Laser Crystallization of a-Si:H films prepared at Ultra Low Temperature(<150˚C) by Catalytic CVD

Sung-Hyun Lee[2], Wan-Shick Hong[2], Jong-Man Kim[1] Hyuck Lim[1], Kuyng-Bae Park[1], Chul-Lae Cho[2], Kyung-Eun Lee[2], Do-Young Kim[1], Ji-Sim Jung[1]

Jang-Yeon Kwon[1] and Takashi Noguch[1]

[1] Samsung Advanced Institute of Technology (SAIT), Kyunggi, Korea

[2] Dept. of Electronics Engineering, Sejong University, 98Kunja-dong, Kwanjin-gu Seoul 143-747

Abstract

We studied laser crystallization of amorphous silicon films prepared at ultra low temperatures (150˚C). Amorphous silicon films having a low content of hydrogen were deposited by using catalytic chemical vapor deposition method. Influence of process parameters on the hydrogen content was investigated. Laser crystallization was performed dispensing with the preliminary dehydrogenation process. Crystallization took place at a laser energy density value as low as 70 mJ/cm^2, and the grain size increased with increasing the laser energy. The ELA crystallization of Catalytic CVD a-Si film is a promising candidate for Poly-Si TFT in active-matrix flexible display on plastic substrates.

1. Introduction

Recently, Excimer laser annealing (ELA) has become a major technology to obtain poly-Si films from crystallization of amorphous silicon (a-Si) layers. The laser crystallized poly-Si layers are the key components for the fabrication of thin-film transistors (TFTs) having high carrier mobility values. It is particularly useful in application for the pixel control of active matrix liquid crystal displays (AMLCDs) or organic light emitting diodes (OLEDs) display. However, if the deposited amorphous films have large content of hydrogen (C_H), bubbling or ablation may occur during crystallization. Therefore, a heat treatment step at approximately 500^{o}C is needed to minimize the C_H prior to crystallization, but such high temperature may also impose another problem, especially when plastic substrates are used.

Catalytic chemical vapor deposition (Cat-CVD) is one of the promising methods to obtain device quality a-Si:H layers. It has several advantages compared to conventional plasma enhanced chemical vapor deposition (PECVD). Especially, a-Si:H films prepared by Cat-CVD contain atomic hydrogen below 3 at.% [1]. This level of C_H is much lower than that could be obtained by the conventional PECVD method, and the crystallization can be performed without the prior thermal process for dehydrogenation [2].

2. Experiment

In this study, the substrates were kept below 150˚C during the entire process. Two main deposition parameters, chamber pressure and source gas flow rate, were optimized to produce the hydrogen content (C_H) as low as possible. Other deposition parameters are listed in Table 1. C_H of as-deposited a-Si:H films was estimated by Fourier–transformed infrared spectroscopy (FTIR) [3] [4].

The SiO_2 buffer layer was deposited on a corning 1737 glass for suppressing a diffusion of impurities from substrate into a-Si:H films during laser crystallization [5]. Cat-CVD a-Si:H films were deposited on these substrates to produce a film thickness of 50 nm. The film thickness was controlled by adjusting the process time. A deposition rate that was as high as 120 nm/min. could be obtained.

Table 1 Deposition condition

Substrate temperature (°C)	150
W wire temperature (°C)	1700~1800
W wire-substrate distance (cm)	3
SiH_4 Gas flow (sccm)	1
Deposition pressure (mtorr)	2

The ELA was used to crystallize the a-Si:H films. The wavelength of the XeCl excimer laser was 308 nm. In order to minimize sudden evolution of hydrogen, multi step laser irradiation method was used [6]. The laser energy density was varied between 60 mJ/cm^2 and 190 mJ/cm^2 at an increment of 10 mJ/cm^2, and only a single shot was illuminated at each step. The ELA were carried out at atmospheric pressure and room temperature, Crystallized films were evaluated

by using optical microscope and UV Reflectance spectroscopy [7]. The grain size was measured by using a Scanning Electron Microscopy (SEM).

