The effect of annealing method on dopant-activation and damage-recovery in ion-shower-doped Poly-Si using PH_3/H_2

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Abstract

Ion shower doping using a source gas of PH_3/H_2 was conducted on excimer-laser-annealed (ELA) Poly-Si. As-implanted damage is accumulated more and more with the increase of an acceleration voltage and a doping time. In this study we found that dopant-activation is relatively a rapid kinetic-process while damage-recovery is not.

1. Introduction

Low temperature poly-Silicon (LTPS) technology is crucial for the fabrication of poly-Si TFT-LCD's and OLED's. Processing temperatures, for deposition of a-Si films, crystallization of a-Si into poly-Si, and dopant activation, are limited to below ~ 600^oC due to glass substrate. Non-mass analyzed ion shower doping technique has been widely used for source/drain doping, for lightly doped drain (LDD) formation, and for channel doping in fabrication of low-temperature poly-Si thin-film transistors (LTPS-TFT's) [1-5]. Dopant activation may be done by furnace annealing, excimer laser annealing, and rapid thermal annealing, respectively [6]. Activation annealing should satisfy both the electrical activation of implanted impurities and the annealing of primary crystalline defects.

2. Experimental

The substrates used were poly-Si produced by excimer laser crystallization on 500 Å-thick PECVD (plasma enhanced chemical vapor deposition) a-Si. Phosphorous was implanted by ion shower doping with a main ion source of P_2H_x using a source gas mixture of PH_3/H_2 [7, 8]. Acceleration voltage was changed from 1 kV to 15 kV and doping time varied from 10 sec to 3 min as variables of implantation conditions. Activation annealing was performed using a tube furnace, or, an RTA system in a nitrogen ambient. The sheet resistance was measured using a 4-point-probe. Crystallinity was determined by UV-transmittance while transmission electron microscopy (TEM) was conducted for the analysis of microstructure.

3. Results and discussion

In order to observe defect generation behavior according to doping conditions, we changed the acceleration voltage from 1 kV to 15 kV and the doping time from 1 min to 3 min, respectively. Fig. 1 shows UV-transmittance as a function of wavelength for the as-implanted samples. Near the region of the wavelength between 350 nm and 550 nm, the transmittance spectrum shows sharp changes with the acceleration voltage. At a doping time of 1 min, as the acceleration voltage increases the slope at around 400 nm decreases, as shown in Fig. 1-(a). The slope finally reaches almost to the value of a-Si at an acceleration voltage of 15 kV. As the doping time increases from 1 min to 3 min the change of the slope becomes greater, as indicated in Fig. 1-(b). These observations mean that the amount of damage, or, that of crystallinity, may correlate with the UV-slope at around 400 nm. We thus differentiated the curves with regard to wavelength. Fig. 2 indicates the derivatives of Fig. 1 as a function of wavelength. We took the value of derivative

at around 400 nm as the value of crystallinity. Crystallinity, obtained from the value at 400 nm in Fig. 2, decreases as acceleration voltage increases. As the doping time increases from 1 min to 3 min it decreases significantly as indicated in Fig. 2-(b). Fig. 3 shows the crystallinity obtained from Fig. 2 as a function of acceleration voltage for the samples doped at 1 min and 3 min, respectively. The values of crystallinity in Fig. 3 are normalized ones assuming that ELA poly-Si as a starting material has the value of 1.0. As the acceleration voltage increases to 15 kV the value of crystallinity approaches to the level of a-Si as shown in Fig.3. The most part of the sample is seen to be amorphized according to TEM observation as demonstrated in Fig. 4.

When we annealed the samples implanted with a doping time of 1 min in the range of 550°C to 650°C for 30 min, the sheet resistance was observed to decrease with an acceleration voltage as indicated in Fig. 5. The sheet resistance was measured to be below the level of 1,000 Ω/□ for the samples implanted with acceleration voltages exceeding 5 kV regardless of the above annealing conditions. Fig. 6 shows crystallinity for the as-implanted samples and for the annealed ones. As-implanted damage is recovered more and more as the annealing temperature increases from 550°C to 650°C. Damage-recovery proceeds gradually with the annealing temperature and time, while the kinetics of dopant activation was observed to be a relatively rapid process. Figure 7 shows TEM micrographs for the 15 kV-implanted samples (a), followed by furnace annealing at 550°C (b) and 600°C (c) for 30 min, respectively. Damage is not recovered to a great extent at an annealing temperature of 550°C, while it is recovered significantly at 600°C. These TEM observations are consistent with the results obtained by UV-transmittance spectroscopy as shown in Fig. 6.

