Dopant activation by using CW laser for LTPS processing

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Abstract

CW laser dopant activation (CLDA) is suggested as an alternative to conventional thermal annealing. The sheet resistance of the ion doped poly-Si after CLDA is sufficiently low compared to the value measured after thermal annealing. The surface damage due to ion doping on the poly-Si can be recovered while CW laser scan for dopant activation. Therefore, the CLDA can be applied to LTPS processing.

1. Introduction

Polycrystalline silicon thin-film transistor has been steadily investigated as a base device for flat panel display applications because of its stable characteristics and high performance. Lowering process temperature is required to fabricate LTPS devices on flexible plastic as well as cheap glass substrates.

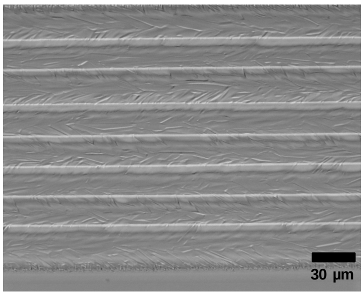
CW laser crystallization using DPSS Nd:YVO_4 laser with wavelength of 532 nm has drawn much attention recently because of its advantages such as stability and good uniformity over excimer laser annealing [1,2]. The excimer laser annealing (ELA) technique has been studied not for crystallization but also for dopant activation. In the present work, CW laser dopant activation is suggested as an alternative method to conventional thermal annealing and excimer laser activation for the fabrication of LTPS devices [3,4].

2. Experiment

400 nm thick silicon oxide (SiO_2) layer and 200 nm thick a-Si:H layer were deposited on Corning 1737 glass substrate consecutively by plasma-enhanced chemical vapor deposition (PECVD). Dehydrogenation of the a-Si:H was done by a furnace annealing at 480 °C for 10 hrs. After these processes, a frequency-doubled (2?) diode-pumped solid-state (DPSS) Nd:YVO_4 continuous-wave (CW) laser with a 532 nm wavelength was used to crystallize the a-Si placed on a computer controlled X-Y translation stage. The a-Si was 50 % overlap scanned to form almost 5 mm wide CLC poly-Si region. Overlap scanning is one of the useful methods to fabricate wide high qualify CLC poly-Si.

Figure 1 shows the photo image of the overlap scanned CLC poly-Si. The laser beam size onto the a-Si surface was 20 µm (short axis, scan direction) × 600 µm (long axis, transverse direction to the scan direction), and the beam shape is Gaussian with the short axis, top-hat with the long axis. The laser output power and the scan speed for crystallization were 8.5 W and 250 mm/s, respectively. The CLC (CW laser crystallized) poly-Si film was ion doped with various B_2H_6/H_2 or PH_3/H_2 plasma ion doses at an acceleration voltage of 16 kV, a RF of 13.56 MHz, and a RF power of 20 W. Then, the dopants were activated by CW laser scan at the laser powers of 7.5, 8 and 8.5W with various scan speeds.

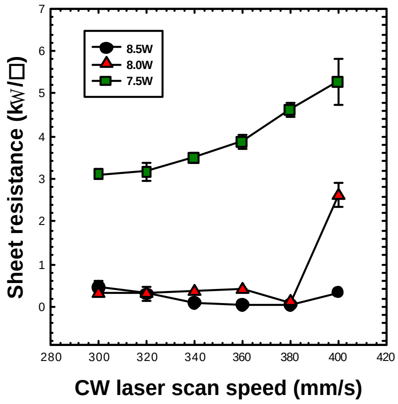
CW laser crystallization and the dopant activation were done in air at room temperature. The properties of ion doped CLC poly-Si were examined by sheet resistance measurement and Raman spectroscopy.



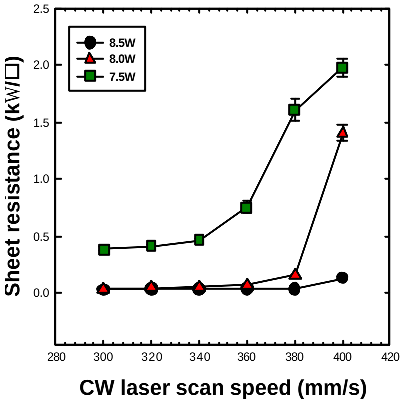
igure 1 Microscopic image of overlap scanne LC poly-Si at the laser power of 8.5 W and e scan speed of 250 mm/s.

3. Results and discussion

To evaluate the crystallinity of the CLC poly-Si and the usefulness of the CW laser dopant activation, the sheet resistances of the ion doped CLC poly-Si films have been measured as a function of CW laser scan speed at each laser power. The sheet resistance of the doped silicon is related directly with crystallinity and the doping efficiency.



