Introducing Purion H, a Scanned Spot Beam High Current Ion Implanter

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***Abstract*—As a member of the Purion ion implanter family, Purion H is Axcelis' next generation high current implanter. Purion H provides customers with an unprecedented level of process flexibility and yield-enabling technology, and features the platform's four common differentiators: Purion Contamination Shield™, Purion Vector™ Dose and Angle Control System, Purion 500 wafer/hour endstation and the Eterna™ ELS source. Like Purion M and Xe, Purion H uses a hybrid scan architecture. Its scanned spot beam technology delivers precise dosage, angle and dose rate on all points of the wafer, by permitting simultaneous and independent implant uniformity and angle control. Purion H high also comprises a five-filter beamline to deliver beam purity for low variability and defects: a series of dipole magnets and a deflecting energy filter separate unwanted contaminants from the ion beam. Magnetic beam scanning permits space-charge neutralization of high beam currents, resulting in high productivity via high beam currents in combination with short tune times and a fast 500 wafer/hour end station. Other new features include a maintenance friendly, integrated source extraction system; a novel uniformity correction algorithm; a new, higher output microwave PEF powered by a solid-state amplifier for metals-free charge neutralization of high current beams; and advanced beam diagnostics to quantify average angles and spread of the scanned spot beam. Finally, the dosimetry system, which is common to the Purion M medium current implanter, extends the application space of Purion H beyond the traditional coverage of high current implanters down to doses < 2e11 /cm2, enabling new applications while maintaining productivity.**

Keywords—ion implantation systems, high current implant

I. Introduction

Purion H was designed to extend the performance envelope of existing high current implanters on two fronts: productivity and yield enhancement. High productivity is ensured by pairing the industry's fastest end station with a high current, scanned spot beam line, and high device yield by building in full control of beam characteristics and wafer processing, including full implant control, process cleanliness and flexibility. Purion H is the third member of the Purion line, after the Purion XE high energy and the Purion M medium current implanter [1].

II. The Purion Platform

All Purion implanters are serial implanters using scanned spot beams with hybrid wafer scan. The use of a common platform entails multiple advantages to the user: common modules between implanters provide greater reliability and lower cost of service, as well as easier equipment training. The Purion platform includes a common end station and wafer handling and a common control system.

A. Common End Station

The Purion end station comprises four load ports, a dual in-air wafer aligner, two atmospheric robots, quad vacuum load locks, two vacuum robots inside a high volume process chamber. With this configuration, the maximum mechanical throughput is 500 wph in single scan mode, and 340 wph in quad mode.

During implant the wafer is scanned vertically across a scanned spot beam. The scan mechanism is a SCARA robot [2] designed to provide optimum scan velocity control, reliability, and process cleanliness: all direct drive motors power a high dexterity, precision mechanism in a small package with long stroke, and all mechanisms reside inside the arm outside the process environment to prevent potential contamination problems and to extend the mechanism's maintenance time.

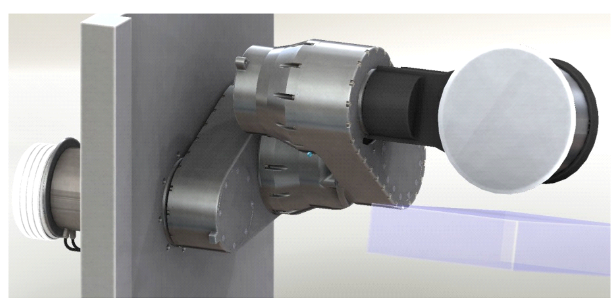

Figure 1: Purion SCARA scan mechanism, showing two in-vacuum link and the universal electrostatic chuck mounted on an arm housing a tilt motor

Axcelis' implanters use constant focal length scan, where the wafer implant plane stays constant for all tilt angles. This is deemed particularly important for low energy ion beams, where beam characteristics can change along the beam path.

Constant focal length scan ensures that all points on the wafer see the same spot beam.

The common process chamber houses beam diagnostics to control both horizontal and vertical beam angles [3].

