were deposited by PECVD. Thicknesses of a-Si:H and n^+ a-Si:H were 2000 Å and 500 Å respectively. Substrate temperature was 200°C, the reactor pressure was 500 mTorr

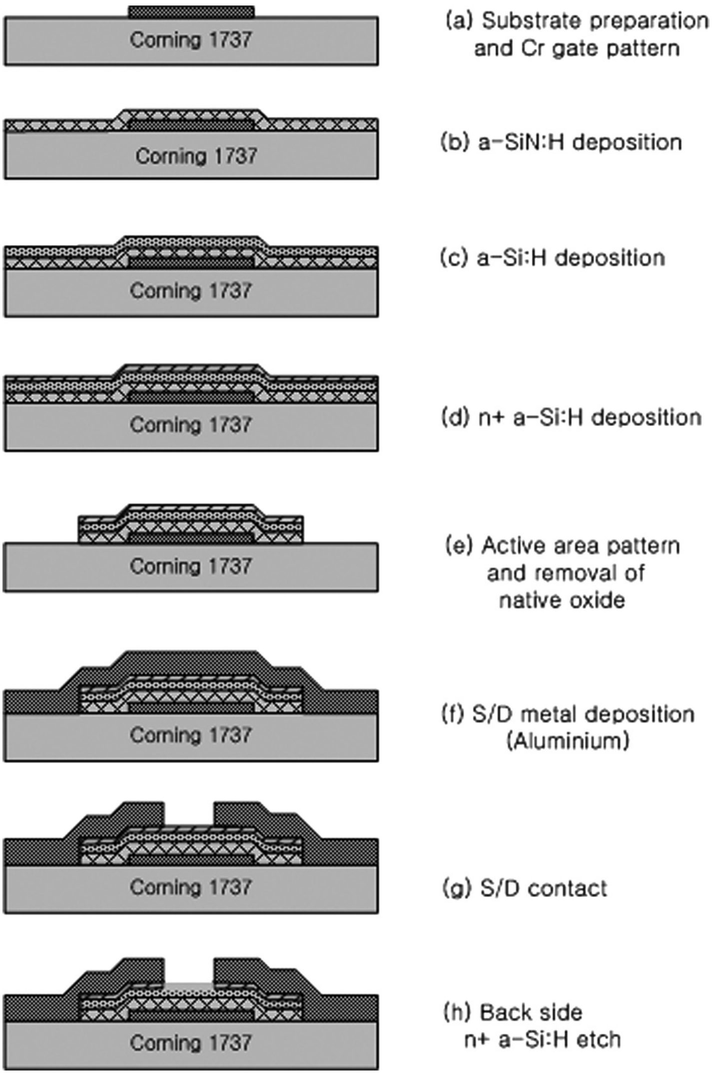

FIGURE 2 Process flow chart of thin film transistor fabrication.

and r.f. power was 100 W both a-Si:H and n^+ a-Si:H deposition. Gas flow was 20 sccm of SiH_4 and 18 sccm of H_2 for a-Si:H. Gas flow for n^+ a-Si:H was 30 sccm of SiH_4 and 50 sccm of PH_3. After deposition, thin films were patterned for active area and etched by reactive ion etch (RIE) method [7,8]. Al was used for source-drain metal and deposited with thickness of 2000 Å by thermal evaporator. After Al

TABLE 1 Deposition Conditions of a-SiN:H, a-Si:H, n^+ a-Si:H Thin Films

Parameter	a-SiN:H	a-Si:H	N^+ a-Si:H
Gas	SiH_4(+90% He)/ Ar/NH_3	SiH_4(+90% He)/ H_2	SiH_4(+90% He)/ PH_3(+99% H_2)
Flow rate (sccm)	30/100/45	20/18	20/50
r.f. power (W)	200	100	100
Substrate temperature (°C)	250	200	200
Working pressure (mTorr)	700	500	500
Deposition time (min)	PECVD 5/RACVD 20	25	8

TABLE 2 Etching Conditions of a-SiN:H, a-Si:H, n^+ a-Si:H and Back Side n^+ a-Si:H

Parameter	a-SiN:H, a-Si:H, n^+a-Si:H	Back channel etch
Gas	SF_6	SF_6
Flow rate (sccm)	20	20
r.f. power (W)	40	20
Substrate temperature (°C)	25	25
Working pressure (mTorr)	300	300
Etching time (min)	18 (227 Å/min)	45 sec (16.7 Å/sec)

patterning, back channel etched by RIE method. Table 1 is deposition conditions of a-SiN:H, a-Si:H, n^+ a-Si:H thin films. Table 2 is etching conditions of active area and back channel etch using RIE.

