Hydrogen Passivation for the Enhancement of Poly-Si Performance Crystallized By Double-Frequency YAG Laser

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Abstract

Here the hydrogen passivation treatment has been adopted to enhance the performance of poly-Si crystallized by YAG laser annealing (LA poly-Si). We have investigated the effects of passivation time, passivation power and passivation temperature on the hall mobility of the LA poly-Si and analyzed the mechanism of the hydrogen passivation preliminary. It has been found that the quality of the poly-Si annealed by YAG laser could be improved after proper hydrogen plasma treatment..

1. Introduction

The low-temperature polycrystalline Si (LTPS) has attracted dramatically interest because of its possible application in flat panel displays[1], solar cells[2~6], sensor[7~9], etc. Laser annealing (LA) is commonly used to crystallize amorphous Si (a-Si) in LTPS TFT fabrication process due to its good performance. However, there are still many defects in the poly-Si material after crystallization by laser annealing, which restricts the further improvement of its electrical performance and stability, as well as its TFTs quaulity. In this paper, the hydrogen passivation treatment has been adopted to enhance the performance of poly-Si crystallized by laser annealing. This method has been used in solar cell to improve its open voltage [1], but the application in micro-electrical field has seldom concerned yet. Additionally, the double-frequency YAG Laser (YAG2ω) laser has been used in this paper. The YAG laser does not require daily maintenance and high-cost working materials, therefore, its cost is lower than the widely used ELA laser.

We have investigated the effects of passivation time, passivation power and passivation temperature on the hall mobility of the YAG2ω LA poly-Si used in TFT in detail and analyzed the mechanism preliminary.

2. Experimental

Firstly, the a-Si thin films were deposited by PECVD and LPCVD, then, annealed by YAG2ω laser with the wavelength of 543 nm. The laser annealing condition was fixed as the following: the pulse frequency is 10Hz, the pulse width was 2-3ns, the spot diameter was 5mm, the scan speed was 0.5mm/s and the pulse energy was 380mJ/cm^2. Next, the resulted poly-Si was treated by H plasma with varies condition. The H plasma emission spectra was measured by PR650 opt meter.

3. Results and discussion

During the passivation process, the hydrogen can be excited to several kinds of H plasma in the chamber and each kind of H plasma will emit light at its unique wavelength. Consequently, we can investigate the passivation process by means of OES (Optical Emission Spectra) technique.

Figure.1 shows the H plasma OES during passivation process at different time. It can be found that in the spectra, there are four main peaks related to H_α, H_β, H_γ and H_δ, which change almost at the same trend, decreasing initially with the increase of passivation time and increasing suddenly when the passivation time is over than about 25 minutes, then, getting to saturate, as shown in figure.2 Firstly, the atomic hydrogen is consumed to passivate the defects in the poly-Si, at this time, the consumption of atomic hydrogen is larger than its supply, so its emission intensity decreases dramatically. When the consumption trend to saturate, the emission intensity become increase due to the continuously supply and then come to a certain balance. This illustrates that all the kinds of atomic hydrogen ions participate in the passivtion process and play a role on the passivation effect. Additinaly, it is worth noting that the emission intensity of H_α and H_δ decrease more dramatically than that of others, which tells us that the effect of the four kinds of H plasma on the passivation treatment is different, the H_α and H_δ consume much more than others and play a leading role during the passivation process.

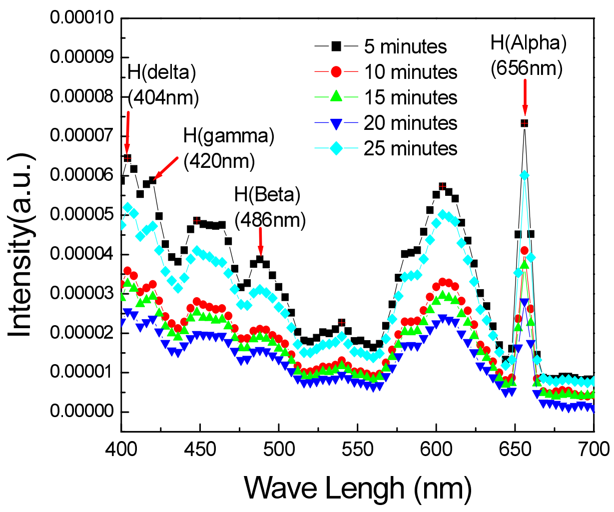

Figure 1. The OES of H plasma during passivation process at different time.

