"A SYSTEM AND APPLICATIONS OVERVIEW OF THE EXTRION 220 MEDIUM CURRENT ION IMPLANTER"

Presented by: Peter van der Meulen
Varian Ion Implant Systems
123 Brimbal Avenue
Beverly, MA 01915 U.S.A.

ABSTRACT

The present paper gives an overview of possible process applications of the parallel beam scan system of the Extrion 220 Medium Current Ion Implanter. The design and measurement of the parallel beam scan mechanism is described. It is shown that even small errors in parallelism can result in non-uniformities of sheet resistances at high tilt angle implants. Uniform channeling of Boron and Phosphorus ions across 150mm wafers will be discussed. The possible formation of a P- or N- well by a single channeling ion implantation is discussed. Energy contamination of doubly charged Phosphorus beams has been studied. Levels of contamination have been measured before and after implantation. A method of measuring energy contamination levels will be presented.

Results of the particle control program will be discussed and particle generation mechanisms will be identified. The design of the load lock vacuum chambers will be discussed in terms of particle reduction.

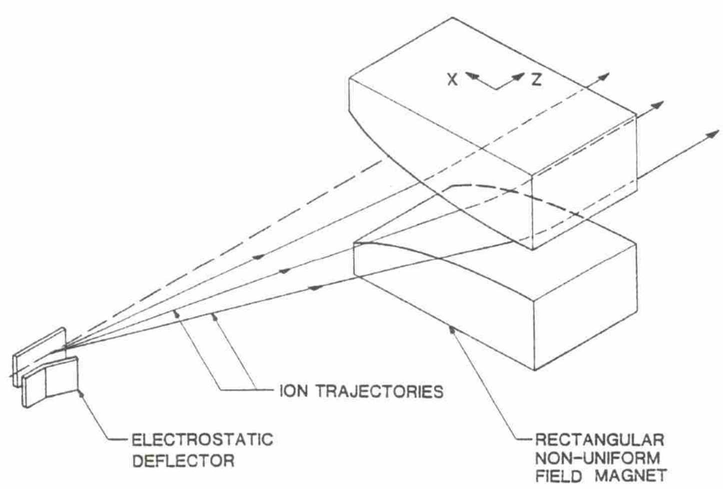

Fig. 1. Schematic of the Extrion 220 parallel beam scanning.

1. The Extrion 220 Parallel Scan Mechanism

Beam scanning in the Extrion 220 is achieved by the combined action of an electrostatic deflector and a rectangular dipole magnet [1]. The field of the magnet varies in such a way as to convert the angular electrostatic scan into a one dimensional parallel scan. In this paper, a short presentation of the design of this scan system is given. More detailed discussions can be found in references [1] and [2].

Figure 1 shows the geometric layout of the magnet and electrostatic deflector. The variable pole gap of the magnet allow for a precisely calibrated magnetic field that varies in strength with the deflection angle α of the beam:

$$B(x) \div \alpha$$

The beam that leaves the magnet will be parallel to the z axis in figure 1, regardless of x. The field over which the beam is parallel has to be at least 200mm wide. An accurate method of determining beam parallelism is illustrated in figure 2: two plates containing patterns of identical slits are installed a fixed distance apart in the Extrion 220 end station. The second plate can be moved using a micrometer screw. The beam is steered sequentially through each of the slits in the first plate. The distance that the second plate has to move in order to obtain maximum beam current on the Faraday plate is a measure of the deviation of the beam from parallel. It is found that the deviation on the Extrion 220 is typically between 0.2° and 0.3°, depending on species and energy (figure 3).

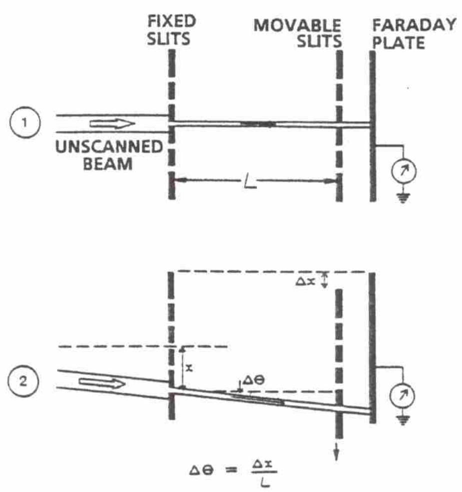

Fig. 2. Method used to measure deviation from parallelism.