Fig. 8 shows the sheet resistance as a function of doping time for the 15 kV-implanted samples after RTA-treatments. RTA was conducted at 700°C, 750°C, and 800°C for 90 sec, respectively. All of the samples show the sheet resistance below the level of 1,000 Ω/□. We then annealed these same samples from 550°C to 800°C using RTA for 90 sec to check the change of crystallinity. Damage is recovered significantly as the annealing temperature approaches to 600°C for the samples doped for less than 1 min, while it is done slowly with the increase of annealing temperature for the ones implanted for a longer time. The RTA-treated samples annealed at higher than 750°C show the value of crystallinity more than ~ 0.6 regardless of doping time as indicated in Fig. 9. TEM observation also shows that damage is recovered profoundly even for the samples implanted with an acceleration voltage of 15 kV at a doping time of 1 min when these are annealed at 750°C for 90 sec using the RTA system as shown in Fig. 10.

4. Conclusions

To summarize, damage-recovery proceeds gradually with the annealing temperature and time, while the kinetics of dopant activation was observed to be a relatively rapid process. Compared to furnace annealing conducted for a long time, RTA annealing seems to be effective in recovering damage induced by ion implantation.

5. Acknowledgements

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6. References

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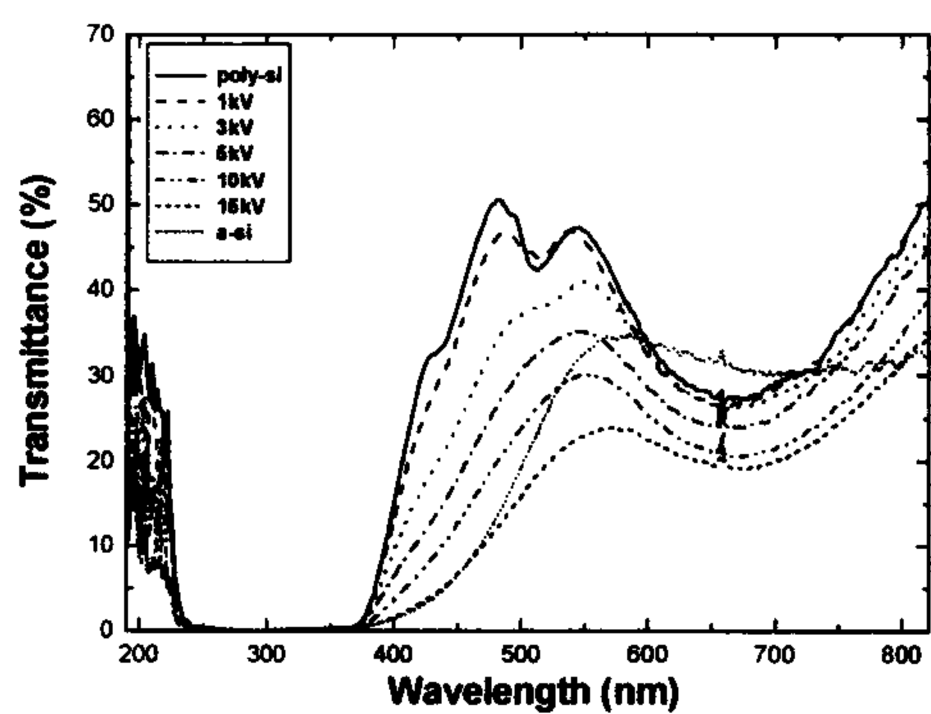
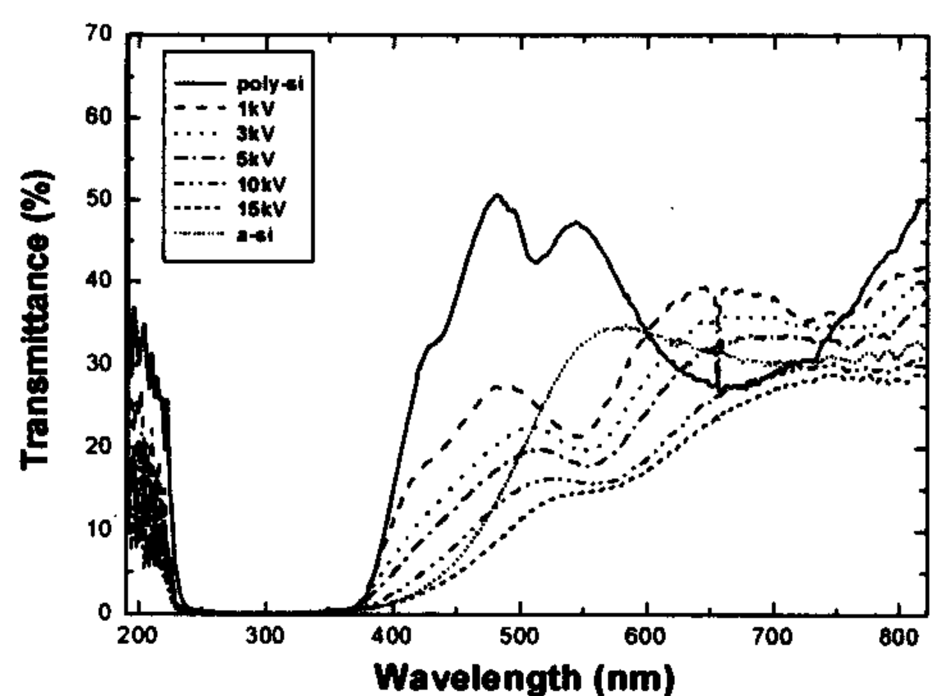
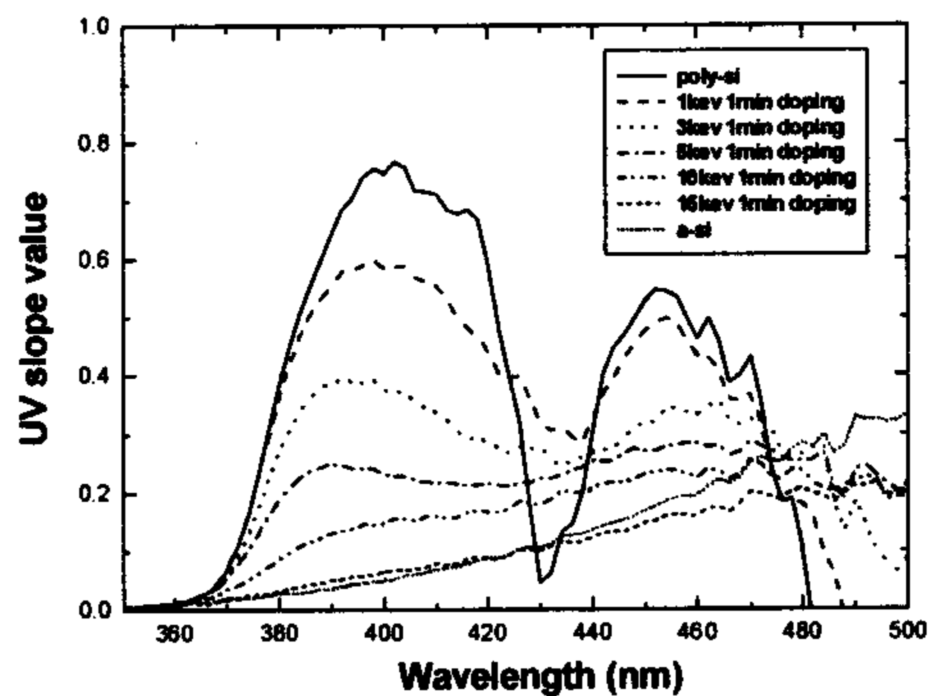


(a)