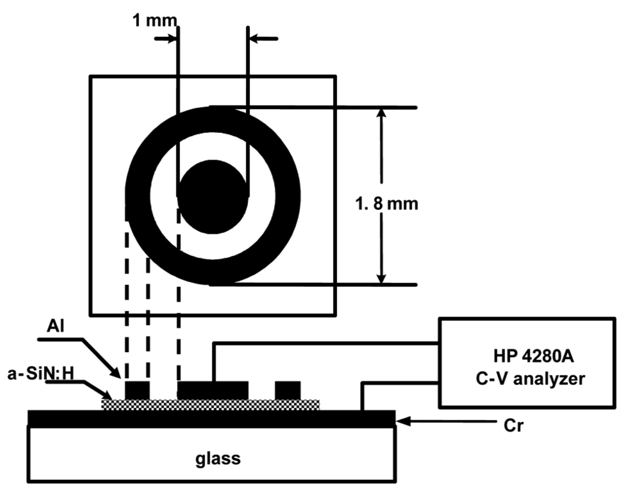

FIGURE 3 Schematic diagram of C-V measurement system.

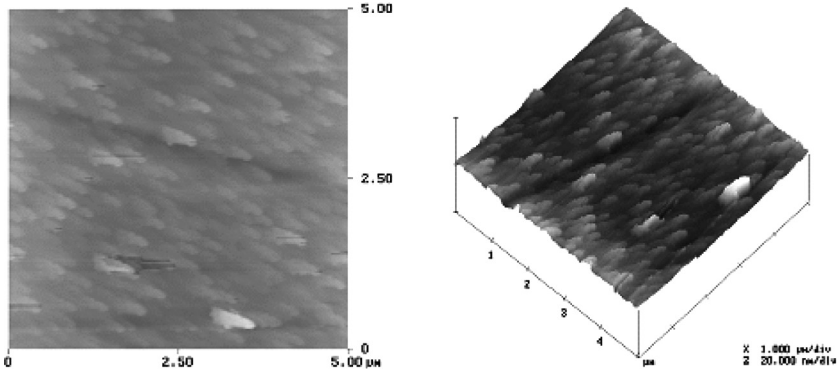

FIGURE 4 Roughness of a-SiN:H dep. by PECVD.

MEASUREMENTS

To investigate surface roughness of the a-SiN:H thin film, AFM (atomic force microscopy) measurement was used [10]. AFM was used to measure physical surface roughness. Figure 3 shows C-V measurement system. Thickness of Cr, a-SiN:H thin film and Al was 1500 Å, 2500 Å and 2000 Å respectively. HP 4280A was used to measure capacitance of a-SiN:H thin film. Alpha-Step was used to measure deposition rate of the a-SiN:H thin film as variation of r.f. power and H_2 flow [9,10]. HP 4155-6A was used to measure I-V, on/off ratio and transfer characteristics of fabricated thin film transistor [1].

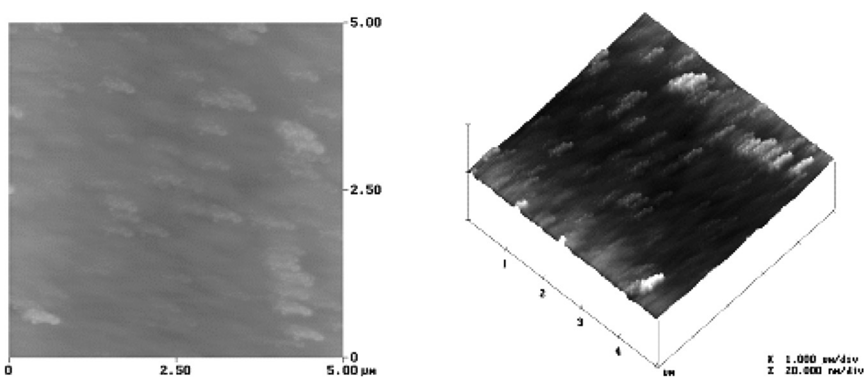

FIGURE 5 Roughness of a-SiN:H dep. by PE/RACVD with r.f. power 200 W.

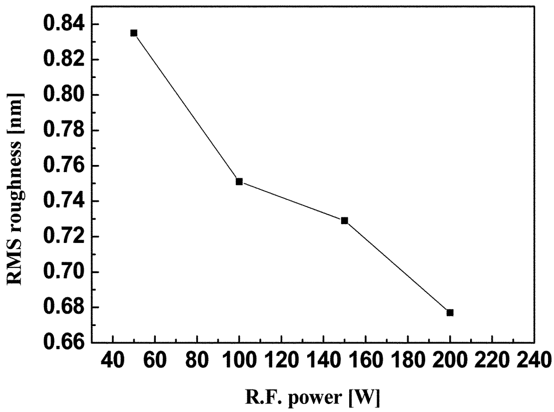

FIGURE 6 RMS with variation of r.f. power.

