Improving Peak-To-Peak Wafer Non-Uniformity On High Power Implants Utilizing Axcelis IntelliScan On The Optima XEx

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Abstract. Axcelis' IntelliScan system is utilized on the Optima XEx, Single Wafer High Energy Ion Implanters to provide optimal Rs uniformity results for high beam power recipes under conditions resulting in heavy photoresist outgassing during implantation. The Optima XEx design is optimized to minimize the effect of outgassing through Axcelis's patented beamline design, larger process chamber and high pumping capacity. However, outgassing on implanters with higher beam powers can sometimes create high peak-to-peak non-uniformity. IntelliScan successfully optimizes the scan speed and continually modifies the scan waveform in order to eliminate systematic patterns. On split production lots using IntelliScan, parametric and probe data analysis demonstrated equivalent performance between modest beam power recipes not utilizing IntelliScan functionality and higher beam power recipes utilizing IntelliScan for several production recipes. This resulted in higher overall productivity. This paper introduces the principles and performance of Axcelis's new IntelliScan system.

Keywords: IntelliScan, PR cups, PR outgassing.
PACS: 61.72.U- 85.40.-e 85.40.Ry

INTRODUCTION

High energy ion implant steps are being increased for sub-30nm NAND Flash device to improve device performance so increasing equipment productivity is the one of most important issues for the NAND Flash manufacturing fabrication. Optima XEx, single wafer high energy ion implanter can produce a maximum single charge beam current of 1500uA. However, PR outgassing on implanters with higher beam powers can sometimes create high peak-to-peak non-uniformity. Axcelis has developed the IntelliScan system to perform high beam power recipes on Optima XEx.

INTELLISCAN SYSTEM

Typically the Optima XEx design is optimized to minimize the effect of PR outgassing through Axcelis' patented beamline design, larger process chamber and high pumping capacity. However, PR outgassing on implants with higher beam powers can sometimes create high peak-to-peak non-umiformity. In Figure 1. during implant on Optima XEx, the real-time beam current is measured with sampling faradays called PR cups, whose location is strategically chosen to minimize the effects from PR outgassing. The signals from the two PR cups are added together to be used for the closed loop velocity control of the horizontal and vertical wafer scan [1]. Figure 2. shows the beam path in the corrector magnet, notice that the outer trajectory in corrector magnet is slightly longer than inner trajectory.

It follows that, the longer outer trajectory loses more beam current and shorter inner trajectory loses less beam current during PR outgassing. As a result, the beam current density at the outer PR cup is lower than at the inner PR cup. This phemomenon is more prominent when the beam power is higher.This results in high dose on the left side of the wafer and low dose on the right side . Consequently, sheet resistance on the left side is lower than at the right. Due to PR outgassing, peak-to-peak wafer non-umiformity on high beam power implant is noticeably worse than low power cases.

In the horizontal direction, the IntelliScan system [2] produces a modified scan waveform with counter-tilt, where the tilt changes with process vacuum as the implant proceeds. Vertical wafer non-uniformity is related to residual error of scan velocity feedback from the PR cups current which produces a difference between the actual flux on the wafer and PR cups current. Typically the PR current is so close to actual flux on the wafer that the IntelliScan system vertical compensation is minimal. Overall, when the IntelliScan system is used, the both horizontal fast scan speed and vertical slow scan speed is simultaneously controlled by scan waveform modulation and wafer scan velocity modulation as a function of measured vacuum condition. More details of IntelliScan are shown in a companion paper [3]

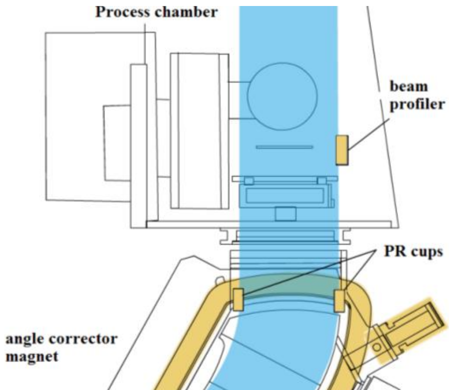

FIGURE 1. Layout of 2nd half of Optima XEx beam line.

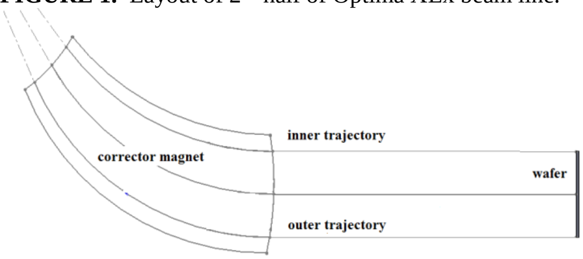

FIGURE 2. Beam path length comparison through the corrector magnet on Optima XEx beam line.