B. Control system

Each Purion platform features fully automated implant control, comprising a set of computers connected by high-speed Ethernet: a data computer provides a graphical user interface, recipe management and data logging; a VxWorks based real time control computer provides implant and beam (Autotune) control; a PMAC system provides motion control and interfaces to dose control. The dose system uses a dedicated dose controller, capable of fast, simultaneous data acquisition of multiple channels.

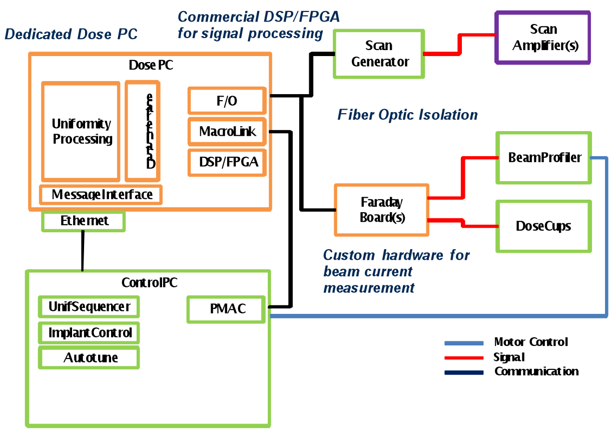

Figure 2: Block diagram of the dosimetry system, including control computers, Faraday interfaces and Faraday cups. Purion H uses magnetic scanning with a single scan amplifier; electric scanning beamlines like Purion M and Xe use two amplifiers.

All Purion implanters use scan waveform correction to reduce scanned flux non-uniformity. This correction can be applied independently of any angle correction, shortening beam tune times and increasing productivity.

PURION H BEAMLINE

No single beam line is capable of covering the vast range of doses and energies of the ion implantation application space. For high dose, low energy implantation, the Purion H beam line uses a high acceptance beam line with final deceleration to mitigate the effects of space-charge on transport [4]. The beam line can thus be divided into two parts, a higher energy transport beam line that injects beam into a decel lens, and a final energy transport part that consists of an energy filter and a final drift region.

C. Injector design

The high current injector uses an ELS ion source [5] to generate a high current ion beam subsequently mass-resolved by a 110 degree dipole for high mass-resolution (>50:1). Purion H uses a magnetic scanner to fan the mass-resolved spot beam into a divergent scanned beam; in contrast to electric scanning, magnetic scanning does not strip the spot beam of neutralizing background electrons, thereby achieving very high purveyance transport. A quad doublet shapes and focuses the spot beam after mass-resolution to the scan vertex of a magnetic scanner. The scanned beam is parallelized via an s-bend corrector, a pair of dipoles with opposing magnetic field direction achieving point-to-parallel optics and permitting simultaneous parallelism (via common magnet current) and average scanned beam angle correction (via differential magnet current tuning). The use of an s-bend corrector has more advantages: the path length through the correctors is independent of scan angle, ensuring spot beam uniformity across the scanned beam. Finally, the spot beam focusing to the scan vertex accomplishes parallelization of the spot beam angles, so that the spot beam angle spread can be tuned with the quad doublet while maintaining scanned beam parallelism.

The use of five optical elements introduces many bends with dispersion in the beam line, such that only the desired ion beam can reach the wafer. Off-mass species, higher charge-state ions and dimers, and particulate contamination therefore get filtered out in the beam line. Purion H therefore can deliver beam purity for low variability and defects.

D. Final energy transport

Deceleration from injected to final energy occurs in a single deceleration gap (see Fig. 3). Immediately following the deceleration, Purion H uses an angular energy filter (AEF) [6], custom designed for high current transport. The AEF deflects ions down such that only ions with the desired energy enter the process chamber. High energy neutrals generated upstream of the filter by charge-exchange processes, in particular, do not get deflected and get trapped in the AEF housing.

The final drift to the wafer occurs inside the process chamber, where the wafer handling components and the wafer are protected from the sputtered material and neutrals energized by collisions with the ion beam by enclosing the final drift path with a beam tunnel (Fig. 4). Inside the tunnel, a plasma electron flood (PEF) provides additional space-charge neutralization to aid low energy beam transport. The PEF is a 3.8 GHz solid-state amplifier driven electron-cyclotron resonance driven microwave discharge PEF, operating at higher frequency than the conventional 2.45 GHz [7] to enable higher PEF densities. These are necessary to promote beam transport at energies as low as 200 eV and to neutralize wafer charging at currents higher than 30 mA.

