Next Generation Medium Current Product: VIISta 900XP

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Abstract. Device fabrication requirements for 65nm and 45nm technologies further increase the demands on medium current implanters for higher process quality as well as for increased productivity and flexibility. Application space continues to grow beyond the traditional Vt adjustment implants to include other well and halo implants, creating the need for a broader energy range. Pressure for reduced CoO drives the need for higher productivity and this, in turn, drives requirements for tuning time, wafer handling speeds, beam currents and reliability that are substantially more aggressive than for older generation tools. Additionally, dose control, angle control and defect control standards have become more stringent. We discuss these requirements in more detail and describe the improvements that have been made to Varian's next generation medium current tool in order to meet them.

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INTRODUCTION

Medium current tools are used for lower dose implants, where they have high productivity and low cost per wafer, and for implants that require the high angle and dose accuracy that can be achieved with the sophisticated control capabilities designed into this type of tool. For CMOS transistor fabrication, medium current implants can be classified as either well or channel engineering (figure 1).

Loosely speaking, channel engineering is used to control the drive characteristics of the transistor and well engineering to control its isolation. For medium current tools, the three channel engineering steps are the halo, threshold voltage adjustment and super-steep retrograde implants. The three well engineering implants are for the shallow well, the deep well and the channel stop.

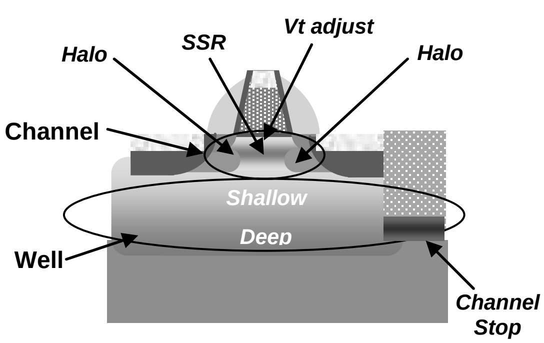

FIGURE 1. Medium current implant applications on a CMOS transistor

The dopant ions that are generally used for well and channel engineering are B, BF_2, As, P, In and Sb. The typical dose and energy requirements for these implants are shown in Table 1. Many, if not all, of these implants have precise placement requirements and need 1.5% (3σ) dose control or better, and 0.2° (3σ) angle control.

TABLE 1. Mid Current Implants

Implant	Dose Range (/cm2)	Energy Range (keV)	Tilt
Channel Eng.			
Halo	1e13-6e13	2-40	Yes
Vt	5e11-5e12	5-40	No
SSR	5e11-8e12	100-200	No
Well Eng.			No
Shallow well	8e12-3e13	100-600	No
Deep well	6e12-1e13	800-1200	No
Channel stop	5e12-1e13	80-200	No

Varian has developed the VIISta 900XP generation of medium current implanters to provide a highly productive solution for addressing a wider range of these applications. The VIISta 900XP is over 25% more productive than its predecessor, the VIISta 810XE, and has improved process capability and a wider process window. These performance improvements are discussed below, along with a brief description of the system changes.

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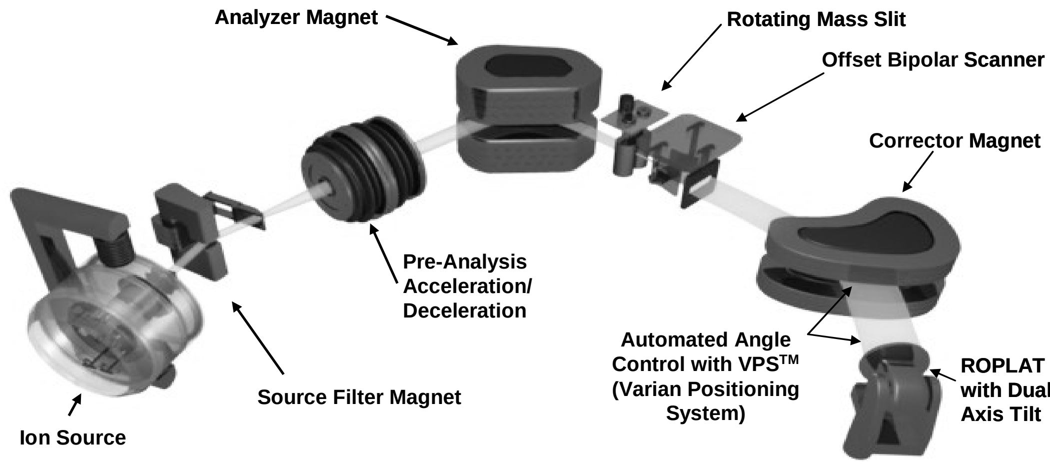