(a)



(b)

Figure 2 The sheet resistance of (a) p-type and (b) n-type doped CLC poly-Si films versus CW laser scan speed at the laser powers of 7.5, 8, and 8.5 W.

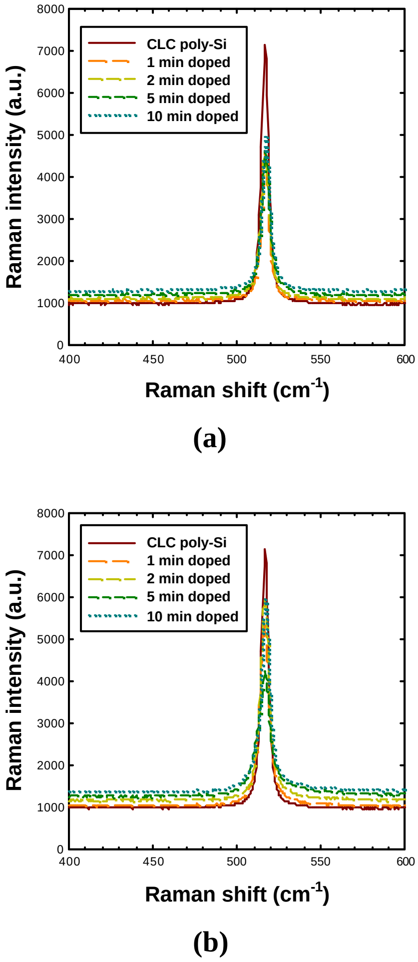
Figure 2 shows the sheet resistance of (a) p-type and (b) n-type doped CLC poly-Si films versus CW laser scan speed at the laser powers of 7.5, 8, and 8.5 W. The ion dose and acceleration voltage were 3.71 × 10^{16} cm^{-1} and 16 kV, respectively. The sheet resistance decreases as the CW laser scan speed decreases down to 360 mm/s at the laser powers of 8 and 8.5 W, and then shows the saturated values of almost 30~40 Ω/□ at slower scan speed than 360 mm/s. When the laser power is 7.5 W the sheet resistance decreases with decreasing CW laser scan speed. The lower sheet resistance at higher laser power and slower scan speed is due to the improved crystallinity. The doping efficiency increases with crystalline fraction in the poly-Si. The sheet resistance is sufficiently low enough for device processing at the laser power of 8 W and the scan speed of 400 mm/s for the CLC poly-Si.

Raman spectroscopy was used to estimate the crystallinity changes before and after the CW laser dopant activation (CLDA).

Figure 3 shows the Raman spectra measured (a) after ion doping with the various B_2H_6/H_2 plasma ion doses, and (b) after CW laser dopant activation at the laser power of 8 W, and the scan speed of 360 mm/s. As B_2H_6/H_2 plasma ion dose increases, the Raman intensity measured after ion doping decreases. That means the crystallinity changes and defect generation have occurred at the surface of the CLC poly-Si due to the surface damage by increasing ion bombardment during ion doping. However, the Raman intensity is almost recovered after the CLDA, which means the surface of the B_2H_6/H_2 plasma ion doped CLC poly-Si is re-crystallized while dopant activation by CW laser scanning.

The sheet resistance of the CLDA samples was compared with that of ion doped CLC poly-Si annealed by conventional thermal annealing at 400 °C for 1 hour.

Figure 4 shows the sheet resistance versus B_2H_6/H_2 plasma ion dose for the CLC poly-Si film after the CLDA and the conventional thermal annealing, respectively. As the B_2H_6/H_2 plasma ion dose increases, the sheet resistance decreases. Decrease in the sheet resistance of the ion doped CLC poly-Si with increasing B_2H_6/H_2 plasma ion dose is due to the increase of activated dopants. The sheet resistance of the CW laser dopant activated CLC poly-Si is 30 Ω/□ when B_2H_6/H_2 plasma ion dose is 7.438×10^{16} cm^{-2}. The sheet resistance measured after CLDA is much lower than that of conventional thermal annealing. The sheet resistance measured after conventional thermal annealing is about 3~4 kΩ/□ at the same B_2H_6/H_2 plasma ion dose to that of CLDA as shown in the Fig. 4.



(a)

(b)

Figure 3 The Raman spectra measured (a) after ion doping with the various B_2H_6/H_2 plasma ion doses, and (b) after CW laser dopant activation at the laser power of 8 W, and the scan speed of 360 mm/s.

