Reverse annealing of P^+/B^+ ion shower doped poly-Si

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Abstract

Reverse annealing was observed in P^+/B^+ *ion shower doped poly-Si upon activation annealing. Phosphorous or boron was implanted by ion shower doping using a source gas mixture of* PH_3/H_2 *or* B_2H_6/H_2*. Activation annealing was conducted using a tube furnace in the temperature ranges from 350 ℃ to 650 ℃. Hall measurement revealed that reverse annealing begins at different annealing temperatures for poly-Si implanted with P and B, respectively. It was observed that reverse annealing starts at 550 ℃ in* P^+ *ion shower doped poly-Si, while at 350 ℃ in the case of B-doping.*

1. Introduction

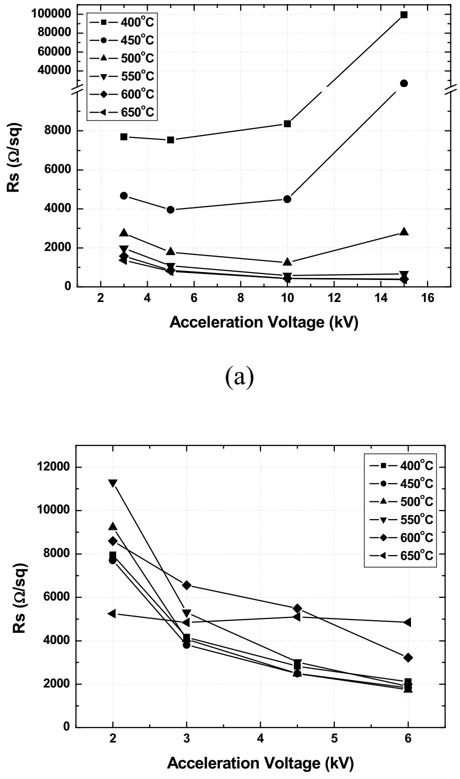
Non-mass analyzed ion shower doping (ISD) technique with a bucket-type ion source has been widely used for source/drain doping, for LDD (lightly-doped-drain) formation, and for channel doping in fabrication of low-temperature poly-Si thin-film transistors (LTPS-TFT's) [1,2,3]. Phosphorous or boron can be implanted using ion shower doping with a mixture gas of PH_3 or B_2H_6, diluted with H_2. Due to non-mass-separation nature of ISD, hydrogen atoms incorporated into poly-Si films after ion shower doping may play an important role in enhanced dopant activation and passivation of defects. Activation efficiency of dopant atoms in single crystalline or polycrystalline silicon is therefore higher for ISD than for mass-separated ion implantation [3]. Greater electrical activation has been reported in the hydrogeneated samples at lower temperatures below 600℃ [4]. In the case of boron implantation, activation at lower temperatures is limited by the formation of boron-interstitial clusters easily formed at concentrations lower than solid solubility limit. The presence of mobile hydrogen atoms may assist in the breakup of boron-interstitial clusters and hydrogen effusion during annealing may create vacancies. Low energy H^+ ion implantation following As implantation with low temperature annealing was reported to be effective for damage passivation and dopant activation [5].

Meanwhile, reverse annealing is a well known phenomenon for B implantation into single crystalline silicon in the temperature ranges between 500℃ and 600℃ [6]. We observed reverse annealing in P^+/B^+ ion shower doped poly-Si and report here on its behavior.

2. Results

For the sample preparation SiO_2 insulation layer with a thickness of 3000 Å was formed on a Corning 7059 glass substrate of 370mm x 470mm x 0.7mm (length x width x thickness) by means of plasma enhanced chemical vapor deposition (PECVD). An a-Si thin film with a thickness of 500 Å was formed successively upon the insulation layer using PECVD. The substrates used were poly-Si produced by excimer laser crystallization on 500 Å-thick PECVD a-Si. The glass substrate was broken into pieces of 20mm x 20mm, thereby preparing a test piece. Phosphorous or boron was implanted by ion shower doping with a main ion source of P_2H_x or B_2H_x using a source gas mixture of PH_3/H_2 or B_2H_6/H_2. Activation annealing was performed in the temperature ranges from 350℃ to 650℃ for 30 min using a tube furnace in a nitrogen ambient. Activation efficiency and mobility of charge carriers were determined by Hall measurement using a van der Paw method. A 4-point-probe was used to check the value of sheet resistance determined by Hall measurements. The as-implanted damage induced by ion shower doping and damage recovery following an activation annealing was assessed with transmission electron microscopy (TEM).

