Low temperature pulsed ion shower doping for poly-Si TFT on plastic

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Abstract

We studied a low temperature ion doping process for poly-Si Thin Film Transistor (TFT) on plastic substrates. The ion doping process was performed using an ion shower system, and subsequently, excimer laser annealing (ELA) was done for the activation. We have studied the crystallinity of Si surface at each step using UV-reflectance spectroscopy and the sheet resistance using 4-point probe.

We found that the temperature has increased during ion shower doping for a-Si film and the activation has not been fulfilled stably because of the thermal damage against the plastic substrate. By trying newly a pulsed ion shower doping, the ion was efficiently incorporated into the a-Si film on plastic substrate. The sheet resistance decreased with the increase of the pulsed doping time, which was corresponded to the incorporated dose. Also we confirmed a relationship between the crystallinity and the sheet resistance. A sheet resistance of 300 Ω/sq for the Si film of 50㎚ thickness was obtained with a good reproducibility. The ion shower technique is a promising doping technique for ultra low temperature poly-Si TFTs on plastic substrates as well as those on glass substrates.

1. Introduction

The development of low cost and rugged plastic displays could lead to a dramatic increase in the consumer display products. In particular, the added feature of flexibility may lead to the creation of entirely new display markets1.2. The primary advantages of plastic substrates with respect to glass are the reduction in the weight of the device, flexibility and in display breakage.

Poly-Si film has been actively investigated for Thin Film Transistors (TFTs) application due to the higher carrier mobility, as compared to amorphous Si (a-Si). In particular, poly-Si technology is very attractive for future Active Matrix Liquid Crystal Displays (AMLCD) as poly-Si TFTs can be applied not only as switching elements of the active matrix but also for the integrated driving circuitry. In fact, in contrast to the a-Si technology, both n- and p-channel transistors can be fabricated as for CMOS circuits.

Ion doping is an effective technique of incorporating impurity (such as phosphorus and boron) into poly-Si film in order to make LTPS (Low temperature poly-Si) process. The low temperature doping process is important in Poly-Si TFT on plastic substrate as well. Also, the ion shower doping system has an advantage, because of using no mass separation system than ion implanter[3]. Low cost equipment, and the structure is simpler than ion implanter. However, as the plastic substrate is fragile, it receives easily a thermal damage (over 200℃). One of the key technologies in poly-Si[4] activation is the laser activation of silicon thin films. Since laser activation is a rapid melt and growth process, it allows us to use low deformation-point plastics for the substrate.

2. Experimental Procedure

500Å-thick sputtered a-Si film was deposited on polyethersulfone (PES) substrate. (Figure 1(a)) A Poly-Si thin film on plastic substrate was prepared (below 150℃) by crystallizing the a-Si using excimer laser irradiation .

Figure 1(b) shows that dopant (phosphorus) impurities were incorporated on the poly-Si film by using an ion shower system. In the ion shower doping, we attempted the continuous doping at a high RF-power and the film has experienced poly-Si film damage of crack. The Poly-Si film damage was caused due to an ion bombardment relating to the self-heating. The more the ions strike the film, the more temperature increases. By adopting newly a pulsed doping, the doping has been carried out successfully without damage. If sufficiently long relaxation periods are allowed between short-term doping (pulsed doping), the ion bombardment may not cause a heavy damage to the film. The pulsed doping technique was used throughout the experiment. The ion shower was carried out intermittently at various levels of RF power. We varied the total doping time (3 minute, 7 minute and 15 minute) at a fixed RF power during the pulsed doping.

Figure 1(c) shows that doped poly-Si was activated by the ELA. We varied the activation laser energy density and the number of laser shots. Sheet resistance was measured using 4-point probe. We measured the crystallinity of Si surface at each step using the UV-reflectance spectroscopy5. Also, The concentration and the depth profile of the dopant atoms were analyzed by Secondary Ion Mass Spectroscopy (SIMS).

