P-60: The Performance Enhancement of the 2ωYAG Laser-Crystallized Poly-Si Using a Back-side Self-Heating Layer of a-Si

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Abstract
Crystallization of a-Si by doubled frequency YAG laser using a self-heating layer technology was proposed in this paper. The grain size and the hall mobility of the resulted poly-Si thin film were enhanced up to almost two times by using the self-heating layer technology. This technology has a dual heating effect: heat-retaining and self-heating with an easier process and wider process window, compared to the conventional capping-layer technology.

1. Introduction
Low-temperature polycrystalline-silicon (LTPS) technology has attracted much attention due to its application to fabricate high-performance thin-film transistors (TFT) devices for active matrix-display devices [1-2]. It can be also used for the integration of peripheral driver electronics in order to achieve the function of System-on-Panel (SOP). The electrical characteristics of poly-Si TFTs, such as field-effect mobility, reliability, and threshold voltage, are strongly dependent on the silicon-grain size, crystalline orientation and location. Defects at grain boundaries could lead to poor performance of poly-Si TFTs. The defect-reduction activities could be implemented by enlarging the grain size as well as reducing grain boundaries [3]. In essence, enlarging grain size crystallized by laser annealing requires increasing the solidification time of the melting Si during laser annealing. In recent years, capping layer technology and heating substrate technology has been proposed to realize the heat-retaining effect [3]. The former technology need a capping layer of SiO_2 deposited under or on the amorphous-Si before laser annealing [4], but the capping layer should be etched after laser annealing. No doubt, with this technology, the interface between the active-layer and the gate insulating layer in TFTs is affected during the etching process, leading to the degradation to TFT performance. Furthermore, this technology need precisely control the parameters for the capping layer etching process in order to avoid the damage to the active-layer as much as possible. Hence, the above technologies make the process complex and the process window narrow.

In this paper, the back-side self-heating layer technology is proposed. This technology can enhance the grain size of the laser-crystallized poly-Si obviously with an easy process and a wide process window. Meanwhile, this technology could not damage the interface between the active-layer and the gate insulating layer in TFTs. Furthermore, the YAG laser was utilized to crystallize poly-Si. The YAG laser does not require daily maintenance and high-cost working materials as excimer laser. Therefore, the technology used in this paper has a potential to obtain high quality poly-Si with a low cost.

2. Experiments
At first, a 300nm-thick silicon oxide and 100nm-thick hydrogenated amorphous silicon (a-Si:H) layer were deposited on a 1737 glass substrate at 300℃ by a PECVD deposition system in sequence. Then, a certain thickness a-Si:H was also deposited on the backside of the glass substrate by PECVD. After a dehydrogenation process at 450 ◦C for 2 h, the sample was

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irradiated at a 2ωYAG laser system just by a single shot of laser with a beam size of ϕ5mm and an energy density of 320mJ/cm^2. The laser wavelength is 532nm, and the pulse frequency of the YAG laser is 10Hz. After laser crystallization, the Si on the backside of the substrate was completely removed by wet etching The crystallinity of the resulted films was measured by Raman spectra using 632.8nm He-Ne laser. The morphologies of the resulted poly-Si was observed by Scanning Electron Microscope (SEM) and the electric performances were measured by Bio-Rad Microscience HL5500 Hall System.

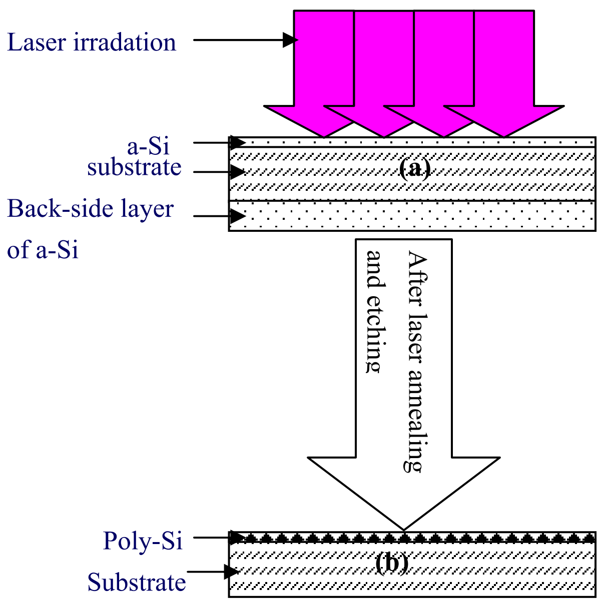

Figure.1.Key processes for the fabrication of LTPS crystallized by 2ωYAG laser with back-side layer. (a) Laser-crystallization process (b) Removal of back-side layer film by wet etching

3. Main Results

Figure 1 shows the Raman spectra of crystallized films with different thickness of the back-side layers. It can be observed that the amorphous shoulder at 480cm^{-1} became weaker and the width of TO mode peak around 520 cm^{-1} became narrower with the increase in the thickness of a-Si on the back-side. It illustrates that the crystallinity of the resulted poly-Si films is enhanced with the increase of the back-side layer thickness. This can be also proved by the SEM images of the poly-Si with and without the back-side layer after etched by Secco. As can be seen from figure 2 (b) with the back-side layer, the grain size of the resulted poly-Si enlarges

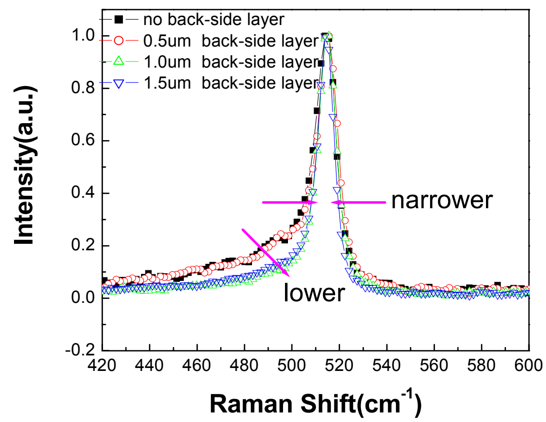

Figure.2. The Raman spectra of crystallized films with different thickness of the back-side layers.

