The Effect of H content in Si Precursor on the Performance of Poly-Si Crystallized by Pulsed YAG2ω Laser on Soft Substrate

Juan Li[1], Yao Ying[1], Zhiguo Meng[1], Wu Chunya[1], Shaozhen Xiong[1]
Hoi Sing Kwok[2]

1. Institute of Photo-electronics, Nankai University, Tianjin, 300071, China
[1]The Tianjin Key Laboratory of Photo-electronic Thin Film Devices and Technology, Nankai University, Key Laboratory of Opto-electronic Information Science and Technology (Nankai University and Tianjin University), Ministry of Education, Tianjin, 300071, China
Tel.:86-22-23501620, E-mail: lj1018@nankai.edu.cn xiongsz@nankai.edu.cn

[2] Department of electronic and computer engineering The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, P. R. China

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Abstract

YAG laser crystallization of Si-based thin film deposited on plastic substrate has been studied. The Si-based thin films as crystallization precursor are with varied hydrogen (H) content. The effect of the H content on the crystallinity of the resulted poly-Si film has been investigated. The experimental results of the poly-Si crystallized by double-frequency YAG laser shows that the initial dehydrogenation process could be left out if μc-Si was adopted as the crystallization precursor. The YAG laser annealing condition on plastic substrate and the crystallization results have been discussed in the paper.

1. Introduction

The study of Low-temperature polycrystalline silicon (LTPS) on soft substrate have been required increasingly for flexible active-matrix flat panel display (AM-FPD), such as flexible organic light-emitting diode (AMOLED) and liquid crystal display (LCD). Excimer-laser annealing (ELA) is commonly used to crystallize amorphous Si (a-Si:H) in the LTPS TFT fabrication process, but it is limited by itself high cost[1-3]. In this paper, a low-cost YAG Laser Crystallization (YLC) was studied. The YAG laser does not require daily maintenance and high-cost working materials, for example, ArF(193nm), KrF(248nm), XeCl (308 nm), XeF(351nm) etc[4]. Normally, the Laser Annealing Crystallization (LAC) needs a dehydrogenation process in order to avoid a-Si film desquamating easily from the substrate. Because the H could burst due to the rapid heating during annealing[5], which will result in an incompact film with poor quality. By the way, it is not a real low temperature process if it needs a initial dehydrogenation process at 300~450℃ for several hours before laser annealing crystallization. But the dehydrogenation at high temperature is not suitable for plastic substrate because the plastic could not withstand sustained high temperatures(even as low as 250℃) required by dehydrogenation process[6]. To resolve the above problem resulted from high temperature, an idea to control the H content in the crystallization precursor has been proposed and the effect of H content on the crystallinity of the resulted poly-Si has also been investigated.

2. Experimental

Series of Si-based thin films deposited by PECVD with varied H dilution ratio on the polyimide (PI) substrate were annealed by YAG laser. The YAG laser has been treated by double frequency with wavelength of 543 nm and different laser pulse energy and at fixed other laser condition: the pulse frequency is 10Hz, pulse width is 2-3ns, the spot diameter is 5mm and the scan speed is 0.5mm/s. The crystalline character of crystallized poly-Si was analyzed by XRD spectra and Raman spectra using 632.8nm He-Ne laser. Here, the crystalline volume fraction (*Xc*) was used to describe the crystalline degree of the crystallized films. The *Xc* can be deduced from its Raman scattering spectra by the ratio of Xc=Ic/(Ic+Ia). Where Ic is the intensity of crystalline peak near around at 520 and 510, but Ia is the amorphous intensity around at $480cm^{-1}$. The relative H content is measured by Secondary Ion Mass Spectrometry (SIMS). Morphologies of the resulted poly-Si were observed by Scanning Electron Microscope (SEM).