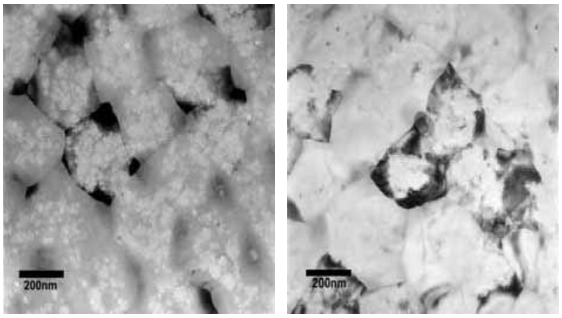
Acceleration voltage was changed from 3 kV to 15 kV for P doping and from 2 kV to 6 kV for B doping. Doping time was kept constant as 1 min for all samples used in this study. Figure 1 shows sheet resistance as a function of acceleration voltage after activation annealing. 30 min-isochronal annealing was conducted in the temperature ranges from 350℃ to 650℃. As shown in Fig. 1-(a), for P-doped samples annealed at temperatures greater than 600℃ the sheet resistance gradually decreases as acceleration voltage increases, while it initially decreases with acceleration voltage and increases again with acceleration voltage beyond a certain value for the samples annealed at temperatures lower than 550℃. A concentration profile of implanted atoms becomes broader and the peak concentration at the projected range gets lower as the acceleration voltage increases. An excess concentration of dopant atoms beyond solid solubility at a given annealing temperature thus becomes large as the acceleration voltage decreases. Activation efficiency is therefore higher as the acceleration voltage increases. This may explain the decrease of sheet resistance with acceleration voltage. Meanwhile, for the samples implanted with higher acceleration voltage followed by low temperature annealing as-implanted damage by high mass ion such as P may not be sufficiently cured. This may explain the increase of sheet resistance with acceleration voltage. Figure 2 shows transmission electron microscopy (TEM) for the samples implanted with acceleration voltage of 15 kV for 1 min. Figure 2-(a) shows TEM micrographs for as-implanted sample, Fig. 2-(b) shows the one annealed at 550℃ for 30 min, and Fig. 2-(c) shows the one annealed at 600℃ for 30 min. TEM results indicate that implanted damage is not recovered sufficiently even for the sample annealed at 550℃. In contrast to the case of P-doping the sheet resistance decreases as the acceleration voltage increases in B-doped sample except for the samples annealed at 650℃. Since boron is a light mass ion damage may not be generated to a significant amount. If we look at Fig. 1-(b) carefully the values of sheet resistance have an abnormal relationship with annealing temperatures. In the case of 6 kV-implanted samples the sheet resistance decreases as annealing temperature increases.



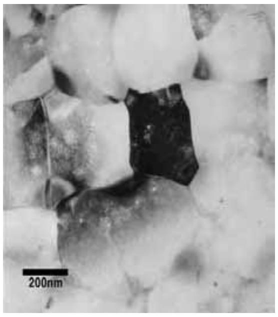
(a)

(b)

Fig. 1 Sheet resistance vs. acceleration voltage for the samples doped with (a) phosphorous and (b) boron, respectively.



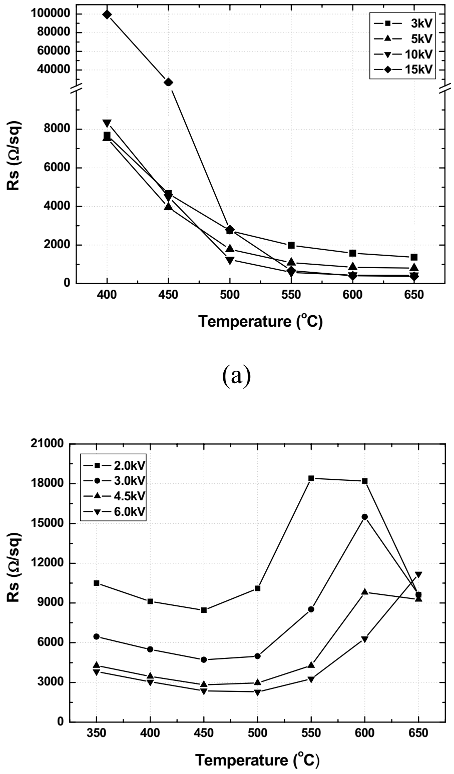
(a) (b)



(c)

Fig. 2 TEM micorgraphs for (a) the sample implanted with 15-kV P^+, followed by (b) 550℃-30 min annealing, and (c) 600℃-30 min annealing.

