Microcrystalline Silicon for Thin Film Transistor

D. Milovzorov, K.B. Kim, M. Lisachenko, J.W. Seo, K. Y. Lee, and H.K. Chung

Corporate R&D Center, SAMSUNG SDI Co., Ltd, 428-5 Gongse, Kiheung 449-577, South Korea,

82-31-2884789, milovzorov.dmitry@samsung.com

Abstract

Microcrystalline silicon films were deposited on glass substrate by using plasma-enhanced chemical vapor deposition (PECVD) method. The crystalline volume fraction was estimated by means of Raman spectrometer with argon laser as light source. The high hydrogen dilution of silane gas was used for increase in content of crystal silicon phase.

1.   Objective and Background

Microcrystalline silicon (µc-Si) film is wide used for thin film transistors (TFT) development in liquid crystal display (LCD) panel. In last decades there are three main technological ways to deposit silicon films and produce TFT device. They are following: metal-induced solid phase crystallization [1], laser-assisted crystallization by annealing the amorphous silicon film [2], and traditional plasma-enhanced chemical vapor deposition [3]. We deposited the µc-Si film on large substrate with sizes 370mm x 400 mm for further TFT development in flat panel displays.

2.   Experimental Results

Polycrystalline silicon films were deposited by using PECVD facility (APEX Company) and characterized by means of micro-Raman Spectrophotometer (NRS-1000 Jasco Company) with argon laser as light source and probe beam diameter around 1 µm. Crystalline volume fraction was estimated from the Raman data.   The uniformity was evaluated by means of atomic-force microscope data and scanning electron microscope for testing the film thickness in different types of film homogeneity by using the micrometer and centimeter scales.

2.1   Effects of Hydrogen Dilution and Substrate Annealing

The samples deposited with different gas mixture [SiH4]:[H2] ratio values: 150, 200 and 247. The crystalline volume fraction was 16%, 13.5% and 11.5% respectively. The thickness was estimated as 80 nm, 57 nm, and 48 nm. RF power was 450W.
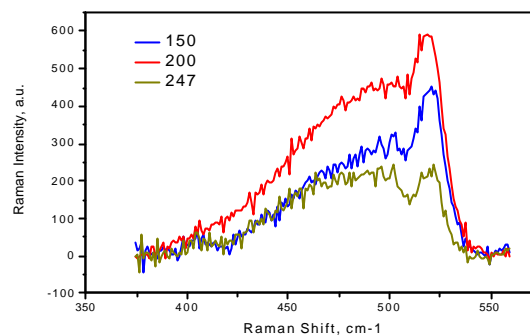
a)
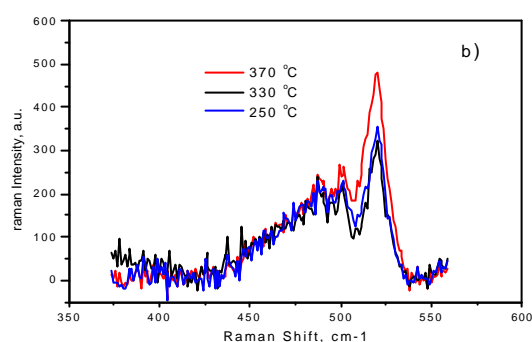
b)

Figure 1. Raman spectra of polycrystalline silicon films deposited by PECVD method by a) fixed deposition temperature (T_d=330°C); b) by fixed RF power and values of ratio [SiH4]:[H2].

Different values of c-Si peak position reflects the stress value of film. There is epilayer between SiO_2 and uc-Si film. From one hand, this is because of Si-Si and Si-O bondlength variations, but, from another hand, there is strong structural difference between both materials. The crystal structure with predominant orientation around (111) for silicon microcrystalline film, the amorphous intermediate layer with random distributed Si-Si, Si-O and even dangling bonds, and polymer-like amorphous silicon dioxide structure with bridges Si-O-Si. The intermediate layer consists of a-Si fraction dominantly. Its thickness is less than 30 nm. To increase the value of crystalline volume fraction we need in hydrogen plasma treatment the SiO_2 film in 10-20 min. Therefore, hydrogen plasma treatment just before deposition creates the hydrogen terminated surface with dangling bonds.