3. Results and discussion

Because the plastic substrate we used could not withstand sustained dehydrogenation treatment at high temperature (even as low as 250 ℃), so the initial dehydrogenation process should be considered to leave out in our case. But in our previous work, we have found that the a-Si with higher content of H would be easily damaged due to the H bursted out from a-Si explosively even at low laser energy if it is without dehydrogenation treatment. The quality of crystallized film could not be high enough. In this case, the maximum Xc and the grain size of the resulted film are only 45% and 10~20nm (calculated from its XRD spectra) respectively. We have also found that the H content in the a-Si precursor has a great influence on the quality of crystallization film. Fig.1 shows the Raman Spectra of the crystallization precursor with different H content (a) and the resulted crystallized-Si on soft substrate. It has been observed that the crystallinity would depend on the H content in Si-based film used as the crystallization precursor. The lower the H content in the crystallization precursor; the more of crystalline Raman shift peak would move. For example, the shift would be from $512cm^{-1}$ to the $519.7cm^{-1}$. It means that the crystallization by YLC would be completed if H content is less enough. The corresponding Raman spectrum width becomes narrower gradually and the amorphous shoulder around $480cm^{-1}$ also becomes lower, until disappears. As well known, in order to obtain the Si-based film with low H content by PECVD, it must enhance the etching effect of H^o or H^+ on the weak Si-Si bond [7] and to release H itself from film during depositing dynamic process. In this case, the deposited Si-based film will have a low crystallization volume ratio before laser crystallization, which could be called micro-crystalline Si (μc-Si). Of cause, the Si-based film deposited by VHF-PECVD would have low H content compared with that deposited by RF-PECVD at the same H-dilution ratio.

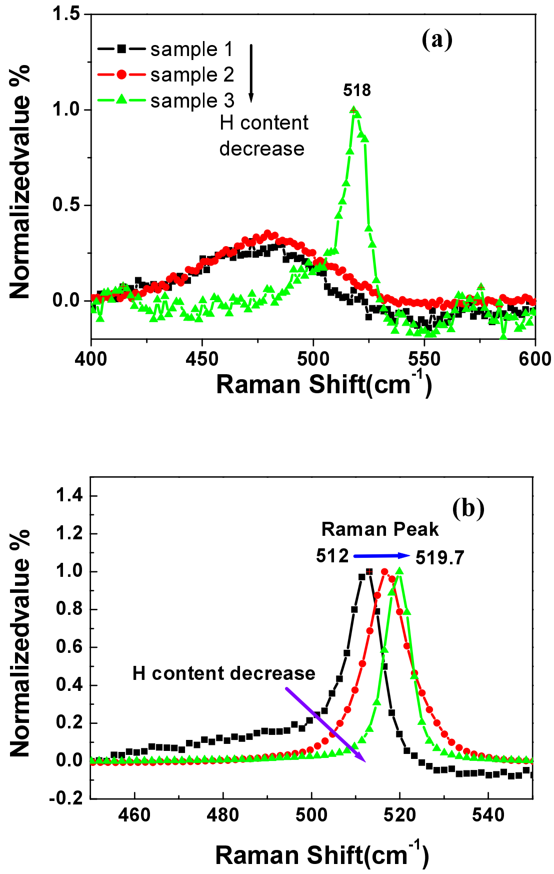

Fig.1 The Raman Spectra of the crystallization precursor with different H content (a) and the resulted poly-Si on soft substrate

The grain size and the Xc of the resulted films varied with H content in the Si-based precursor as shown in Fig.2. The H content is measured by SIMS which is shown in Fig.3 and normalized to the ratio of Si content in the precursor. It can be seen that the Xc and the grain size of the resulted films increase with the decrease of H content, they are varying from 10nm and 57% to 50nm and 85%, respectively. The above results illustrate that the crystallinity of resulted film could be better by controlling the H content in the precursor. Fig.4 shows SEM image of the poly-Si crystallized by 2ωYAG laser on plastic substrate using μc-Si as crystallization precursor. As shown, the grain, whose size is about 50nm, can be observed clearly, and the Xc has reached to 85%. Consequently, a simple and effective method has been found to crystallize poly-Si with good quality but does not need the dehydrogenation process at higher temperature.