Figure 5 shows the relationship between the difference in Raman shift (? ?) and B_2H_6/H_2 plasma ion dose for the CLC poly-Si after the CW laser dopant activation at the laser power of 8 W and the scan speed of 360 mm/s. It is known that the stress of Si thin film is related to ? ? [5]. The ? ? of the CLC poly-Si is 2.3 cm^{-1}, and the ? ? of ion doped CLC poly-Si after CLDA is similar to that of CLC poly-Si, which means ion doped CLC poly-Si does not suffer from the severe stress after CLDA.

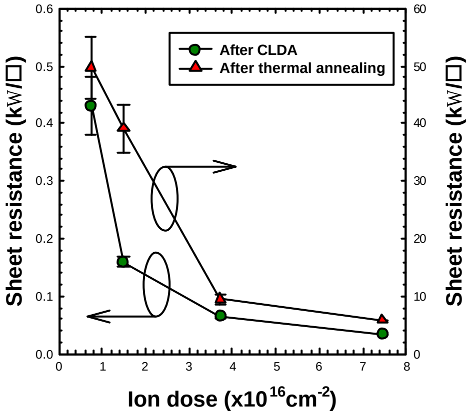


Figure 4 The sheet resistance versus B_2H_6/H_2 plasma ion dose for the CLC poly-Si film after the CLDA and the conventional thermal annealing.

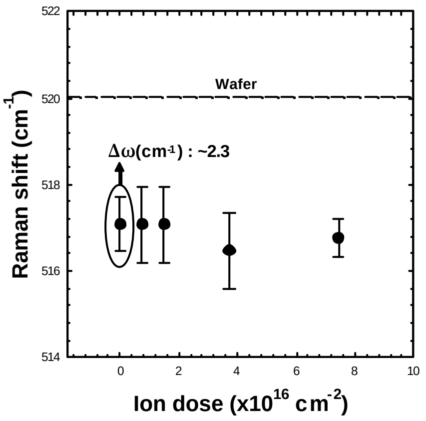


Figure 5 The relationship between Raman shift difference and B_2H_6/H_2 plasma ion dose for the CLC poly-Si after the CLDA at the laser power of 8 W and the scan speed of 360 mm/s.

Although the CLC poly-Si film scanned at the laser power of 8.5 W exhibited the lowest sheet resistance less than 30 Ω/□ as shown in the Fig. 2, CW laser power and the scan speed should be optimized to avoid damage on gate metal by CW laser scan when it is used for conventional coplanar structured LTPS TFT fabrication.

Figure 6 shows the microscopic view of gate patterned Si after CW laser scan at the laser power of 800 W and the scan speed of 360 mm/s. The pattern size is the same as the LTPS TFT for LCD. After the CW laser scanning at the above condition, the damage on the gate metal was not observed. CW laser scan for dopant activation after ion doping can be done on the channel region by using computer controlled X-Y translation stage.

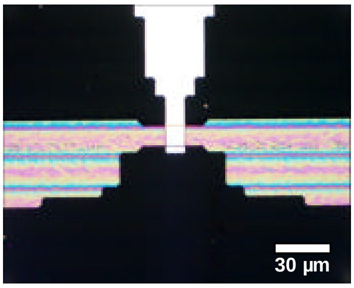


Figure 6 Microscopic view of the gate pattern after CW laser scan at the laser power of 800 W and the scan speed of 360 mm/s.

4. Conclusion

CW laser dopant activation (CLDA) is suggested as an alternative way to conventional thermal annealing. The sheet resistance of the CW laser dopant activated CLC poly-Si is 30 Ω/□ when B_2H_6/H_2 plasma ion dose is 7.438×10^{16} cm^{-2}. The sheet resistance measured after CLDA is much lower than that of conventional thermal annealing. The surface damage due to ion doping on the poly-Si can be recovered while CW laser scan for dopant activation. Therefore, the proposed CLDA method can be applied to LTPS processing, and this was confirmed by the CW laser scan on the patterned Si.

5. References

[1] A. Hara, F. Takeuchi. M. Takei, K. Suga, K. Yoshimo, M. Chida, Y. Sano, N. Sasaki, Jpn. J. Appl. Phys., 41, p. L311 (2002).

[2] Y. M. Ku, K. H. Kim, S. H. Kang, S. J. Park, J. Jang, IDW'04, p. 509 (2004).

[3] K. H. Kim, S. Y. Yoon, C. O. Kim, J. Jang, J. Korean Phys. Soc., 30, p. S231 (1997).

[4] J. M. Kim, W. S. Hong, D. Y. Kim, J. S. Jung, J. Y. Kwon, T. Noguchi, IMID'04, p. 95 (2004).

[5] K. Kitahara, R. Yamazaki, T. Kurosawa, K. Nakazima, A. Moritani, Jpn. J. Appl. Phys., 41, p. 5055 (2002).