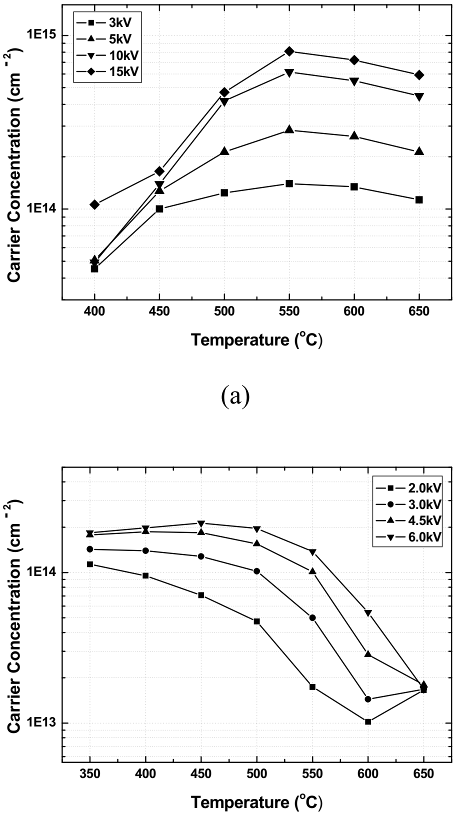
Figure 3 shows sheet resistance as a function of annealing temperature for P-doped samples with acceleration voltage from 3 kV to 15 kV, and for B-doped samples with acceleration voltage from 2 kV to 6 kV, respectively. The sheet resistance decreases as annealing temperature increases as indicated in Fig. 3-(a) for P-doped samples. Large increase in sheet resistance for 15 kV-implanted samples annealed at temperatures blow 500℃ can be explained by the effect of uncured damage. The sheet resistance, however, has an unusual relationship with annealing temperature for B-doped samples as shown in Fig. 3-(b). Figure 4 shows sheet carrier concentration determined by Hall measurement using a van der Paw method as a function of annealing temperature for the samples implanted with P and B, respectively. Carrier concentration increases as acceleration voltage increases at a given annealing temperature as shown in Fig. 4. Carrier concentration, however, increases as annealing temperature increases up to 550℃, while it decreases as annealing temperature increases beyond 550℃, for P-doped samples as indicated in Fig. 4-(a). Reverse annealing is a well known phenomenon for B-doped single crystalline silicon using a mass separated ion implanter [6]. Siedel et. al. reported that reverse annealing is observed in single crystalline silicon implanted with boron in the temperature ranges between 500℃ and 600℃. Since the maximum annealing temperature used in this study was limited to 650℃ due to thermally susceptible glass substrate we could not determine the whole temperature ranges of reverse annealing. It was, however, observed that reverse annealing starts at 550℃ in P^+ ion shower doped poly-Si. B-doped samples also exhibit reverse annealing behavior as indicated in Fig. 4-(b). Reverse annealing, however, begins at lower temperatures in these samples. Reverse annealing already starts from 350℃ in B^+ ion shower doped poly-Si. Reverse annealing seems to end at 600℃ for the samples implanted with lower acceleration voltage.



(a)

(b)

Fig. 3 Sheet resistance as a function of annealing temperature (a) Phosphorous doping with acceleration voltages from 3 kV to 15 kV. (b) Boron doping with acceleration voltages from 2 kV to 6 kV.



(a)

(b)

Fig. 4 Sheet carrier concentration as a function of annealing temperature determined by Hall measurement. (a) Phosphorous doping with acceleration voltages from 3 kV to 15 kV. (b) Boron doping with acceleration voltages from 2 kV to 6 kV.

3. Conclusion

Reverse annealing was observed in P^+/B^+ ion shower doped poly-Si upon activation annealing. It was observed that reverse annealing starts at 550℃ in P^+ ion shower doped poly-Si, while at 350℃ in the case of B-doping.

4. Acknowledgements

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5. References

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