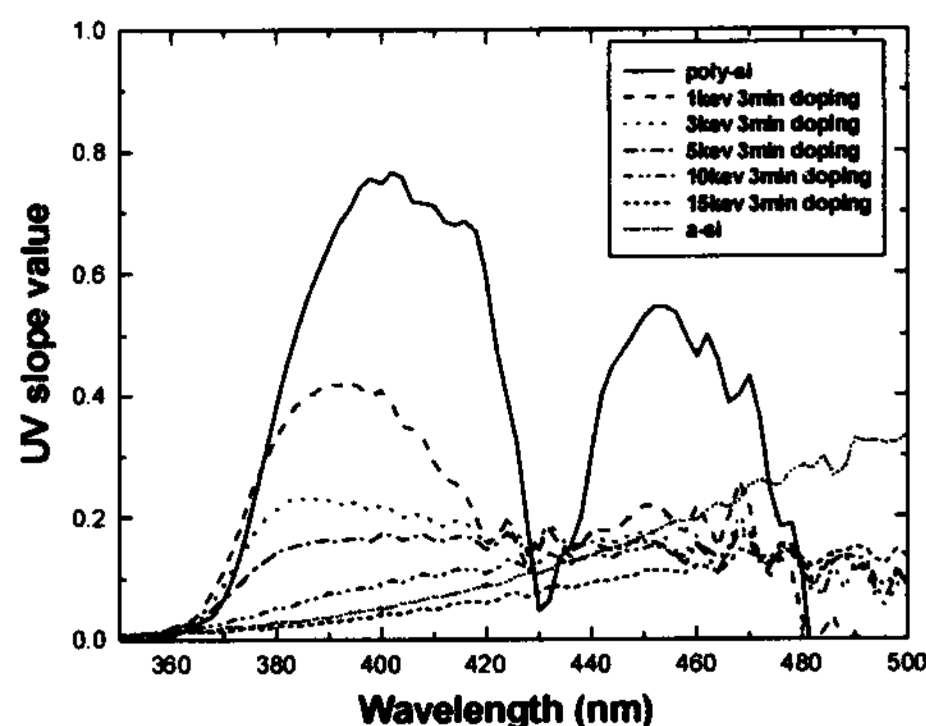


(b)

Fig. 1 UV-transmittance as a function of wavelength (a) for the as-implanted samples at a doping time of 1 min, and (b) for the as-implanted samples at a doping time of 3 min, respectively. The samples were implanted using acceleration voltages of 1, 3, 5, 10 and 15 kV, respectively. Note that the curves of ELA Poly-Si and a-Si are also indicated in the figures.



(a)



(b)

Fig. 2 Derivatives of Fig. 1 as a function of wavelength (a) for the as-implanted samples at a doping time of 1 min, and (b) for the as-implanted samples at a doping time of 3 min, respectively.