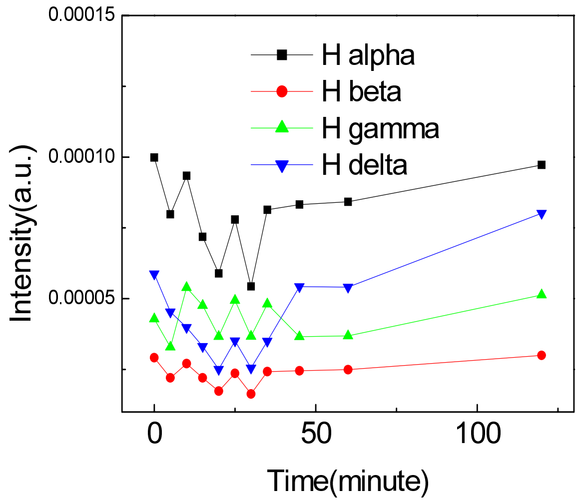

Figure 2. The spectra intensity of H plasma .vs. passivation time

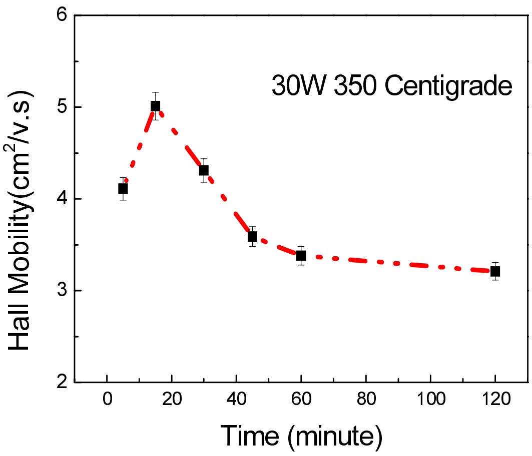

Figure 3 The hall mobility of the YAG LA poly-Si passivated with different time

The hall mobility of the LA poly-Si with different passivation time is shown in figure 3.The maximum value also occurs at 20~25 minutes and decrease contrarily with further passivation time, corresponding with the results of figure 2. Integrating these results, we can suppose that there are three mechanisms in the passivation process simultaneously: defect passivation, surface damage due to the bombardment effect and etching effect on the film. In strictly speaking, these mechanisms work simultaneously but when the passivation process accomplishes, the drawback effects become obvious. Consequently, not the longer passivation time it is, the better film performance can be received.

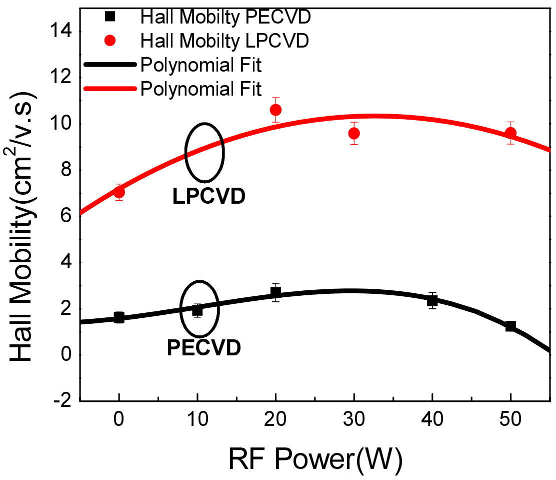

Figure 4. The hall mobility of the YAG LA poly-Si passivated with different RF power.