2.2 Film Uniformity of Micro-and Macroscopic Scales

Film uniformity was evaluated by using the surface morphology and film thickness (see Fig. 2, Fig. 3, Fig. 4, and Tables 1 and 2).
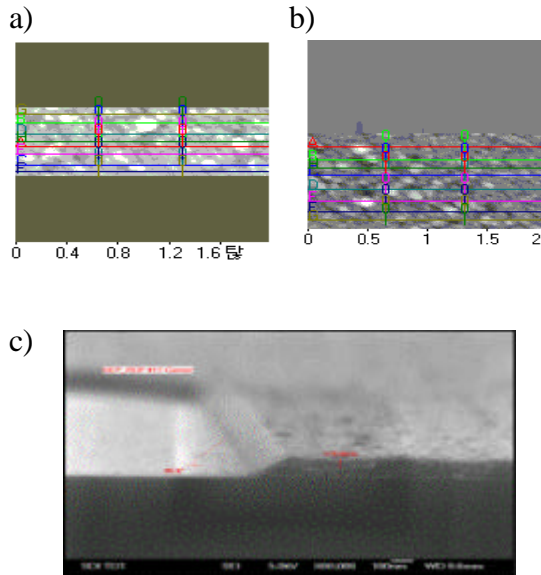
a)   b)

c)

Figure 2 . Atomic -force microscopic data of central area (area $0.7x2\mu m^2$) of large substrate (with sizes: width 370mm and length 400 mm) –a);and edge area- b); scanning electron microscopic (SEM) data for film thickness estimations-c).
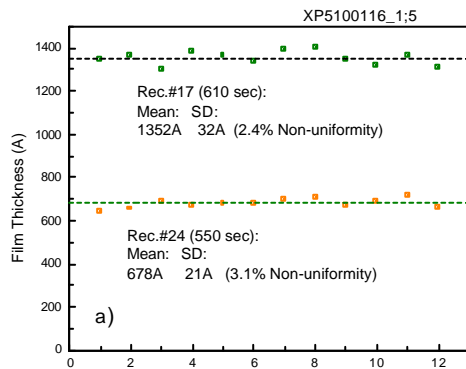

Figure 3. The film thickness measurement data of 12 selected points on large substrate for two samples with different deposition rates.

It is known that the film thickness depends on the RF power, silane /hydrogen ratio and deposition temperature, but its deviation are determined by the facility technical parameters.
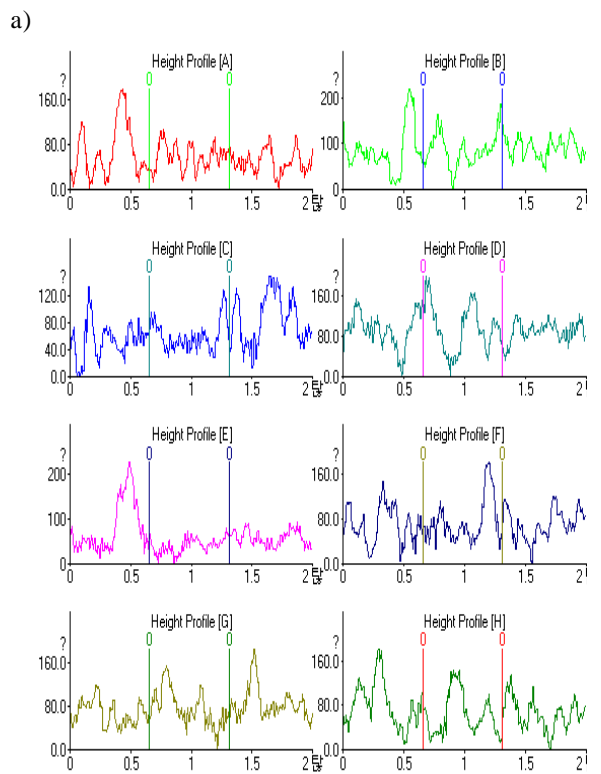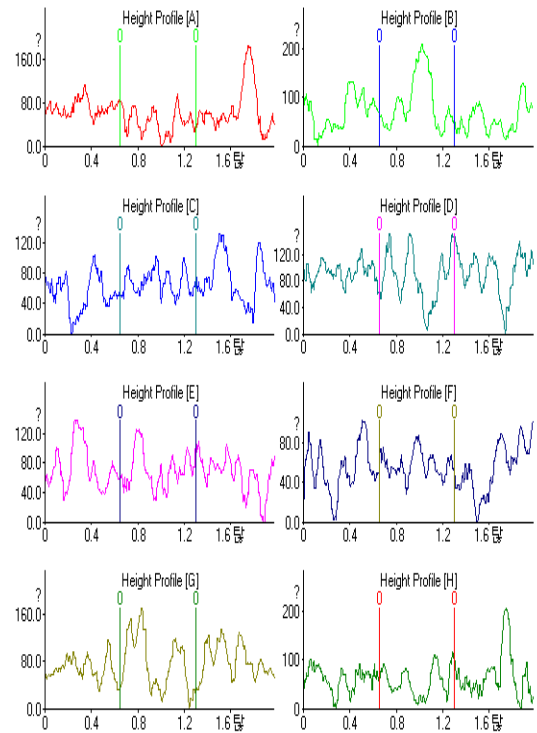