3. Result and discussion

3.1 H-content

In Cat-CVD, the deposition rate and the composition of the film depend largely on the chamber pressure and the silane gas flow rate, and these two process condition were chosen as main control parameters [8] [9]. Especially, C_H of a-Si:H films that is the most important factor in crystallization, and also depends on deposition parameters.

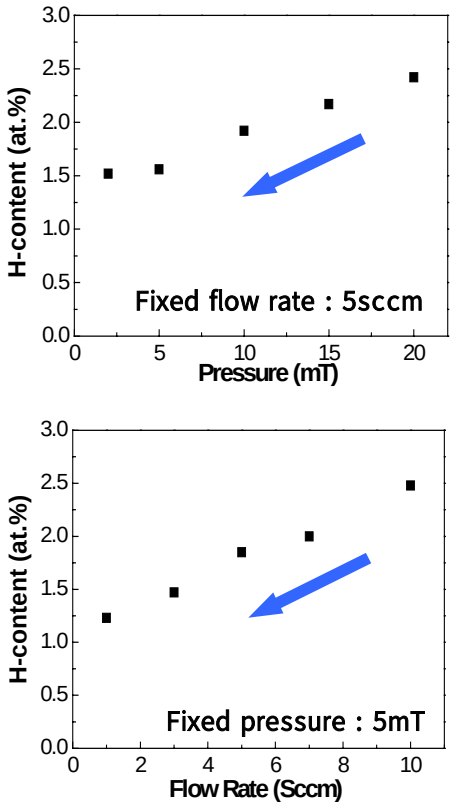


Fig.1 Variation of the hydrogen content with the chamber pressure and the SiH_4 flow rate

Fig.1 shows the variation of H-content (C_H) on the process parameters. C_H decreased as either the chamber pressure or the source gas flow rate decreased. From this result, we decided deposition conditions that are as shown in Table 1.

3.2 Laser crystallization

The Cat-CVD films deposited at low temperatures were successfully crystallized without preliminary dehydrogenation step. Fig. 2 shows optical microscopy images of the Cat-CVD films after laser-crystallization. As seen in fig. 2 (a), no bubbling or ablation was observed. There was no damage at a final laser energy density value that was lower than 170 mJ/cm^2. However, if final laser energy density was higher than 180 mJ/cm^2, the films experienced some damages, as seen in fig. (b).

Fig.3 shows the UV-Reflectance spectra of the laser-crystallized films. A spectrum of silicon wafer is also included as a reference. The characteristic peaks near wavelengths of 280 nm and 370 nm indicate the formation of crystalline phase [4]. Multi step laser irradiation method was used to minimize the damage due to abrupt effusion of hydrogen. The degree of crystallinity was changed as the final laser energy density was increased from 60 to 180 mJ/cm^2. When the final laser energy density was 60 mJ/cm^2, laser irradiated films were in the amorphous state. If final laser energy density has reached 70 mJ/cm^2, films start to crystallize.

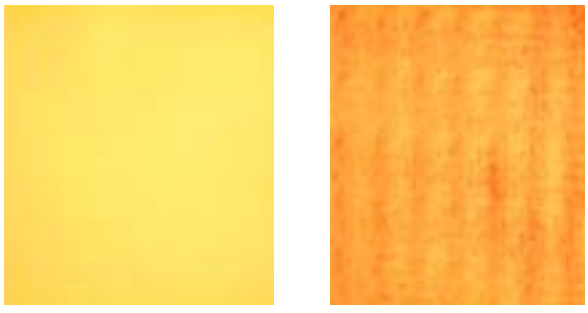


Fig. 2 Optical microscope images of crystallized films. Final laser energy density of (a) 170mJ/cm^2 and (b) 190 mJ/cm^2