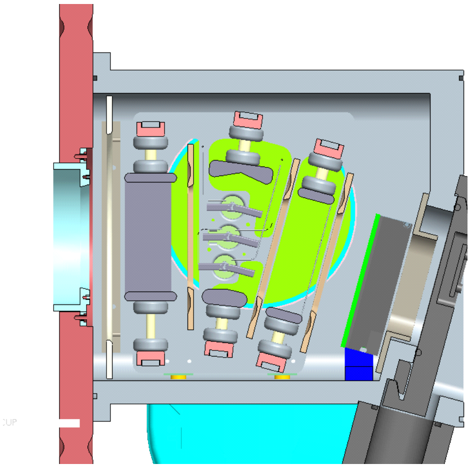

Figure 3: Angular Energy Filter (AEF). From left to right, the optical train comprises: terminal electrode – terminal suppression – decel gap – deflection electrodes – ground suppression. Also shown is a gate valve to isolate the beam line vacuum from the process chamber.

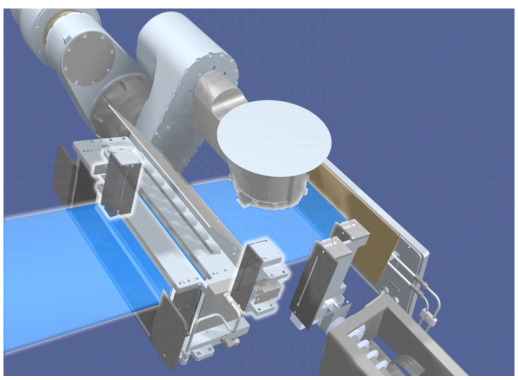

Figure 4: Rendered view of the beam tunnel inside the process chamber. The scanned spot beam is shown in blue, and the microwave PEF is under the beam in close proximity to the wafer plane.

III. PROCESS RESULTS

Like any qualified implanter, Purion H has to deliver simultaneous compliance to specifications of productivity, process control, and reliability. We will here highlight two performances related to process control that we deem exceptional for high current implanters.

A. Energy contamination

The use of an AEF enables energy contamination free ion implantation at relatively high deceleration ratios, defined as the ratio of injected to final energy. To illustrate this performance, Fig. 5 shows SIMS profiles of two high current implants: a reference drift implant (no deceleration) on Axcelis' Optima HDx, and a 10:1 decel ratio implant on Purion H. Both implants are performed at high spot beam currents (14 mA), with adequate PEF settings to ensure wafer charge neutralization. The implants were performed into dual pre-amorphized Silicon wafers using two different energy Ge implants. As can be seen, excellent agreement between the profiles is obtained, with possible energy contamination on Purion H close to the detection levels on present SIMS capability.

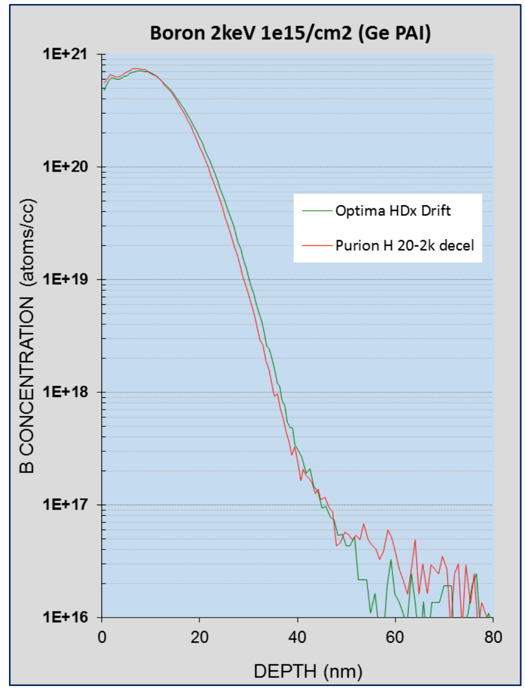

Figure 5: Comparison of SIMS profiles of a reference drift and 10:1 decel implant on Purion H. No energy contamination can be seen on a high-decel Purion H implant at present detection levels of low energy SIMS.