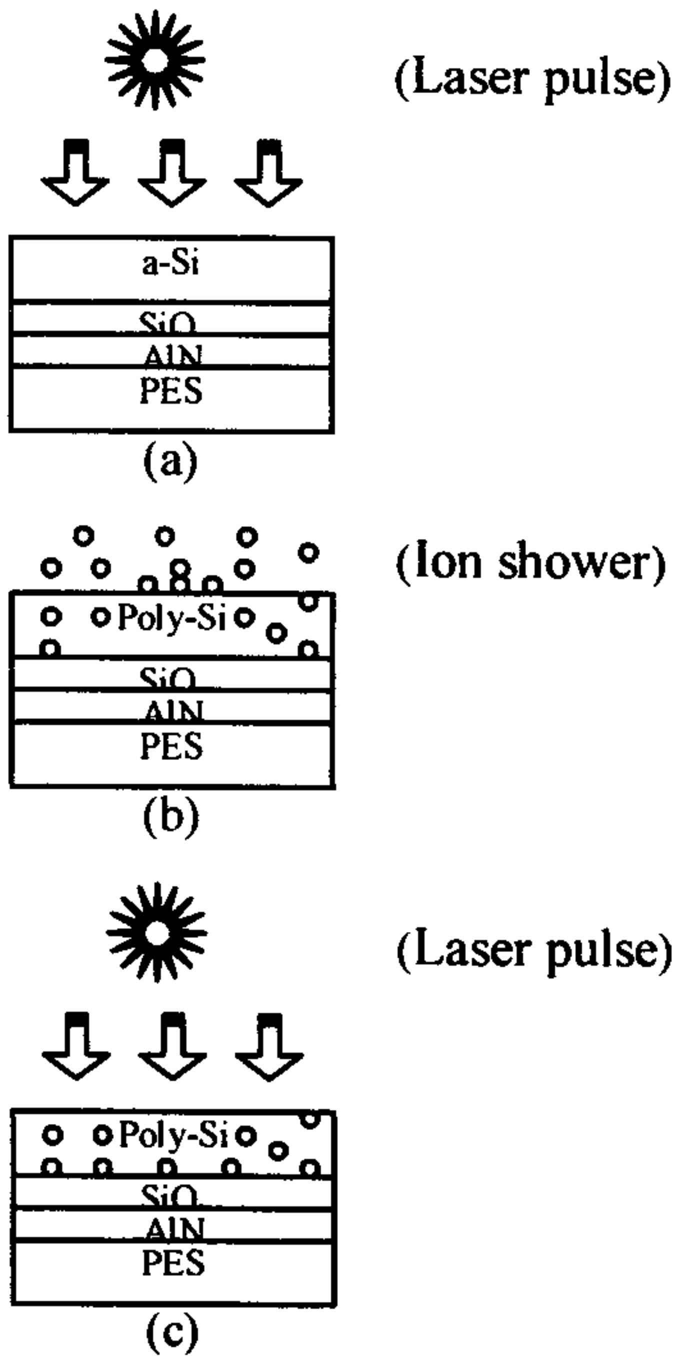

Figure 1. Schematic drawing of sample preparation
(a) Crystallization, (b) Doping, (c) Activation

3. Result and Discussion

When the doping process using ion shower system was performed a continuous doping at room temperature on plastic, glass or Si wafer substrate. the rising temperature of the substrate increased over 210 ℃. However, the damage is serious on plastic substrate. In this case, the process could not be carried out by a formation of crack, metamorphosis or bubble on the plastic substrate. As a result, we could not measure the sheet resistance at plastic substrate.

The increase of the temperature is speculated due to an ion bombardment by the continuous doping. So, we have conducted newly a pulsed doping to suppress the rising temperature with controlling the acceleration bias voltage. As a result, the doping process temperature can be controlled under 150 ℃ during the doping process. Thus, we have overcome the temperature problem for the plastic substrates.

Figure 2 shows that the crystallinity[6] of Si surface changed according to the various doping times. For the as deposited Si (line 2), there is no reflectance peak at 280 nm. After crystallization, poly-Si peak (at 280 nm wavelength) is seen. After the ion shower doping, phase of poly-Si is changed to a-Si, i.e. there is no peak in curve. The lattice of covalent Si network may be broken by the ion shower doping caused by an ion bombardment. The poly-Si peak appears again due to the re-growth of Si after laser activation.

Considering the surface roughness, the reflectance of a single crystal Si (as a standard) showed quite high value at 200 nm wavelength. For the As-deposited a-Si, the value showed almost 50 % at 200 nm. The UV-reflectance spectroscopy implies that the surface roughness increases by increasing the process.

In figure 3, the sheet resistance decreased monotonically with the increase in doping time. The sheet resistance related to the dose. In case of higher dose, the sheet resistance decreased. Also we can know that the dose increases with the increase in doping time (3 min: 6e15 cm^{-2}, 5 min: 2e16 cm^{-2}, 15 min: 5e16 cm^{-2}). We have obtained fairly low sheet resistance sufficiently to induce the Ohmic contact between metal and poly-Si.