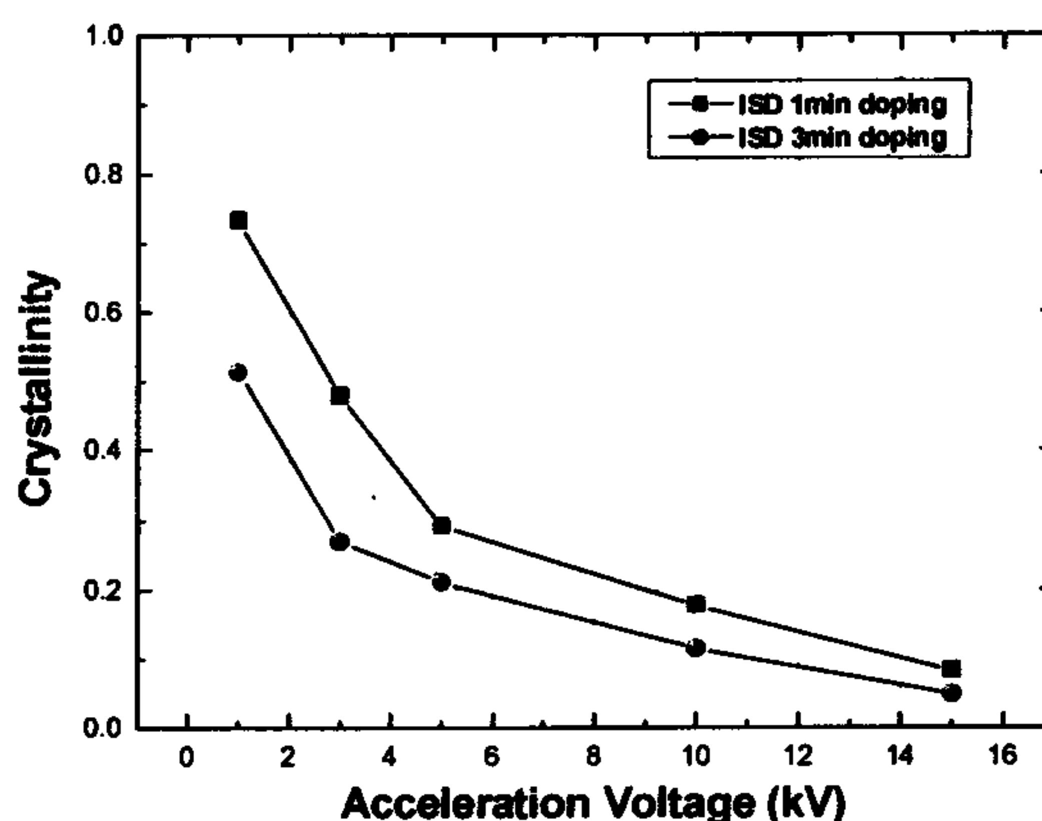
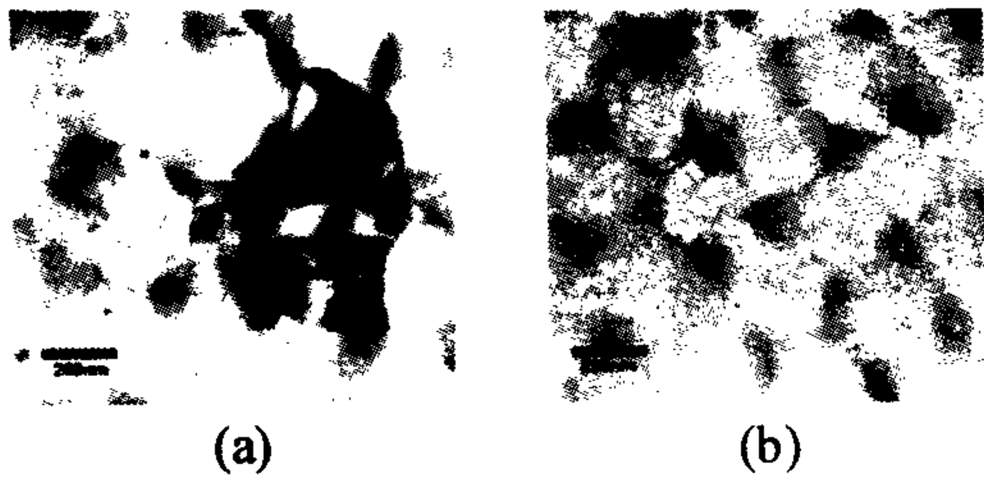


Fig. 3 Measured crystallinity vs. acceleration voltage using UV-transmittance for the samples implanted with 1 min and 3 min, respectively. The value of UV-slope at 400 nm was taken as crystallinity.



(a) (b)

Fig. 4 TEM micrographs for Poly-Si implanted with an acceleration voltage of (a) 5 kV and (b) 15 kV at a doping time of 1 min, respectively.