EXPERIMENTAL

For this study, all implants were performed on an Optima XEx High Energy Ion Implanter on 300mm Si wafers with a typical resistivity of 20 – 60 Ohm.cm. The test matrix is shown in TABLE 1.

- Two different Single charge Phosphorus conditions ; P^+1200keV, P^+770keV
- One Double charge Phosphorus condition ; P^{++}1800keV
- One Single charge Boron condition ; B^+1500keV

The photoresist patterned wafers had 4um thick resist with a cross-hair pattern etched away at an offset of 27° counterclockwise from the notch, allowing the bare silicon stripes of approximately 1inch to remain. When implanted at a tilt/twist angle of 7°/27°, the cross-hair pattern remained aligned vertically and horizontally referenced to gravity. Each wafer consisted of over 90% resist coverage. After implantation, the wafer processing consisted of vertical and horizontal Thermawave linescans, resist removal in an acetone wet bench, anneal with Axcelis's standard recipe of 1150°C, 30sec with 4000ppm of O_2, and then final vertical and horizontal Rs linescans. For the dose shift calculation, one bare wafer was implanted at each beam condition.

TABLE 1. Testing matrix for IntelliScan system.

Species	Energy (keV)	Dose (ions/cm2)	Current (puA)	Power (w)	Type	Iscan
P	1200	2E+13	1000	1200	Bare	OFF
			1000	1200	PR	ON
			1000	1200	PR	ON
			1000	1200	PR	OFF
P	770	2E+13	400	308	Bare	OFF
			400	308	PR	ON
			1500	1155	PR	ON
			1500	1155	PR	OFF
P++	1800	2E+13	200	360	Bare	OFF
			200	360	PR	ON
B+	1500	2E+13	1500	2250	Bare	OFF
			1500	2250	PR	OFF

RESULTS AND DISCUSSTION

Bare Wafer Study

Figure 3 and 4 shows horizontal and vertical distribution of sheet resistance of the P^+1200keV implanted silicon wafers with cross-hair pattern. As expected, in Figure 4, horizontal Rs distribution without IntelliScan system showed a sheet resistance at the left lower than at the right. The uniformity was 1.73% (1σ) due to this variation. Even though PR outgassing during higher beam power implants can sometimes create this kind of high peak-to-peak non-uniformity, the IntelliScan system successfully optimizes the scan speed and eliminates this systematic pattern. This is shown in Figure 3. where the IntelliScan system is ON. Horizontal Rs distribution with IntelliScan system ON showed that there was no significant sheet resistance variation between left and right and showed very good uniformity, less than 0.5% (1σ). In addition, the horizontal Rs trend with IntelliScan ON was nearly equivalent to that of bare wafer with IntelliScan OFF. This means that when the IntelliScan system is used, the scan waveform is modified so that scan speed is changed and as a result, the peak-to-peak wafer non-uniformity on high beam power implants is improved. Figure 4 shows the vertical distribution of sheet resistance of P^+1200keV. The IntelliScan system includes vertical compensation as well but unlike the horizontal direction, the vertical direction only needed as small compensation. The vertical Rs distribution without IntelliScan showed less variation between top and bottom, 0.65% (1σ). After applying IntelliScan the Rs variation between top and bottom showed lower variation of 0.26% (1σ). Ultimately, the vertical Rs trend with IntelliScan ON was almost equivalent to that of the bare wafer with IntelliScan OFF

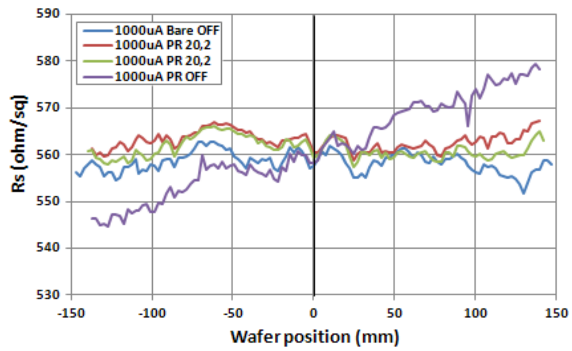

FIGURE 3. Horizontal Rs linescans of P+1200keV 2E13 ions/cm2 with and without IntelliScan system