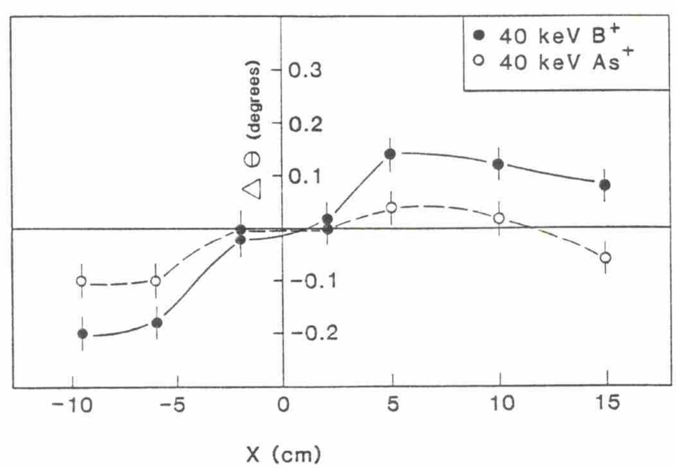

Fig. 3. Deviations from parallelism for 40keV B+ and As+.

Deviations from parallelism will result in non-uniformities of the implanted layer. One way of demonstrating such non-uniformities is to look at high tilt angle implants (60^{o}). This type of implant can be done quite easily on the Extrion 220, since the design of the implant head assembly allows for implantation at any tilt angle [3]. Non parallelism of the beam will result in a small but measurable degradation of implant uniformity [4]. In figure 4 the implant uniformity as a function of tilt angle is displayed for a prototype magnet and for a standard production magnet. It can be seen that at very high tilt angle, the prototype magnet caused slightly worse uniformities than a production magnet.

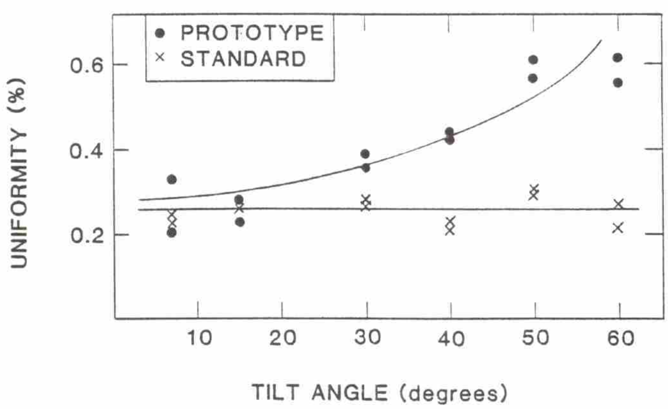

Fig. 4. Implant uniformity as a function of tilt angle.

2. Channeled Implants in Silicon

The parallel scan system of the E220 allows for deliberately channeled implants across wafers up to 200mm while maintaining a very high degree of uniformity. Channeled implants offer several advantages over conventional implants [5]. When the ion beam is aligned along one of the major axes of a crystal, less damage is caused and the penetration depth of the ions is considerably larger. However, applying the channeling technique requires a high degree of angle control which has prevented the use of channeling implantation in conventional ion implanters. In figure 5 [6], we have shown SIMS profiles for a random and a channeled B^+ implant at 200keV and 2E15 ions/cm^2 into a Si (100) 6-inch wafer. The three channeled doping profiles shown were measured at three different spots along a line parallel to the horizontal electrostatic scan. One spot was in the center, while the other two spots were at opposite sides of the wafer.

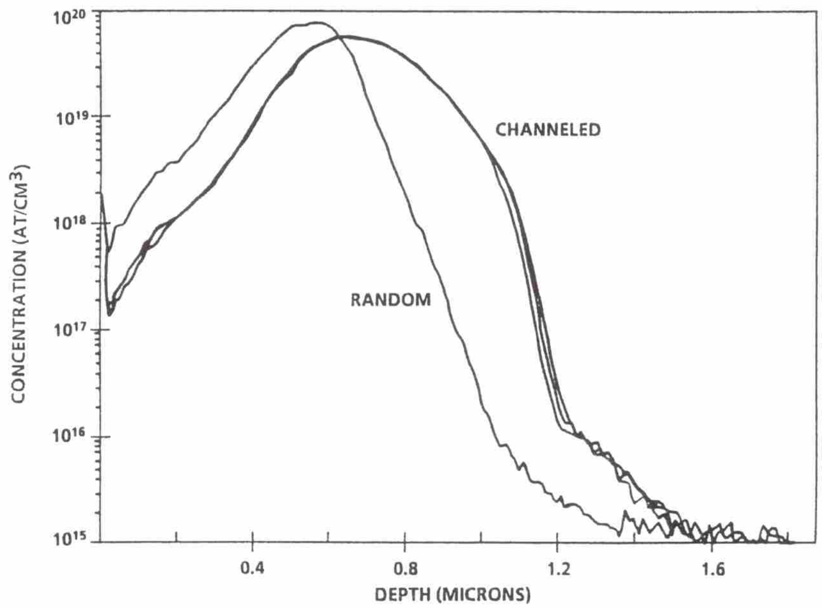

Fig. 5. Random vs. channeled implants for 200keV B+, 2E15.