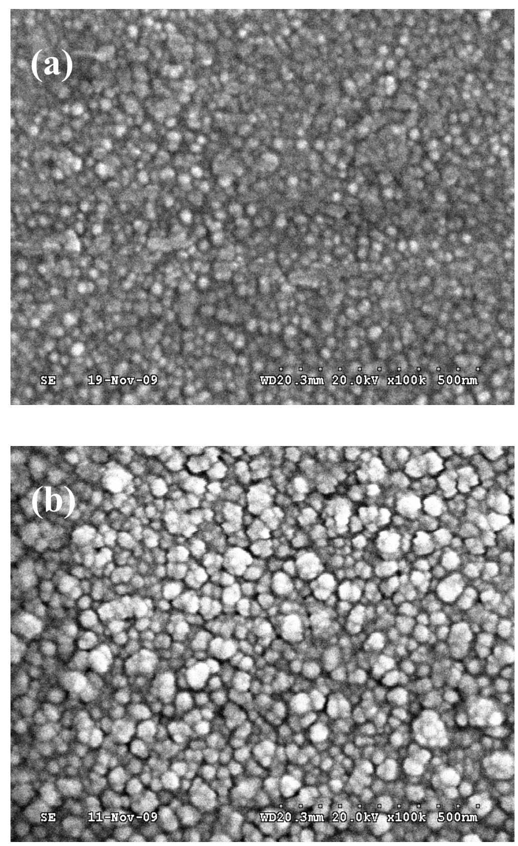

Figure.3. The SEM images of the laser crystallized poly-Si with 1.5μm (b) and without (a) the back-side layer after etched by Secco

almost by two times compared to the sample without back-side layer as shown in figure 2 (a). We think this is attributed to the heat effect of the back-side layer of Si. As well known, a fast cooling rate would cause the appearance of bulk nucleation and stop the lateral grain growth. In order to obtain a large grain, it was generally necessary to prolong the Si melting duration. On the other hand, the YAG laser can not be completely absorbed by the a-Si:H film like the Excimer Laser irradiation because the absorption coefficient at the wavelength of 532 nm is smaller than that at 308 nm by approximately one order of magnitude[5]. Therefore, some rest laser penetrates through the a-Si:H film, and then is absorbed by the back-side Si, which makes its temperature go up. This supplies a heat source for the substrate. So, the back-side layer can play not only a heat-retaining role but also a self-heating role. This is a dual heating effect on slowing down the cooling rate, which thereby retains relatively long duration of melting process and further enhances poly-Si-grain growth, resulting in the increase of the grain size. Consequently, the performance of the laser crystallized poly-Si is enhanced with the increase of the back-side layer thickness as shown in figure 3. We can find that by adopting the self-heating layer, the hall mobility of the resulted poly-Si increases by almost two times.

4. Conclusions and Impact

We have successfully enhanced the performance of the 2ω YAG laser crystallized poly-Si thin film by the self-heating layer technology. The grain size and the Hall mobility of the resulted poly-Si have increased by almost two times. Though the absolute grain size is not very large, this is because the laser crystallization condition was not optimized. In fact, what we mainly concern is the effect of this technology. The above results show that the self-heating layer technology is indeed effective on the enhancement of the 2ω YAG laser crystallized poly-Si performance. Unlike the usual SiO_2 or SiN_x capping-layer technology, the technology adopted in this paper has a dual heating effect: heat-retaining and self-heating. Meanwhile, the rest laser penetrated through the a-Si:H thin film can be also utilized by the back-side layer of a-Si, which brings the benefit of saving energy. Furthermore, we need not exactly control the etching time of the back-side layer after crystallization because we need not worry about the damage to the interface between the active-layer and the gate insulating layer during the etching process, resulting in the easier process and wider process window compared with the conventional capping-layer technology.

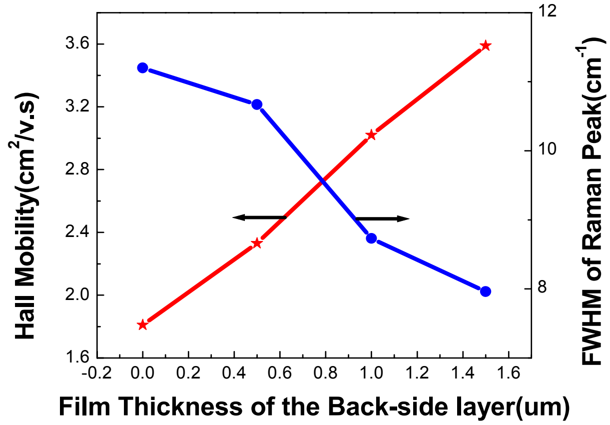

Figure.4. The Hall mobility and the FWHM of the Raman peak at TO mode of crystalline silicon vs. the thickness of poly-Si thin film crystallized by 2ωYAG laser

Additionally, the YAG laser with a lower cost than the excimer laser has been used. Therefore, the technologies using in this paper has the potentiality to realize the high quality and low cost poly-Si thin film material with the further optimization of laser annealing condition.

Acknowledgements

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