a)

b)

Figure 4. The 8 estimations graphs selected for calculation the surface roughness and other morphological parameters for central area of large substrate 370x400 mm –a); and edge-b).

Table 1a The surface roughness and morphology parameters for central part of substrate.

Line	Height A	Distance, μm	Rms, A	Average, A
A	43.1	0.651	32.2	21.8
B	11.5	0.651	43.1	33.5
C	23.9	0.651	25.3	19.4
D	71.8	0.651	30.2	22.8
E	45.0	0.651	26.9	20.4
F	18.2	0.651	21.6	16.8
G	7.66	0.651	32.7	26.2
H	48.9	0.651	35.1	25.5

Table 1 b The surface roughness and morphology parameters for edge part of substrate.

Line	Height, A	Distance, μm	Rms, A	Average, A
A	41.2	0.659	33.5	25.1
B	91.0	0.659	37.5	26.7
C	33.5	0.659	32.1	24.7
D	10.4	0.659	35.1	26.0
E	4.79	0.659	40.0	26.4
F	7.66	0.659	33.9	26.3
G	2.87	0.659	30.0	22.0
H	19.2	0.659	36.6	28.9

2.3 Crystalline volume fraction homogeneity

Analysis of spatial homogeneity of crystallites in μc-Si films on area 45x45μm^2 .
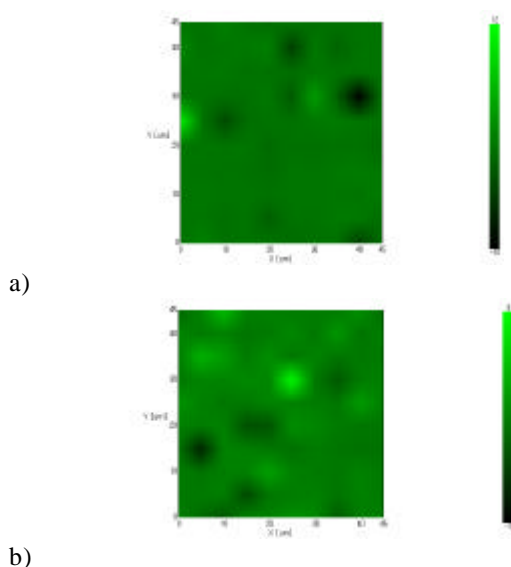

a)

b)

Figure 5. Raman spectral peaks area ratio c-Si/a-Si for two different films.

It is seen on Fig. 5 the micro-scale homogeneity of crystalline volume fraction value by using micro-Raman measurements with laser beam diameter around 4 μm.

3.   Discussion

The crystalline volume fraction value increases by increase in RF power and has maximum at 450 W. The crystalline volume fraction changes by variations in gas mixture ratio are negligible. The film thickness increases as due to the increase in RF power value, as increase of silane gas contents in gas mixture [3]. The uniformity of film thickness was sufficient on both scales: microscopic and macroscopic. The crystalline volume fraction homogeneity was better than for the low temperature PECVD method [4]. However, the value of crystalline volume fraction is lower than data of previous work [3]. We assume the further increase in crystalline volume fraction by improving the technological procedure for TFT.

4.   Acknowledgements

5.   Reference:

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[3] D. Milovzorov, T. Inokuma, Y. Kurata, and S. Hasegawa, , Journ. of the Electrochem. Soc., **145**, N 10, 3615-3620 (1998).
[4] D. Milovzorov, T. Inokuma, Y. Kurata, and S. Hasegawa, Nanostructured Materials, **10(8),** 1301-1306 (1999).