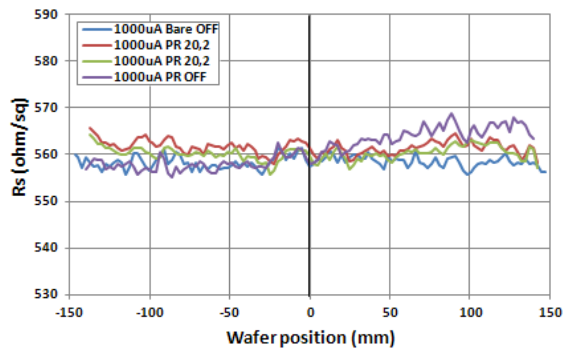

FIGURE 4. Vertical Rs linescans of P^+1200keV 2E13 ions/cm^2 with and without IntelliScan

Figures 5 and 6 show horizontal and vertical distributions of sheet resistance for the P^+770keV implant. In this case, the peak-to-peak wafer non-uniformity at P^+770keV implant is a less affected by PR outgassing compared to P^+1200keV but the left-right non-uniformity pattern is still present like before, the IntelliScan system corrects for this non-uniformity pattern.

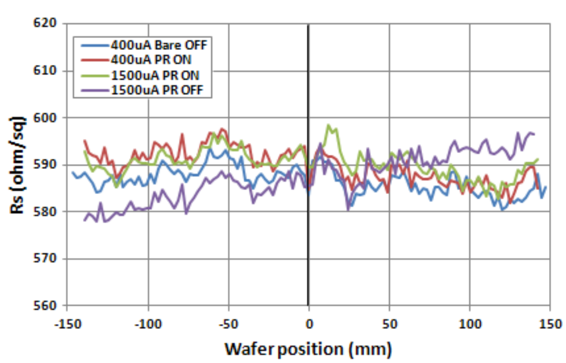

FIGURE 5. Horizontal Rs linescans of P^+770keV 2E13 ions/cm^2 with and without IntelliScan system

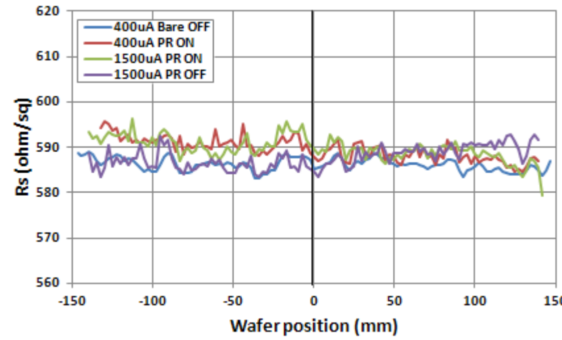

FIGURE 6. Vertical Rs linescans of P^+770keV 2E13 ions/cm^2 with and without IntelliScan

Figures 7 and 8 show horizontal and vertical distribution of sheet resistance for the P^{++}1800keV implant. Here, the horizontal Rs trend with IntelliScan ON is nearly equivalent to that of the bare wafer with IntelliScan OFF. Therefore the IntelliScan system works very well for double charge Phosphorus implant.

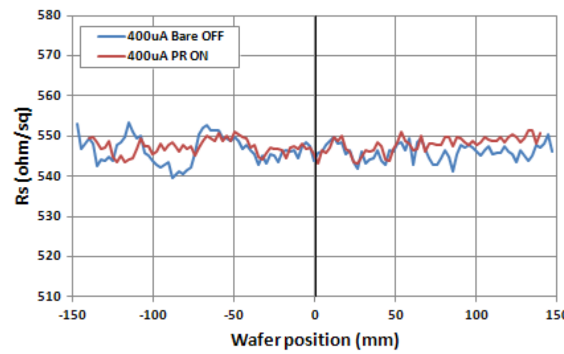

FIGURE 7. Horizontal Rs linescans of P^{++}1800keV 2E13 ions/cm^2 with and without IntelliScan

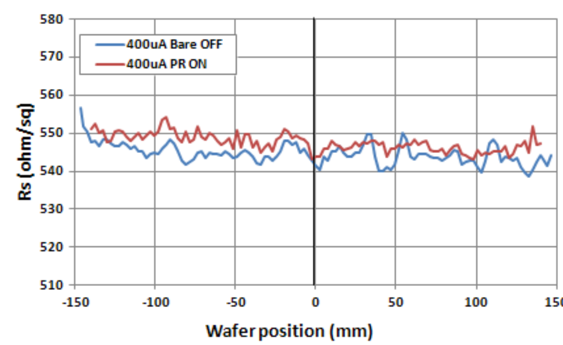

FIGURE 8. Vertical Rs linescans of P^{++}1800keV 2E13 ions/cm^2 with and without IntelliScan system

Figures 9 and 10 show horizontal and vertical distribution of sheet resistance for the B+1500keV implant. In this case, there was no significant difference between bare and PR patterned wafer results. Therefore, single boron implant with high beam power does not need the IntelliScan system to match the Rs distribution and uniformity in the horizontal and vertical directions.