FIGURE 2. VIISta 900XP beam line

SYSTEM DESCRIPTION

The VIISta 900XP beam line is shown in figure 2. The overall architecture is similar to the original VIISta 810 [1]. Output from the source is filtered before entering the beam line to control contamination. The beam is at final energy before mass analysis to prevent any energy contamination. The dose uniformity and angle uniformity are close loop controlled to ensure precise dopant placement [2].

The changes that have been made to the system for the VIISta 900XP are: to the accel/decel column of the beam line, to increase lower energy beam currents; to the wafer handling and wafer processing systems, to increase the maximum throughput; to the operating voltage of the tool, to increase the application space; to the dose control system, to eliminate the detrimental effects of photo-resist outgassing; and to the software and hardware, to reduce beam tuning time and increase reliability. The effect of each of these improvements is described in more detail below.

PRODUCTIVITY

An implanter's productivity is controlled by the wafer handling time, the implant time, the tune time and the availability.

For most of the implants shown in Table 1, the dose and energy are such that the steady-state throughput is not limited by beam current. So, for the majority of mid-current implants, the implant time is controlled by the mechanical throughput. For the VIISta 900XP mid-current tool the maximum wafer scanning velocity has been increased, and significant improvements have been made to the timing sequence for atmospheric and vacuum wafer handling and to the vent and rough cycles. These have resulted in a maximum throughput for the tool in excess of 500WPH (figure 3a). Since its introduction, the mechanical throughput of the VIISta 810 has more than doubled (figure 3b).

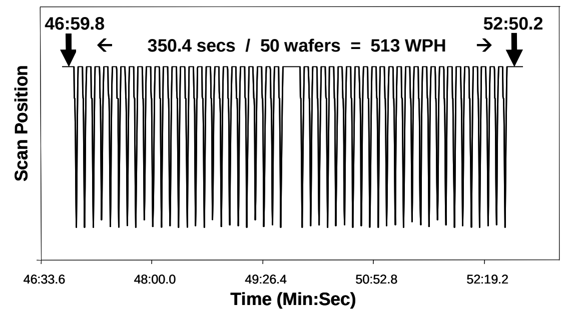

FIGURE 3a. Throughput calculated from scan position

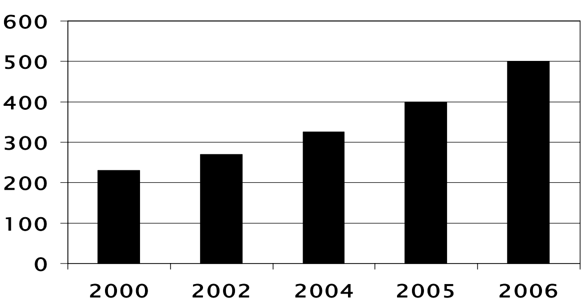

FIGURE 3b. VIISta medium current throughput increase since introduction

When throughputs are as high as they are on the VIISta 900XP, tuning time becomes a critical aspect of productivity. For example, with a steady state throughput of 500WPH, a lot of 25 wafers will be processed in 3 minutes. If the average tune time is 3 minutes then a fully utilized tool running these types of lots will spend 50% of its time tuning recipes. Significant effort has therefore been dedicated to tune