Figure 4 shows a doping profile obtained by secondary ion mass spectroscopy (SIMS) analysis. The concentration increased with increasing the doping time. The dose was concentrated mainly near surface of Si film. In the surface of region (at 500 Å depth), the profile has suddenly fallen down because the region is a interface between poly-Si and SiO_2. After the activation, the curve changed slightly because the injected dopant would diffuse to deeper region by laser activation.

Figure 5 shows a sheet resistance depending on laser shots number at fixed laser energy for three different doping times. It is seen that sheet resistance did not change with the number of laser shots because dose was sufficient to decrease the sheet resistance at this energy condition. The Sheet resistance value of 300 Ω/sq. was obtained at 15 minute doping time. Theses values were sufficiently low for n$^+$ contact in poly-Si TFT's.

4. Conclusion

Excimer laser annealing (ELA) subsequently after ion shower doping process has been done, and the activation behavior has been studied. By adopting newly a pulse ion shower doping, the ion was incorporated effectively into the Si surface. Laser activation was successfully done for the activation of

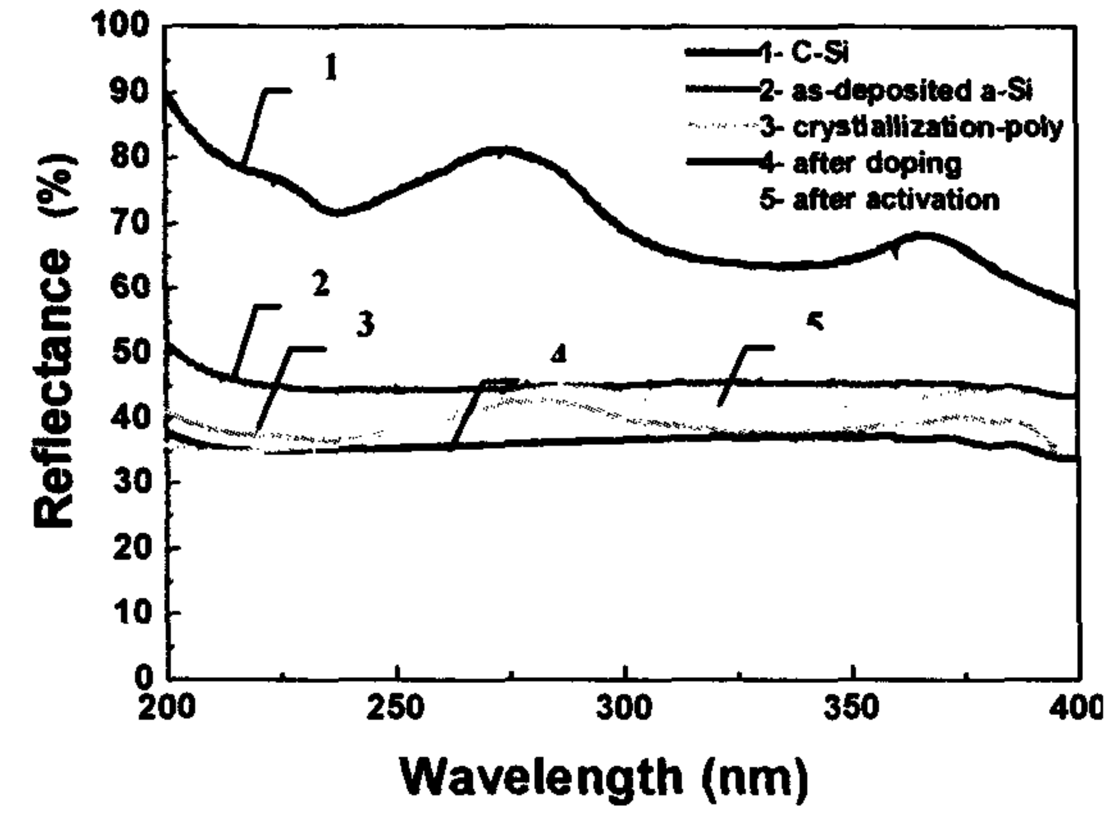

Figure 2. UV-reflectance spectra of poly-Si on plastic

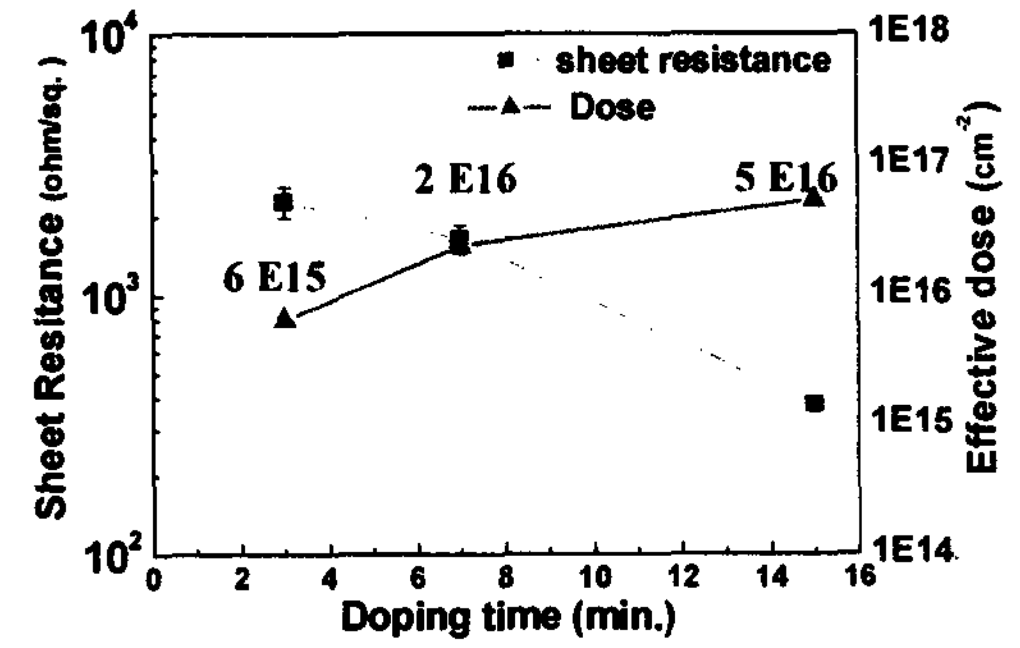

Figure 3. Variation of the sheet resistance as a function of the doping time (Phosphorous)