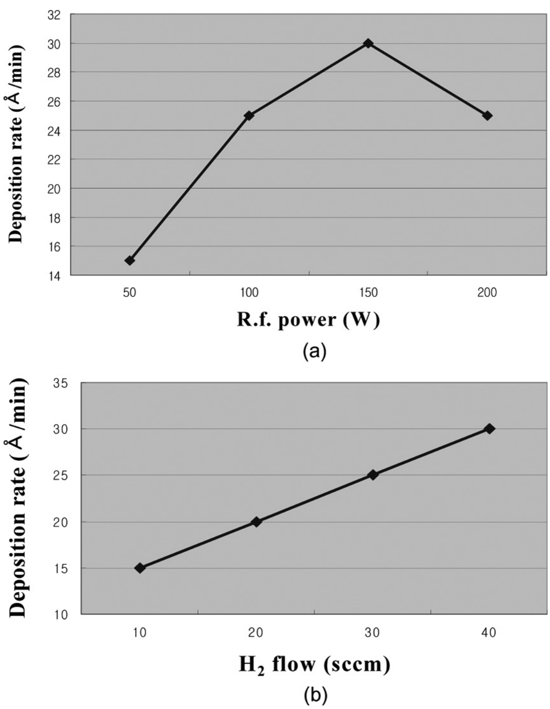

FIGURE 7 Deposition rate of a-SiN:H thin film with variation of r.f. power and H_2 flow. (a) Dep. rate with variation of r.f. power, (b) Dep. rate with variation of H_2 flow.

RESULTS AND DISCUSSION

Figure 4 shows AFM images of a-SiN:H thin film deposited by PECVD. RMS (root mean square) roughness of a-SiN:H thin film surface was 0.862 nm. Figure 5 shows AFM images of a-SiN:H thin film deposited by PE/RACVD. R.f. power of RACVD was 200 W with fixed r.f. power of 200 W of PECVD. RMS roughness of the a-SiN:H thin film surface 0.677 nm. Surface roughness of a-SiN:H deposited by PE/RACVD was smoother than that of the a-SiN:H thin film deposited by PECVD. In RACVD with increasing r.f. power, RMS roughness of a-SiN:H surface was decreased.

Figure 6 shows variation of RMS roughness of a-SiN:H thin film surface deposited by PE/RACVD with variation of r.f. power.

Figure 7 shows deposition rate of the a-SiN:H thin film deposited by PE/RACVD with variation of r.f. power and H_2 flow. In variation of r.f. power, deposition rate was increased to 30 Å/min at 150 W. And

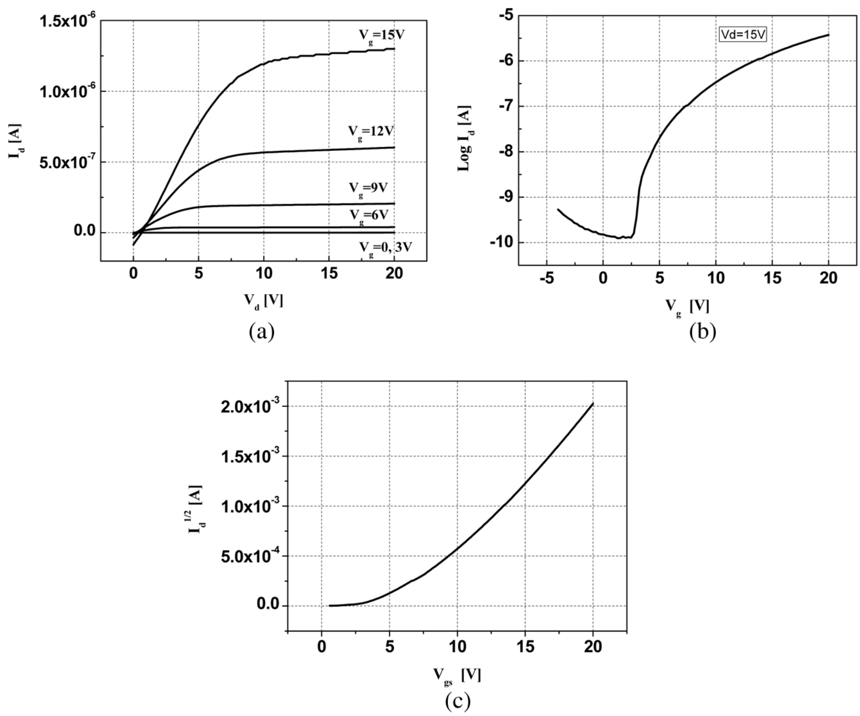

FIGURE 8 Electrical characteristics of thin film transistor with a-SiN:H thin film dep. by PECVD. (a) Id-Vd characteristic, (b) on/off current ratio, (c) transfer characteristic.