B. Low energy-low dose

Purion H's advanced dosimetry system permits complete setup and closed-loop controlled implant. Since the dosimetry system is shared between all Purion implanters, Purion H has the dynamic range of beam current measurement of Purion M's and Xe's, and can measure and control beam currents in the microampere range. This enables low dose implantation capability at low energies, previously not possible on high current implanters. As examples, we show two wafer maps of relatively low dose implants on Purion H: a ^{11}B 6 keV 5e13/cm^2 sheet resistance R_s map, and a ^{11}B 5 keV 2e11/cm^2 Thermawave TW maps. The reason for two maps lies in the limitations of implant mapping capability, where sub-e13 R_s maps are every insensitive to dopant distribution, whereas TW maps at high doses, low energy are insensitive [8]. The two snapshots of low dose implant together demonstrate the new capability of Purion, extending the implant application space, as illustrated in Fig. 7.

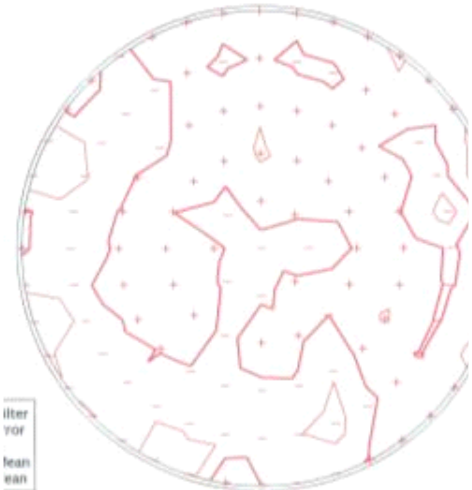

Figure 6: B 6 keV 5e13/cm2, 1255 Ohm/sq, 0.35% 1σ

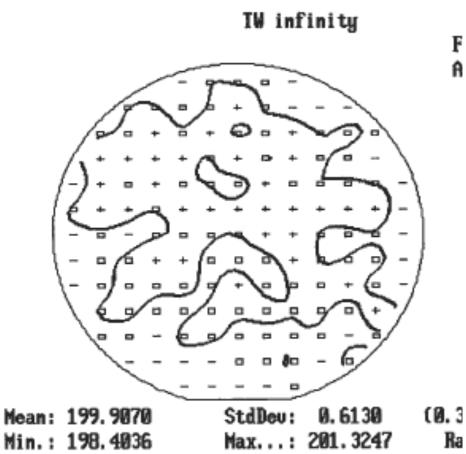

Figure 7: B 5 keV 30 uA unscanned, 2e11/cm2, 0.31% 1σ , 200 TW units

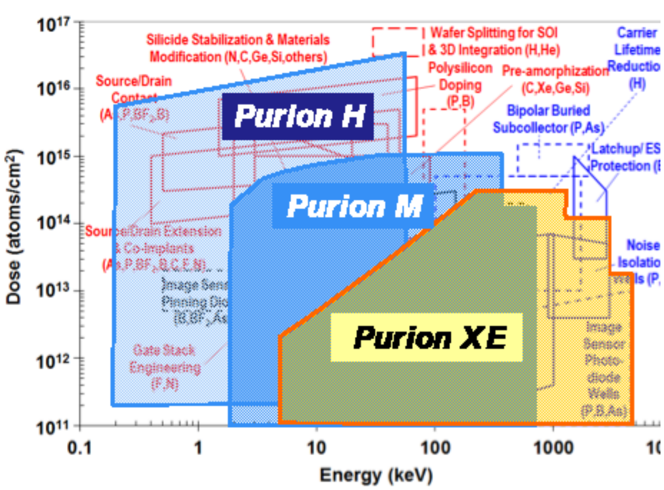

Figure 8: Application space of the Purion platform. Purion H extends the space to low dose, low energy.

SUMMARY

Purion H is Axcelis' next generation ion implanter, combining high productivity and yield enabling technology. Commonality of control system, wafer handling and dosimetry enables an extension of the application space beyond the traditional coverage of high current implanters down to doses < 2e11 /cm^2. While maintaining productivity, this could prove enabling technology for new applications.

ACKNOWLEDGMENT

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