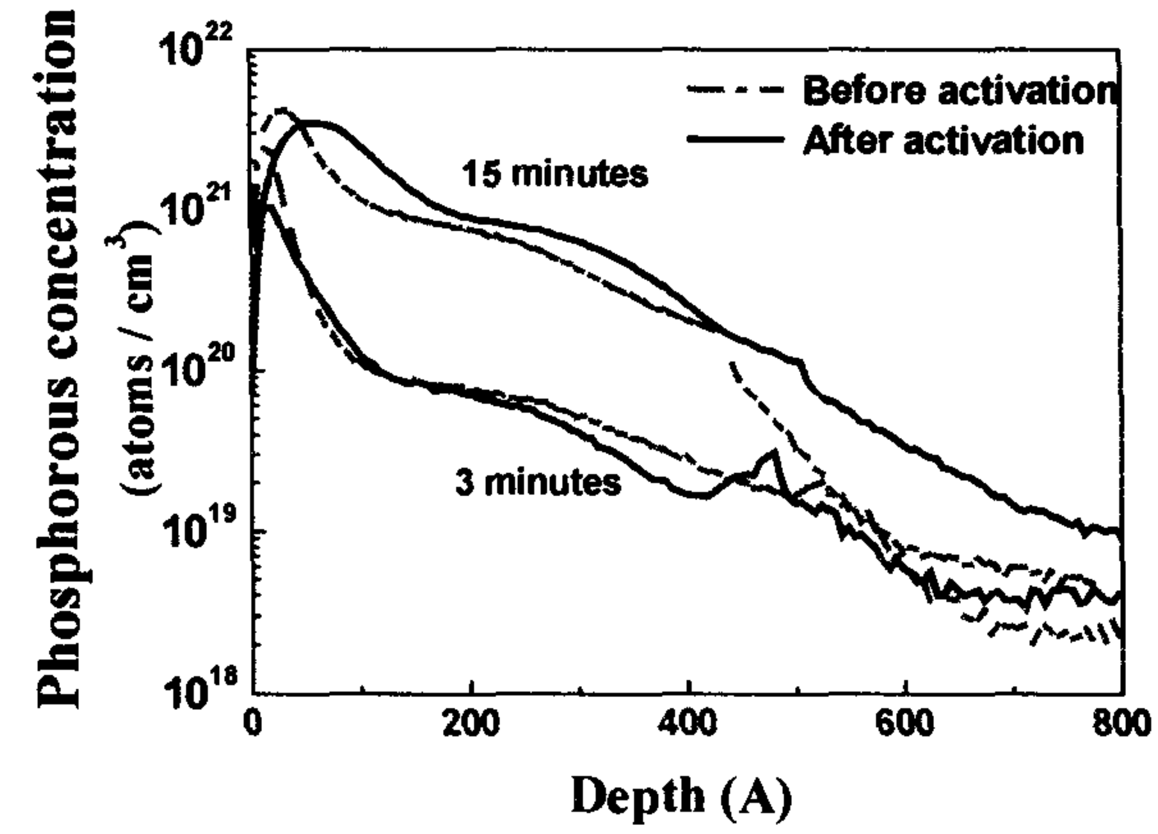

Figure 4. Phosphorous profile in silicon film on plastic substrates: before and after laser activation for the Dopant doping time

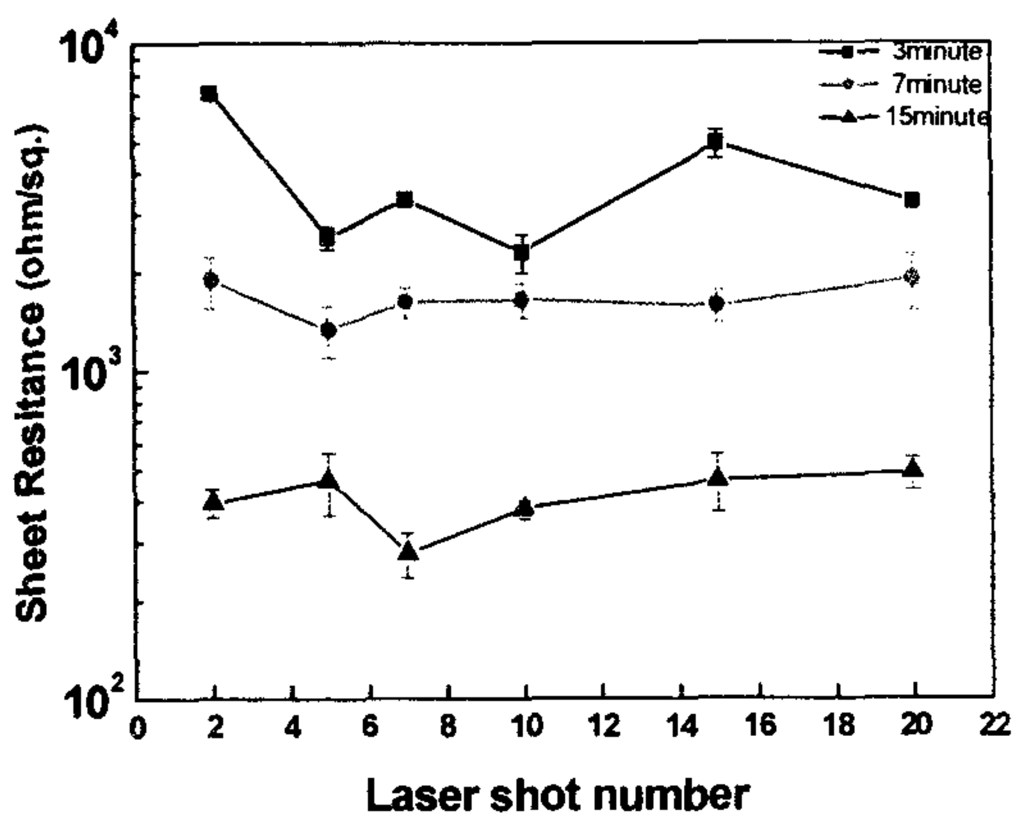

Figure 5. Change in the sheet resistance with the number of laser shots for various doping time

poly-Si film on plastic. The sheet resistance decreased as the doping time increased. Over the dose of 1 x 10^{16}atoms/cm², the sheet resistance did not change with the number of laser shots. A sheet resistance as low as 300 Ω/sq. has been obtained. During the entire process, the substrate was kept below 150°C. This doping technique is expected to be effective for fabricating poly-Si TFT's on plastic substrates.

5. Acknowledgements

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6. References

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