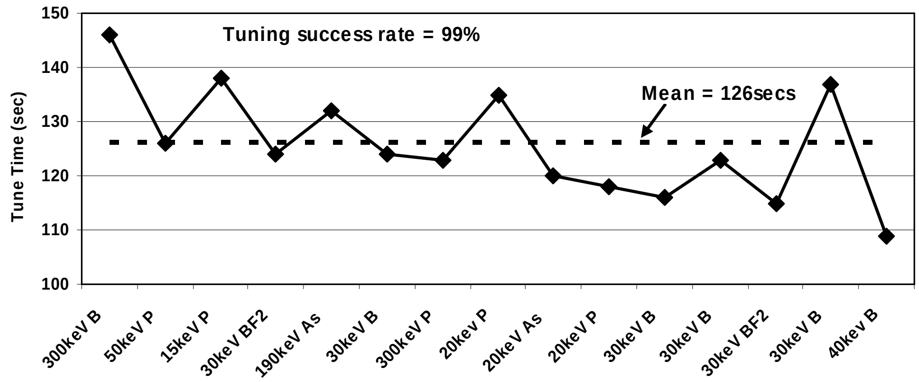

FIGURE 4. VIISta 900XP auto-tune performance for the VSEA 'standard memory and logic recipe set'. Data is from a one week marathon. Each point represents the average of many set ups. The spec tune time for this recipe set is 2.5 min.

time reduction using a 'VSEA standard memory and logic recipe set' as representative of the traditional (excluding deep well) application space. The average tune time specification for this recipe set is 2.5 minutes. The tool's performance is shown in figure 4.

For implants that are lower energy or higher dose, such as the halo implants, beam current may limit productivity. For this reason, some modifications have been made to the accel/decel column of the beam line, to substantially increase the beam currents in the low to mid energy range. These are illustrated in Figure 5. For beams at or below 40keV the spec currents have been increased by between 25% and 100%.

The final component of productivity is tool reliability. Figure 6 shows the performance of some of the over 200 VIISta medium current tools that are in production worldwide.

PROCESS CONTROL

The important components of process control for low dose applications are dose control, angle control, energy contamination control, metals contamination control and particle control. The angle control capabilities of the VIISta 810 have been discussed elsewhere [2], as have the aspects of the beam line design that ensures zero energy contamination [3].

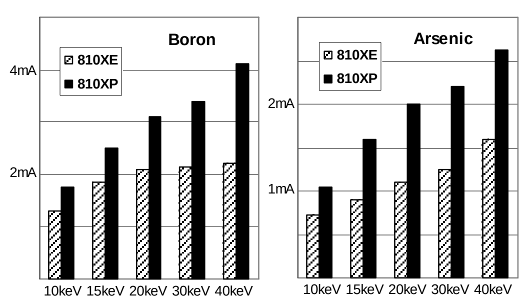

FIGURE 5. Low and mid energy beam currents. The 810XP referred to here is a VIISta 900XP without the extended terminal voltage.

This architecture, along with the simple end station design, also provides excellent control of metals and particle contamination. An example of the particle performance is shown in figure 7, which shows that

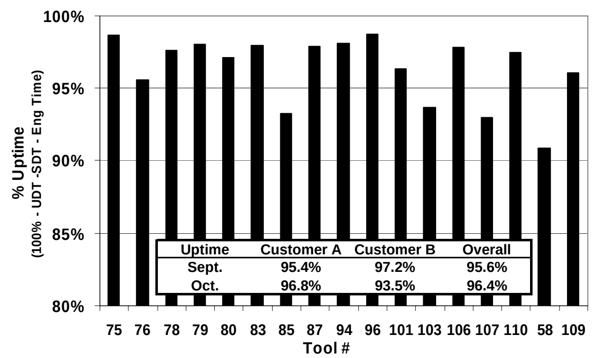

FIGURE 6. Reliability of 17 VIISta 810 implanters measured over 2 months at 2 customer sites.

the tool's performance exceeds its spec of <21 adders $\geq$0.12µm. The metal contamination of the tool is also well within its spec of 5ppm for heavy metals and 30ppm for aluminum. Moreover, a significant improvement beyond these levels has been made possible by new technologies that have been developed for the tool, such as the new plasma flood gun [4].