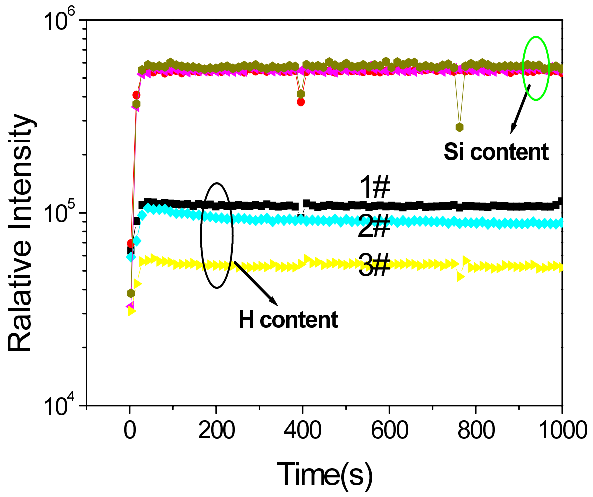

Fig.2 The comparison of H and Si content in different samples extracted from its SIMS Spectra of the resulted poly-Si on soft substrate

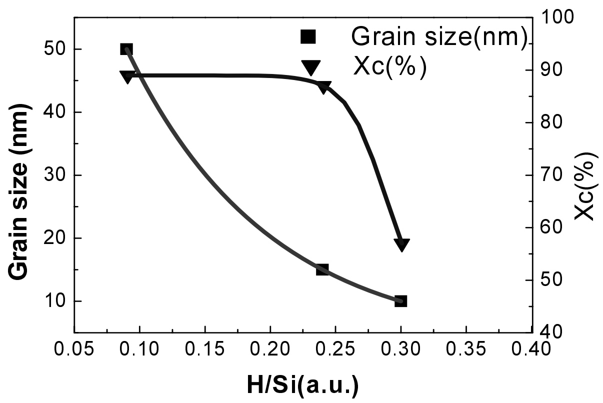

Fig.3 The grain size and the crystallization volume ratio of the resulted poly-Si as a function of H content in the Si-based crystallization precursor

By this way, the plastic substrate could be applied in the poly-Si crystallization by Laser annealing without dehydrogenation at high temperature. As a result, the YAG laser crystallized poly-Si on soft substrate could be obtained. Nevertheless, it must be noted that the laser energy needed to crystallize the μc-Si precursor is a little bit higher than that crystallization the conventional a-Si:H precursor with normal H content. The reason maybe that the precursor with low H content could be microcrystalline silicon (μc-Si) with a lower band-gap, which would has a lower absorption coefficient to the laser wavelength of 543nm compared to the conventional a-Si:H[8].

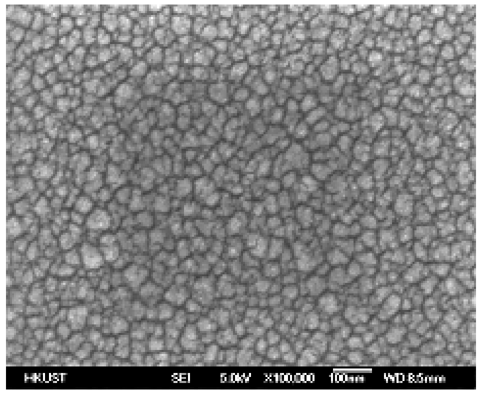

Fig.4. The SEM image of the resulted poly-Si on plastic substrate crystallized by 2ωYAG laser using μc-Si as the crystallization precursor

Summary

The 2ωYAG laser with low cost has been used to crystallize Si-based film on plastic substrate to poly-Si. The problem that plastic substrate could not withstand sustained high temperature (even as low as 250 °C) during dehydrogenation in LAC, but without the initial dehydrogenation process, the conventional a-Si:H crystallization precursor is easy to be damaged due to the instantaneous explosive dehydrogenation effect. So, its crystallinity is not good. It has been found that the H content in the crystallization precursor has much effect on the crystallinity of the resulted poly-Si film. Decreasing the H content could alleviate the explosive dehydrogenation effect, resulting in the better crystallinity of the obtained poly-Si. By this method, the initial dehydrogenation process could be left out and the poly-Si on plastic substrate with the Xc of 85% and the grain size of 50nm has been achieved. We are convinced that with the further optimization of the crystallization condition, the performance of the resulted poly-Si film will be much better.

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5. References

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