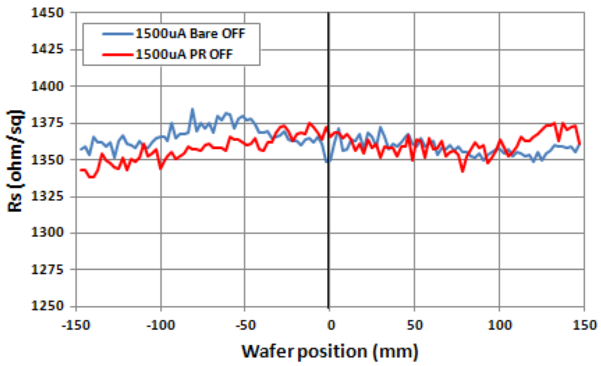

FIGURE 9. Horizontal Rs linescans of B^+1500keV 2E13 ions/cm^2 without IntelliScan system

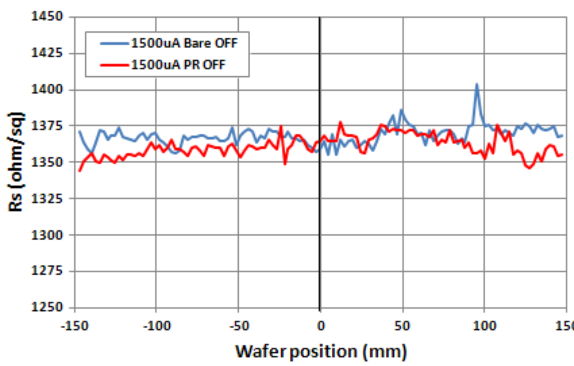

FIGURE 10. Vertical Rs linescans of B^+1500keV 2E13 ions/cm^2 without IntelliScan system

NAND Flash Device Wafer Study

Figure 11 shows left-center-right TW trend of the P^+1200keV implanted device wafer with IntelliScan ON and OFF. At 600uA beam current, there was not much left-right TW variation with IntelliScan OFF. It was about 21.9 TW units. At 1000uA a higher beam current, there was a clear overdose from PR outgassing with IntelliScan OFF. Also, TW variation across the wafer has increased to almost 48.9 TW units. With IntelliScan ON, however, left-right TW variation was much closer to the set of 600uA data, which showed 21.5 TW units. TW unit on the left-center-right also shows very similar to the 600uA TW data with IntelliScan OFF

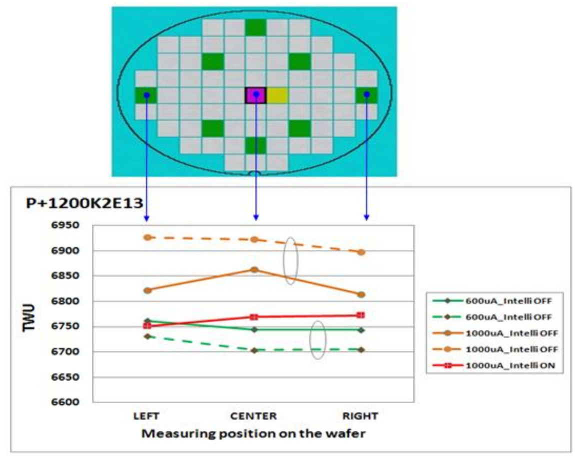

FIGURE 11. Left-Center-Right TW variation of the P^+1200keV implanted device wafer.

CONCULSIONS

To provide optimal Rs uniformity results for high beam power recipes on Optima XEx, the wafer non-uniformity effect caused by PR outgassing need to be resolved. The IntelliScan system has been developed to compensate for this wafer non-uniformity in both horizontal and vertical directions. Therefore, the Optima XEx, Single Wafer High Energy Ion Implanters can utilize the maximum beam current of 1500uA single charge. As a result, Optima XEx productivity will be increased more than 300%.

ACKNOWLEDGMENTS

The authors wish to thank Ron Lessard for running all implants at Axcelis and also thank Samsung L16 customers who have shared data with us.

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