Extended Abstracts of the 2015 International Conference on Solid State Devices and Materials, Sapporo, 2015, pp22-23

UV Raman and Multiwavelength Photoluminescence Characterization of Ion Implanted Silicon for In-Line Dopant Activation Process Monitoring Applications

Woo Sik Yoo,[1] Toshikazu Ishigaki,[1] Takeshi Ueda,[1] Kitaek Kang,[1] Noriyuki Hasuike,[2] Hiroshi Harima[2] and Masahiro Yoshimoto[2]

[1]WaferMasters, Inc., 254 East Gish Road, San Jose, CA 95112, U.S.A.
[2]Kyoto Institute of Technology, Matsugasaki, Sakyo, Kyoto 606-8585, Japan
Phone: +1-408-451-0850 E-mail: woosik.yoo@wafermasters.com

Abstract

The degree of dopant activation in ion implanted Si wafers was characterized by UV Raman and multi-wavelength RTPL characterization as a function of annealing conditions in an effort to develop in-line dopant activation process monitoring techniques.

1. Introduction

Therma-Probe and secondary ion mass spectroscopy (SIMS) have been widely used for monitoring implant dose and as-implanted depth profiles. Retained dose, dopant profile and sheet resistance (Rs) are routinely measured after dopant activation anneal to quantify electrical activation of implanted species. Rutherford backscattering spectroscopy (RBS) and transmission electron microscopy (TEM) are also used for monitoring crystal quality and defects [1]. Most of these characterization techniques require physical contact or destructive sample preparations.

Suitable non-contact, non-destructive, subsurface characterization techniques for implanted Si dopant activation and crystal quality characterization are needed with fast feedback for process monitoring applications. In this paper, ultra violet (UV) Raman spectroscopy and multiwavelength room temperature photoluminescence (RTPL) are used to characterize ion implanted p^+/n Si junctions, after rapid thermal annealing (RTA).

2. Experiment

Boron (B^+ 5 keV 2.0 x 10^{15}cm^{-2}) implanted n-type 300 mmϕ Si wafers for p^+/n junctions were prepared. The dopant activation RTA was done in a resistively heated, single wafer rapid thermal furnace [2] (WaferMasters SRTF-302LP) in N_2. The RTA temperature and residence time (from wafer insertion to wafer removal) ranges were 800°C~1100°C and 45 ~ 120 s, respectively.

The implanted Si wafers were characterized by a four point probe, SIMS, UV Raman spectroscopy and RTPL spectroscopy, before and after RTA. For Raman measurements, a 363.8 nm UV laser line was used. For PL measurements, 532, 650 and 830 nm laser lines were used to probe dopant activation and junction integrity at different depths.

3. Results and Discussions

Rs of B^+ implanted p^+/n junctions, after various RTA conditions, is summarized in Fig. 1 as a function of RTA temperature (heated chamber temperature) and annealing time (wafer residence time) in the heated chamber. The Rs initially decreases with increasing RTA temperature and time due to enhancement of B dopant activation. From the RTA temperature of 900°C, the Rs rapidly decreases with annealing time increase due to continued increase in B activation. The Rs then increases with RTA temperature and time above 1050°C due to B diffusion and p^+ layer thickening. RTA temperature dependence of B SIMS depth profiles for annealing time of 45 and 90 s, are summarized in Fig. 2. Significant B diffusion was observed from the p^+/n junctions annealed above 1000°C. The junction depth (x_j at B concentration of 5.0 x 10^{19} cm^{-3}) was increased with the increase of RTA temperature and time.

UV Raman and RTPL measurements were taken from an as implanted wafer with all p^+/n junctions formed under various RTA conditions (Figs. 3 and 4). An Ar^+ laser line at 363.8 nm was used for Raman measurements. Penetration depth for UV Raman measurements is ~5 nm and >90% of the Raman signal comes within the probing depth (~15 nm) from the Si surface. For RTPL measurements, three excitation wavelengths, from 532 nm, 650 nm, and 830 nm laser beams were used. Penetration depths for RTPL measurements are in the range of ~1.5 and ~10.0 μm. The spot sizes for Raman and RTPL measurements are ~1 and 200 μm in diameter.