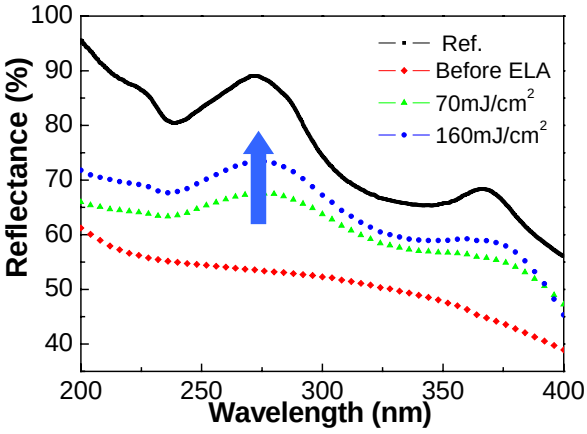
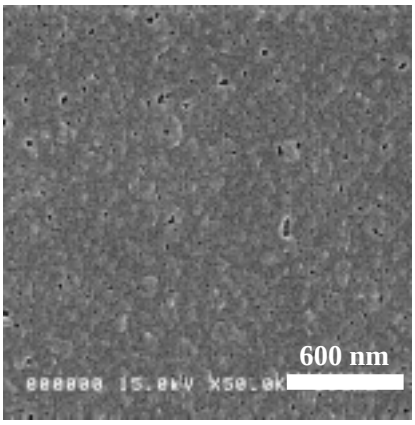
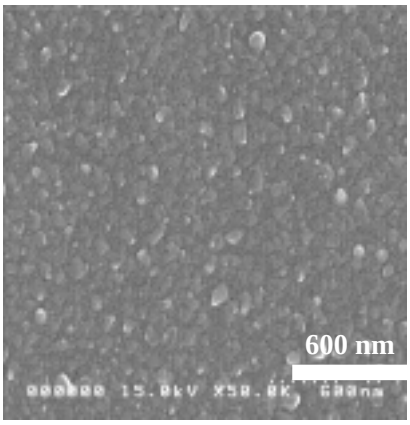


Fig. 3 UV-Reflectance spectra of laser crystallized films. Full crystallization can be accomplished at final laser energy above 90mJ/cm^2

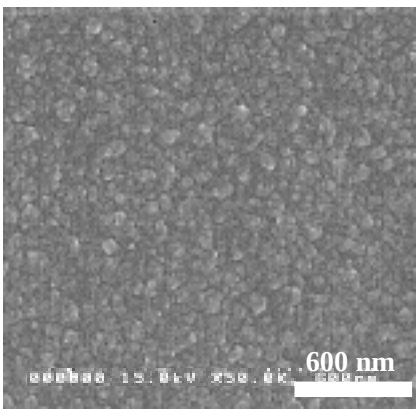
The grain size was estimated from Scanning Electron Microscopy (SEM). Prior to the SEM analysis, the Secco etching was performed to enhance the visibility of the grain morphology.



(a)



(b)



(c)

Fig. 4 SEM images for crystallized films surface (a) final energy density: 90 mJ/cm^2 (b) 100 mJ/cm^2 (c) 160 mJ/cm^2

Fig. 4 shows the variation of grain growth with the final laser energy density. We could observe conspicuous grain growth of Cat-CVD a-Si films with the laser energy density. Average grain size was approximately 100nm at the final laser energy density of 160 mJ/cm^2.

4. Conclusion

Amorphous silicon films were deposited at low temperature (150˚C) by using Cat-CVD method to obtain poly-Si. As-deposited films showed a content of atomic hydrogen as low as 1%, which was sufficiently low for dispensing with the dehydrogenation step prior to crystallization using excimer laser. The Cat-CVD films were successfully crystallized at a laser energy density that was higher than 70 mJ/cm^2, and the grain size increased with increasing the laser energy. The ELA crystallization of Cat-CVD a-Si film is a candidate for Poly-Si TFT in active-matrix flexible display on plastic substrates.

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