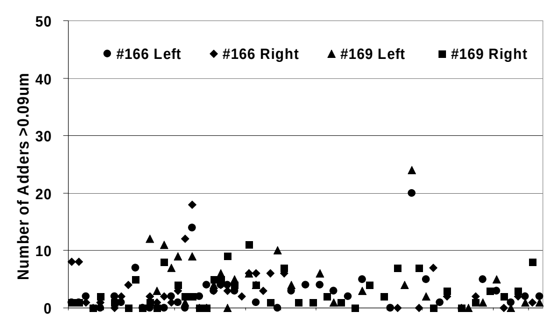

FIGURE 7. Particle adders (>0.09µm) as measured over 3 months on two VIISta 810 tools in production at a memory fab.

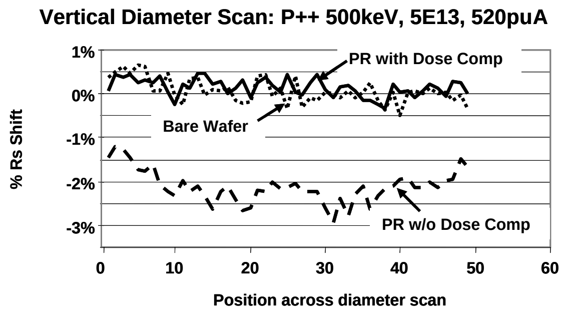

FIGURE 8. Control of photo-resist out-gassing effects. The dashed line shows that out-gassing effects can cause significant dose shift from the bare wafer results (dotted line). The VIISta 900XP's automatic dose compensation (solid line) prevents this.

The dose control system has been improved significantly for the VIISta 900XP by incorporating a patented [5] means for controlling the effects of photo-resist outgassing. This operates automatically and, unlike other schemes for dealing with neutralization, it is not based on pressure compensation. The effectiveness of the automatic dose compensation feature is illustrated by the data in figure 8.

APPLICATION RANGE

Traditional high energy tools use complex and less efficient LINAC [6] or tandem [7] technologies. These tools are much less productive than one based on DC technology with a simple high throughput end station like that used by the VIISta tools. Moreover, CMOS scaling continues to reduce the required energies of many of the low dose implants. So, in order to provide a more productive solution, the upper energy range of the VIISta 900XP has been increased to 300keV (singly charged) and 600keV (doubly charged). This extended application window allows the VIISta 900XP to perform well implants at more than double the productivity of a high energy tool and, in some cases, enables it to provide all the required low dose implants for a semiconductor fab. This benefit is illustrated in figure 9.

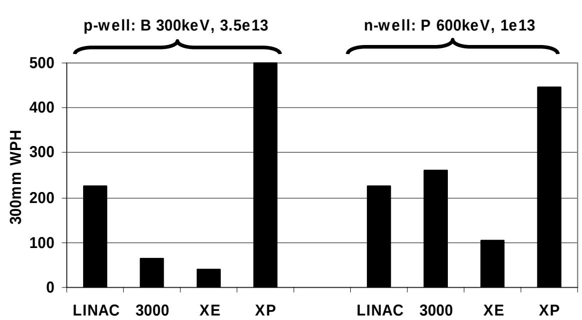

FIGURE 9. Well implant throughputs on a) LINAC with 225WPH mech. limit, b) VIISta 3000, c) VIISta 810XE which had to use B^{++} and P^{+++}, d) VIISta 900XP with 3.8mA B^{+} and 0.75pmA P^{++}

CONCLUSION

The VIISta 900XP offers a dramatic improvement in productivity for low dose implants. All of the key components for productivity have been improved significantly. Substantial improvements have also been made to the process integrity of the tool, particularly in the area of photo-resist gas load handling. The application window of the tool has also been extended by increasing its energy range.

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