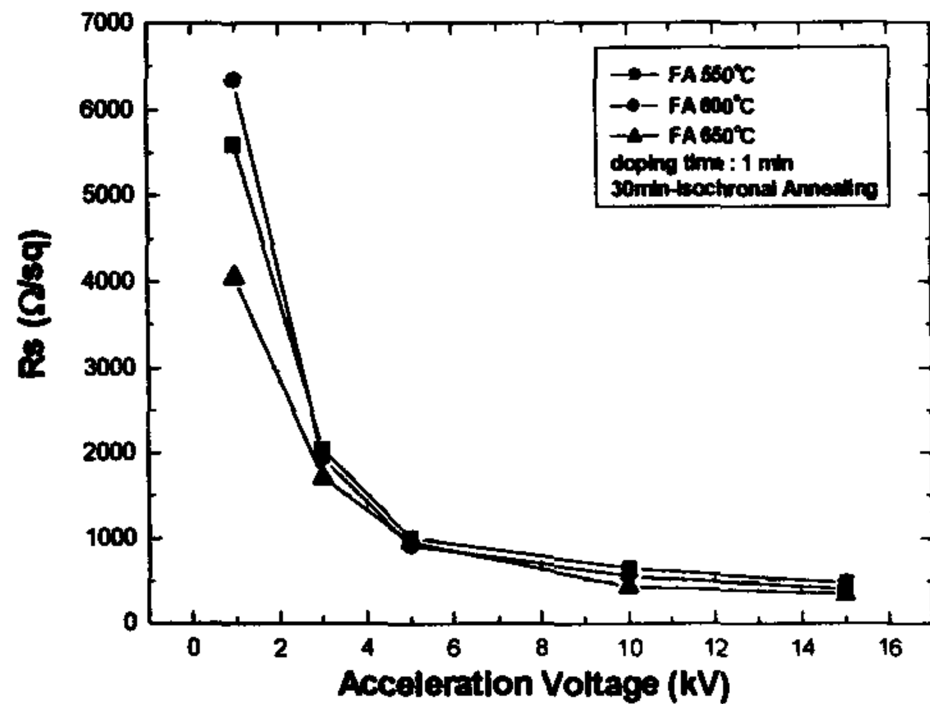


Fig. 5 Sheet resistance as a function of acceleration voltage. Annealing was conducted after ion shower doping at 550°C (squares), 600°C (circles), and 650°C (triangles) for 30 min, respectively.

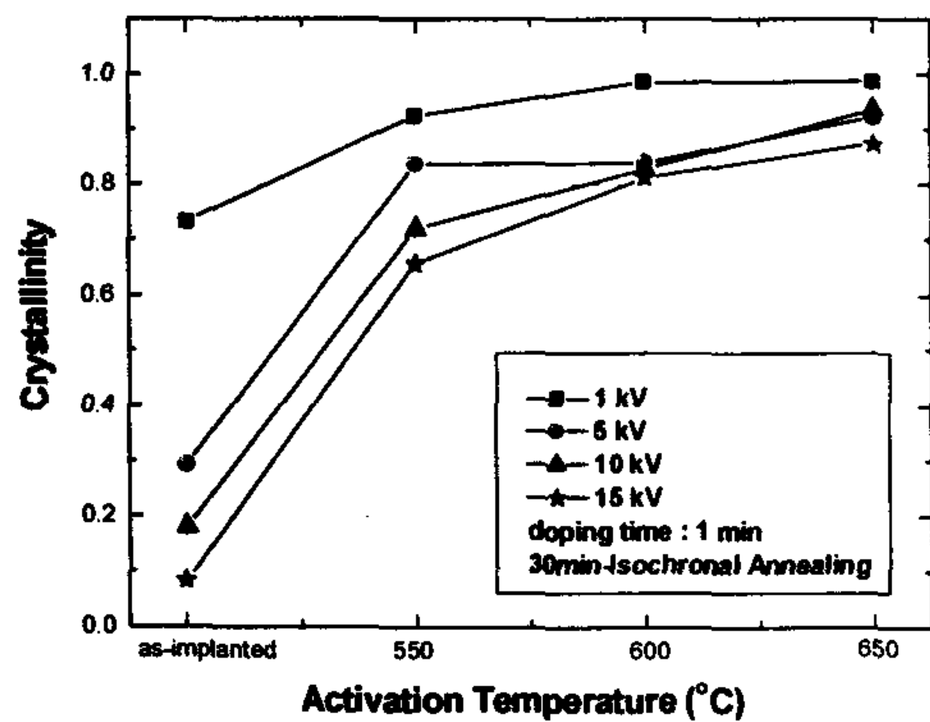
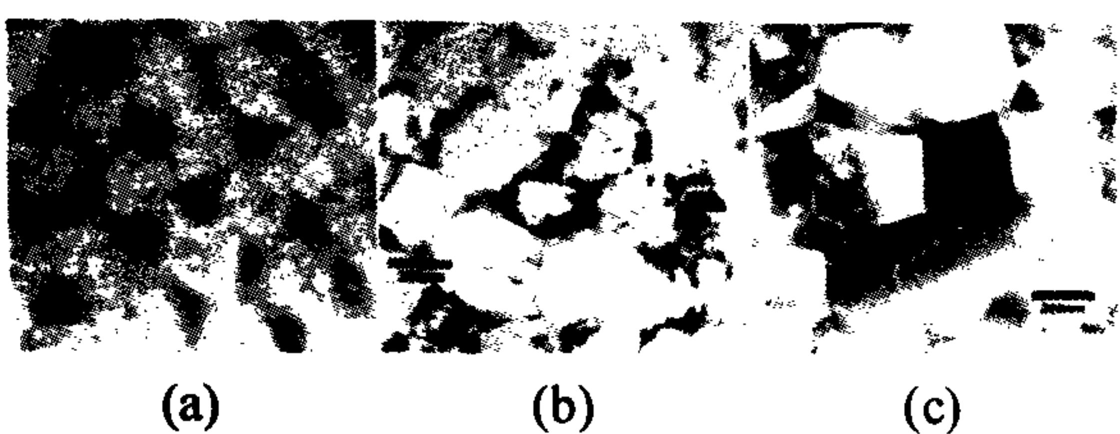