The UV Raman spectra underwent significant changes in intensity, shift, full-width-at-half-maximum (FWHM) and symmetry with RTA conditions. As implanted wafers showed a very weak Raman signal with ~3 cm^{-1} shift towards the lower wavenumber side from the reference Si. As recrystallization and dopant activation progress, the intensity of the Raman signal was increased. The peak shape and position were also changed with RTA. Wafers annealed at, or below, 850°C showed significant asymmetry (inverted triangles in Fig. 3 (a)) due to severe lattice damage. All wafers showed significantly broadened Raman peaks due to high B concentration within the probing depth (~15 nm) of the excitation wavelength (363.8 nm).

Similar trends in RTPL intensity, as a function of RTA temperature and time, were observed from 532, 650 and 830 nm excitation. Highly activated p^+/n junctions, with lower Rs values, showed stronger RTPL signals under all three excitation wavelengths. Due to the severe surface damage and implant damage in the substrate, 532 and 830 nm excited RTPL signals were significantly weaker than those from 650 nm excitation.

4. Summary

UV Raman and RTPL characterization results are well correlated with the characterization results from conventional dopant activation and diffusion monitoring techniques. They can be used as non-contact dopant activation monitoring techniques.

References

[1] D. K. Schroder, *Semiconductor Material and Device Characterization*, 3rd. Eds., Hoboken, New Jersey, John Wiley & Sons, 2006.

[2] W. S. Yoo et al, Jpn. J. Appl. Phys. Vol. 39 (2000) 6143.

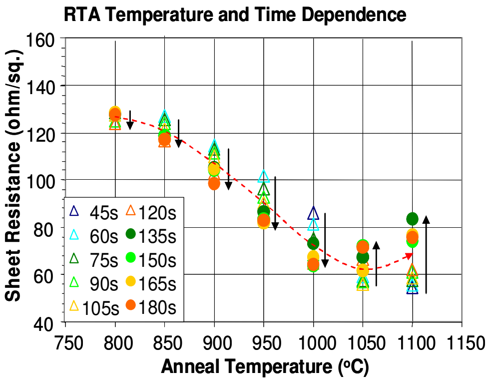

Fig. 1. RTA temperature and time dependence of sheet resistance of B implanted Si wafers.

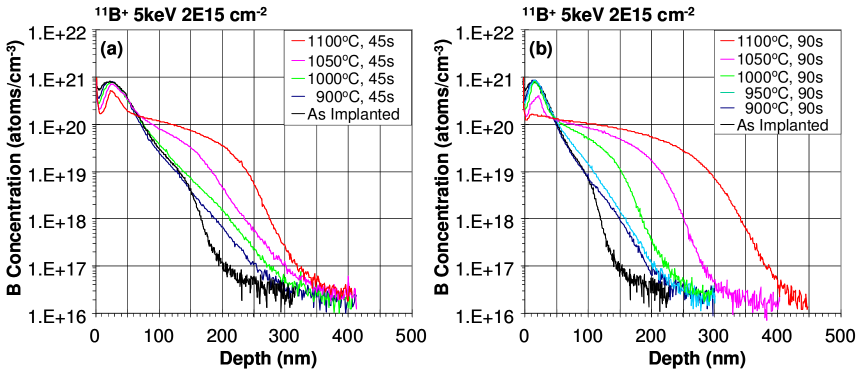

Fig. 2. RTA temperature dependence of B SIMS depth profiles for fixed residence times of 45 s (a) and 90 s (b).