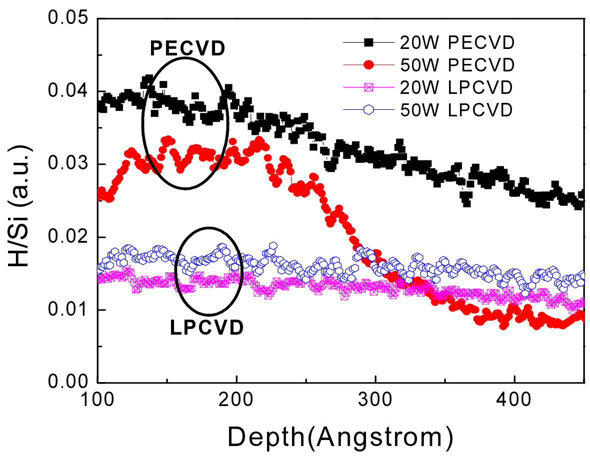

Figure 5. The ratio of H and Si content extracted from SIMS results of the YAG LA poly-Si

Furthermore, the passivation power and temperature also has an effect on the electrical performance of YAG LA poly-Si as can be seen in Figure 4 and Figure 6. The optimal power values for both PECVD and LPCVD sample are about 30W. As well known, the relatively high power will make the bombardment effect serious, which can damage the poly-Si material, therefore, the hall mobility decrease with further the increase of RF power. Besides, as can be observed form the SIMS results in figure.5, for the PECVD sample, the H content will reduce with relatively high RF power because of the release of H due to the etching effect. As for the growth of Si:H by PECVD, unlike LPCVD, the atomic hydrogen can break the weak Si– Si bonds in the amorphous network structure, leading to a removal of Si atoms weakly bonded to another Si and release SiH4 from the film, resulting the decrease of H content in the film. If the RF power is too high, the etching effect will be obvious. Hence, we suggest that during the H passivation process, the passivation effect and etching effect by H plasma exist simultaneously and compete for the Si-based film deposited by PECVD, while, it is not for that by LPCVD.

On the other hand, the poly-Si deposited by PECVD and LPCVD show almost contrary trend with the passivation temperature in figure 6. For the PECVD poly-Si, about 350℃ may be the optimal value, while, for the LPCVD poly-Si, the higher temperature (about 600℃～650℃) is proper. This phenomenon may be attributed to the different H content in the poly-Si deposited by different technique. As we all know, the PECVD Si-based film has H content of about 5%～10%, which is richer than the LPCVD one. The H will release at the temperature higher than 380℃～400℃, leaving donling-bonds in the poly-Si. As a result, there is a temperature restrict for the PECVD poly-Si passivation treatment. Conclusion, besides the parameters mentioned before, the passivaton effect also correlates with the kind of precursor and the defect type in it. We should consider comprehensively when we choose the H passivation condition.

4. Summary

We have investigated the effect of H passivation treatment on the electrical performance of poly-Si crystallized by YAG laser annealing. It has been found that the H_α and H_δ play a leading role during the passivation process. The H passivation treatment time, power and temperature have their optimal values. Additionally, the passivaton effect also correlates with the kind of precursor and the defect type in it. By choosing a proper H passivation treatment condition, the performance of YAG LA poly-Si can be improved effectively.

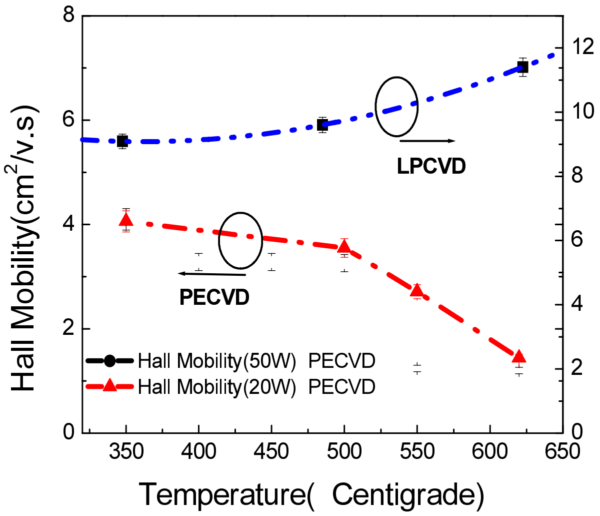

Figure 6. The hall mobility of the YAG LA poly-Si passivated with different temperature.

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5. References

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