Fig. 6 Measured crystallinity for as-implanted samples and as-annealed samples, respectively.



(a) (b) (c)

Fig. 7 TEM micrographs for the 15 kV – implanted samples. (a) as-implanted, (b) 550°C-30 min, furnace annealing and (c) 600°C-30 min, furnace annealing

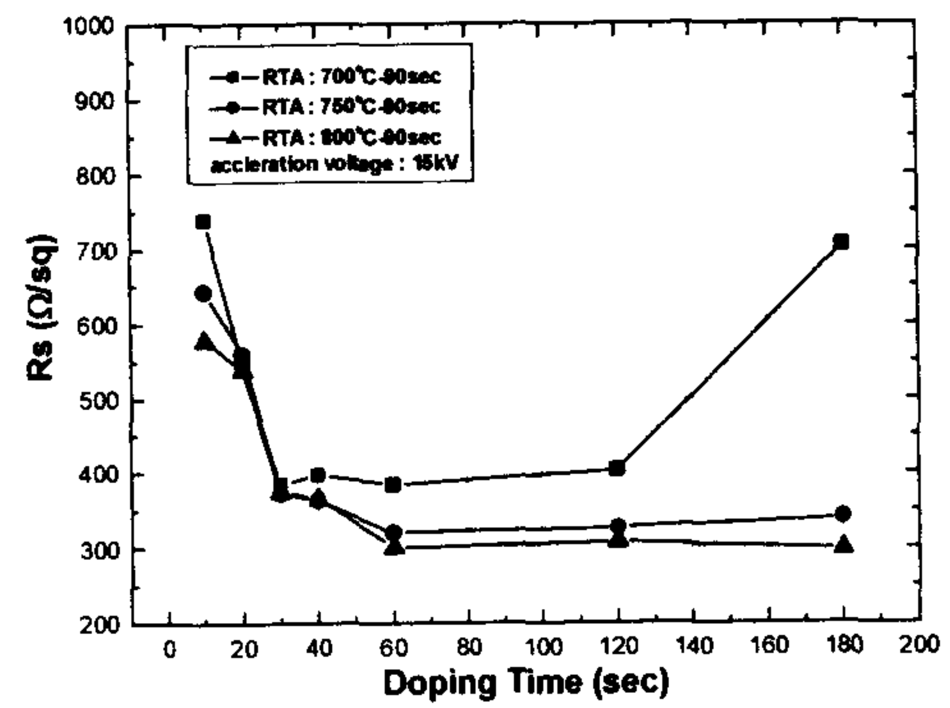


Fig. 8 Sheet resistance vs. doping time for the 15 kV-implanted samples. RTA was conducted at 700°C, 750°C, and 800°C for 90 sec, respectively.