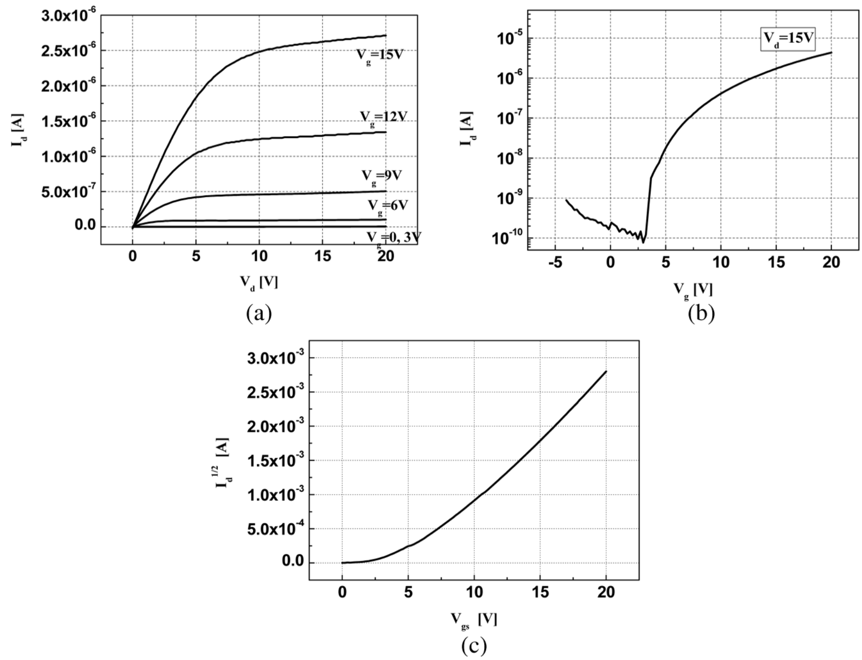

FIGURE 9 Electrical characteristics of thin film transistor with a-SiN:H thin film dep. by PE/RACVD r.f. power 200 W. (a) Id-Vd characteristic, (b) on/off current ratio, (c) transfer characteristic.

then it was decreased to 25 Å/min at 200 W. Deposition rate was increased with H_2 flow and it was 30 Å/min at 40 sccm of H_2 flow.

Figure 8 shows electrical characteristics of a thin film transistor with a-SiN:H thin film deposited by PECVD. Figure 8(a) is I_d–V_d curve with gate voltages of 0, 3, 6, 9, 12 and 15 V. When gate voltage was 15 V, drain current was about 1.3 μA. Figure 8(b) is I_d–V_g curve that fixing V_d for 15 V to measure on/off ratio. Compared with maximum and minimum value, on/off ratio was 5×10^4. Figure 8(c) is Vg–$I_d{}^{1/2}$ curve that $V_d = V_g$ to calculate field effect mobility.

Figure 9 shows electrical characteristics of the thin film transistor with the a-SiN:H thin film deposited by PE/RACVD r.f. power 200 W. Drain current of TFT was about 2.7 μA at 15 V of gate voltage. On/off ration was about 10^5. On/Off ratio was not changed much for both deposited by PECVD and deposited by PE/RACVD.

Figure 10 shows relationship between field effect mobility and RMS roughness of the a-SiN:H thin film with variation of r.f. power. With increasing r.f. power RMS roughness decreased and field effect

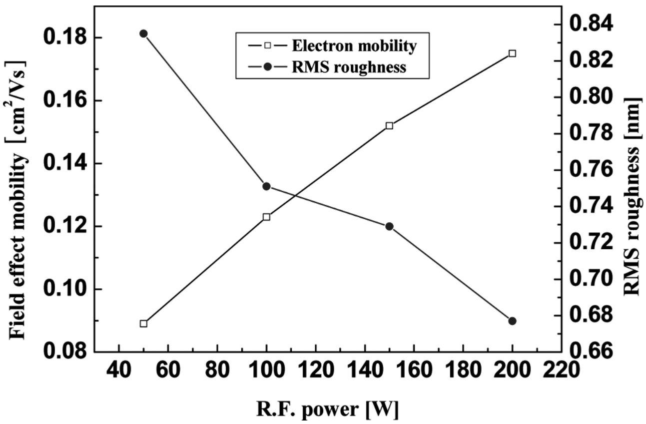

FIGURE 10 Relationship between mobility and RMS roughness with r.f. power.

mobility of the TFT was increased. As roughness of the a-SiN:H was smoothened, the field effect mobility of the TFT was increased.

CONCLUSIONS

As r.f. power increased, surface roughness of the a-SiN:H thin film deposited by PE/RACVD was decreased. Deposition rate with variation of r.f. power was increased until 150 W. As r.f. power was increased, field effect mobility of TFT was increased. It means that as roughness of a-SiN:H thin film decreased, field effect mobility of TFT was increased. As result of AFM, RACVD method affects physically since substrates were free from plasma damage.

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