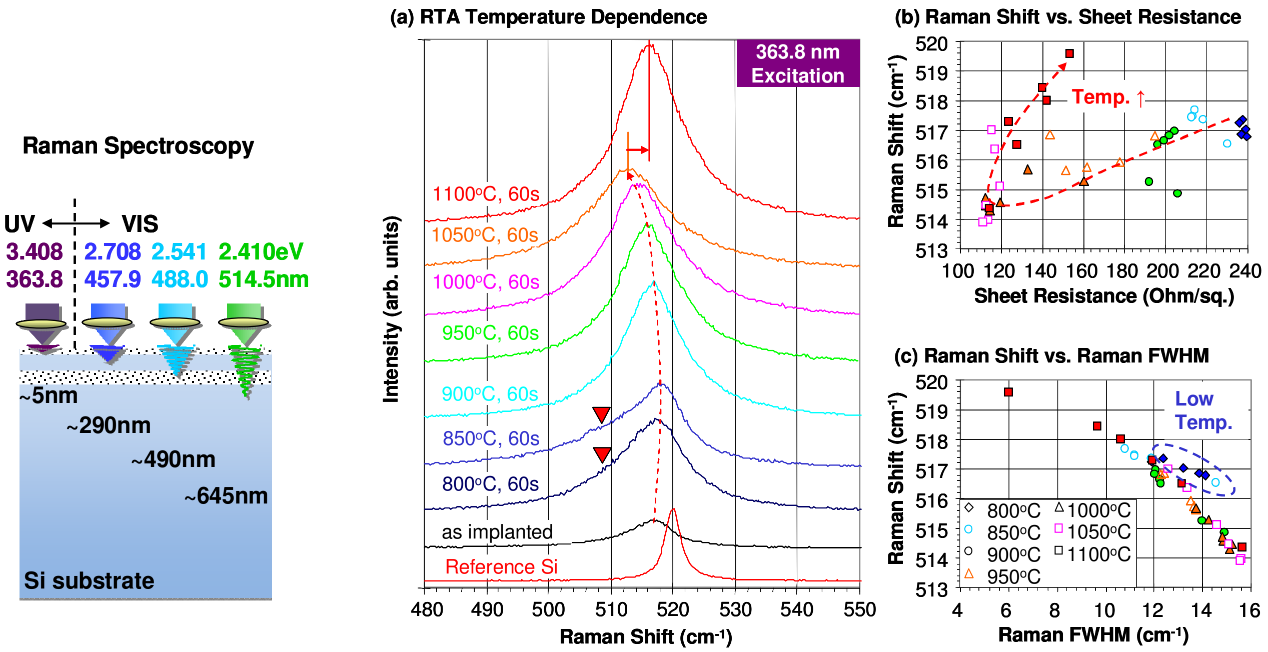

Fig. 3. (a) UV Raman spectra for 60 s annealed samples, (b) Raman shift vs. Rs and (c) Raman shift vs. Raman FWHM.

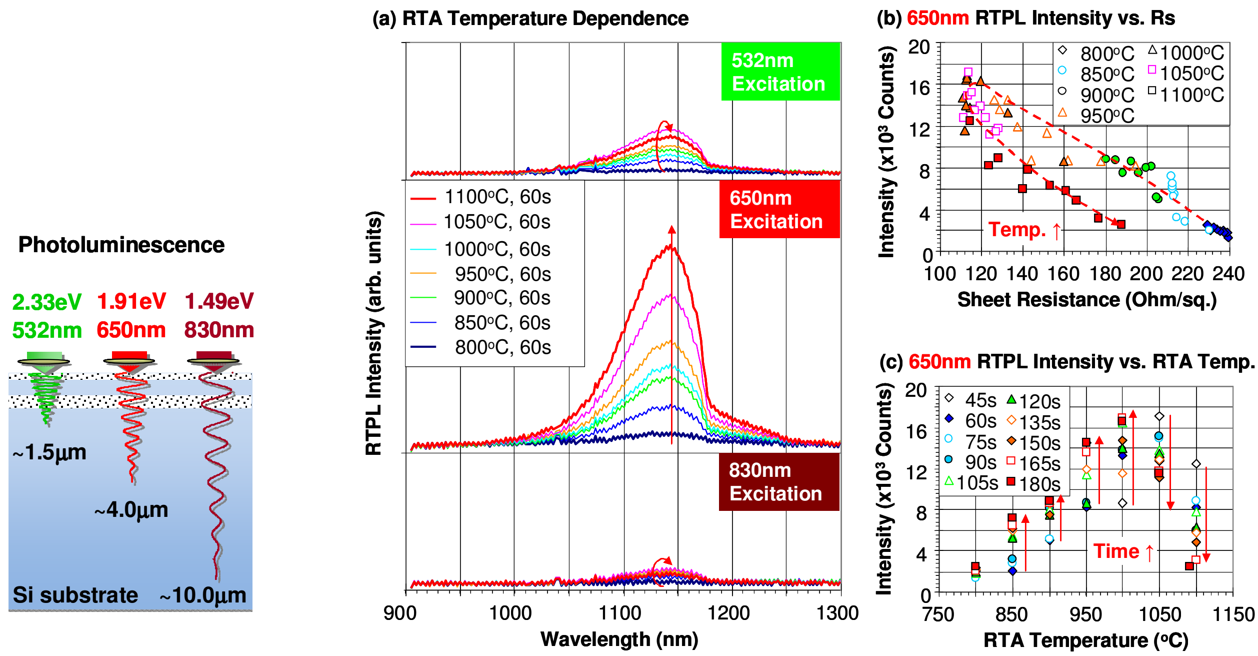

Fig. 4. (a) RTPL spectra for 60 s annealed samples, (b) RTPL intensity vs. Rs and (c) RTPL intensity vs. RTA temperature.