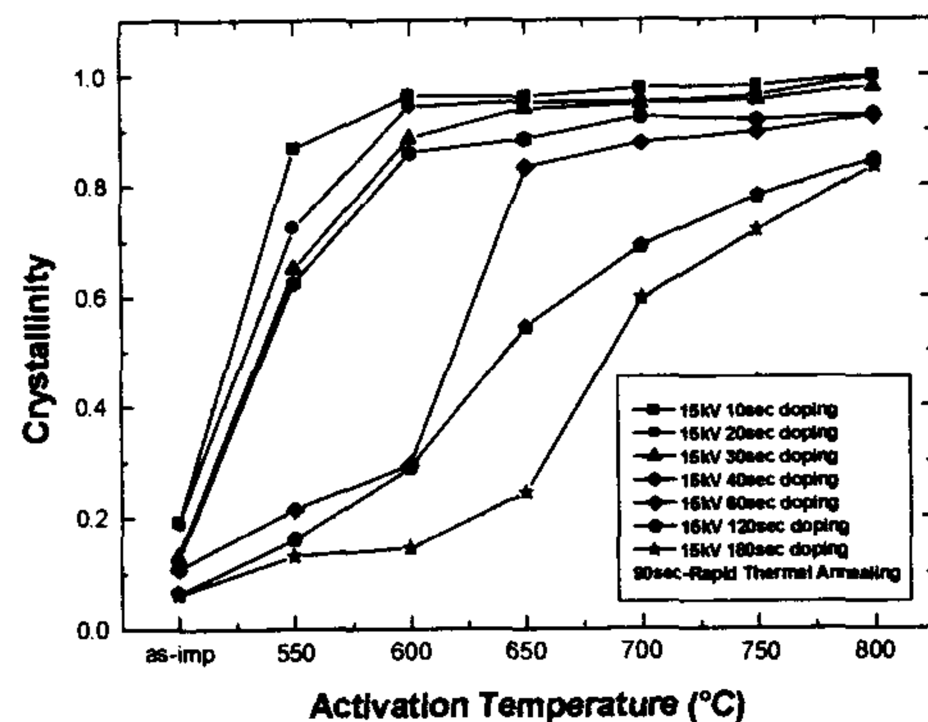
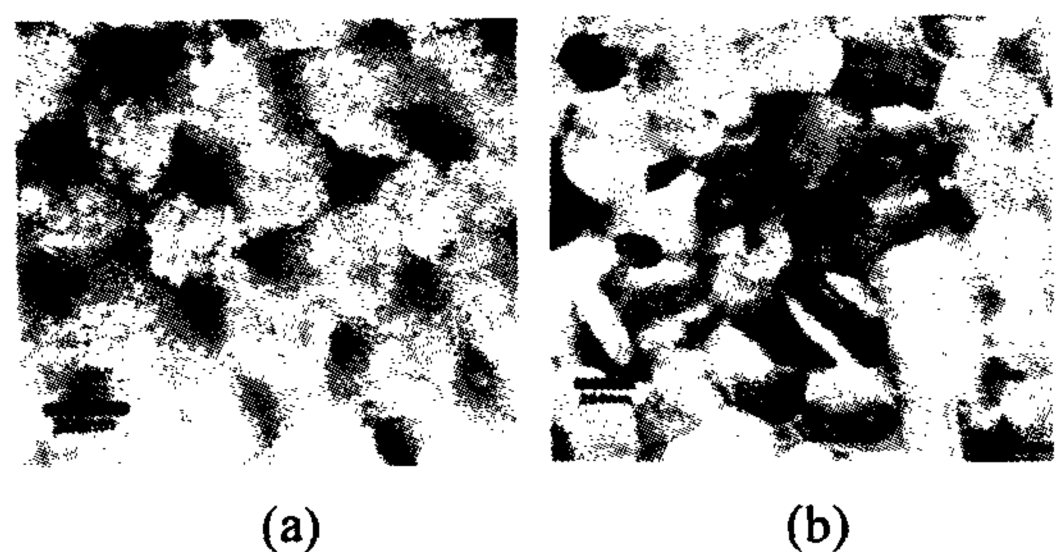


Fig. 9 Measured crystallinity vs. RTA temperatures for the samples implanted with various doping time



(a) (b)

Fig. 10 TEM micrographs for the samples implanted with 15 kV at a doping time of 1 min. (a) as-implanted, (b) 750°C-90 sec, RTA annealing