The maximum penetration depth of the channeling implantations was R_{max} = 1.22 um based on a modified Firsov theory [7]. The critical angle for channeling of 200keV B+ is 2^{o}. Earlier work [8] has shown that a variation of 1^{o} has a significant influence on the resulting depth profile. Since there is no difference observed between the three Boron profiles at the three spots, this means that well channeled conditions were maintained across the wafer. The decrease in B concentration at the maximum penetration depth is roughly 23(2) decades/um. This, along with the proven uniformity and depth of the implant could allow for P- or N- well by a single channeling ion implantation. The uniformity has also been checked for various species, implantation energies and doses using sheet resistance and RBS measurements [9, 10].

3. Energy Contamination

Doubly charged ion beams are utilized to extend the energy range of ion implanters. One potential disadvantage of doubly charged beams is energy contamination, which is caused by interaction of the extracted ions with residual gas molecules [11, 12]. Energy contamination results in changes in uniformity, implant depth and dosimetry.

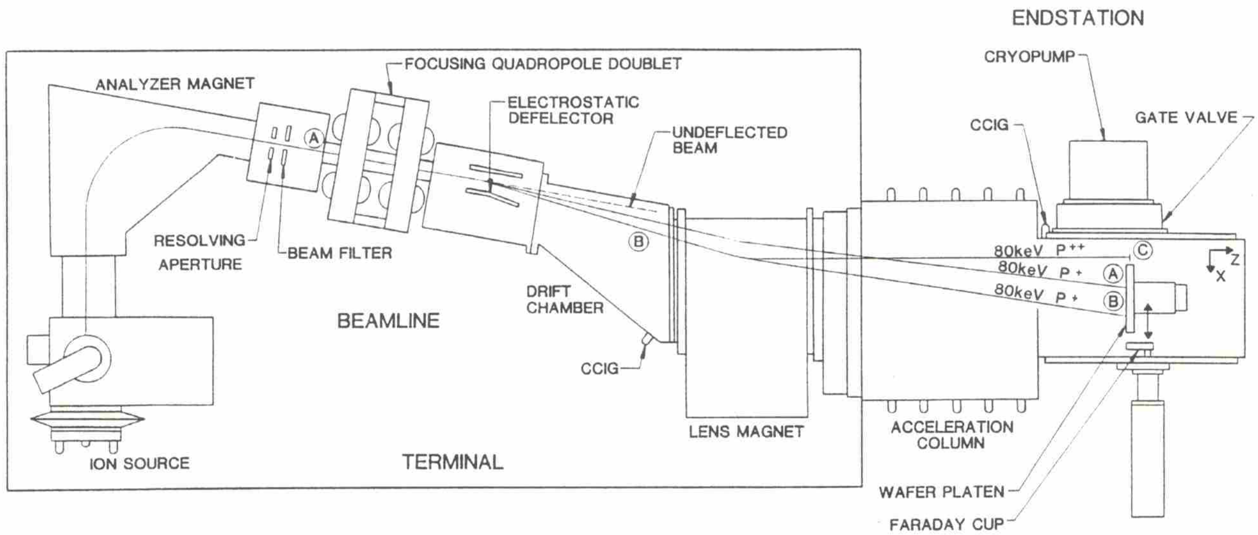

Fig. 6. Energy contamination is generated in regions A, B. and C.

A technique to measure energy contamination prior to implanting has been developed on the Extrion 220. In figure 6 we have shown where the main contribution to energy contamination arises. Region A, between the beam filter and the electrostatic scanner, contributes to a contaminant beam A in the end station. Region B, between the electrostatic scanner and the lens magnet, contributes to beam B. Region C (the acceleration column) only contributes a small amount because of the low system pressure in that area and the reduced cross-section for charge exchange for the accelerated ions. Energy contamination generated in that region remains hidden in the main beam.

Using a travelling Faraday cup, one can measure the current in the main beam and in beams B and C (fig. 7). This measurement gives the relative amount of energy contamination with the following formula:

$$EC = \frac{I^{+}}{(I^{++} - I^{+})/2} \cdot 100\%$$

This measurement has been used to monitor the effect of energy contamination on sheet resistance maps (Fig. 8) and SIMS profiles (Fig. 9 and ref. [12]).

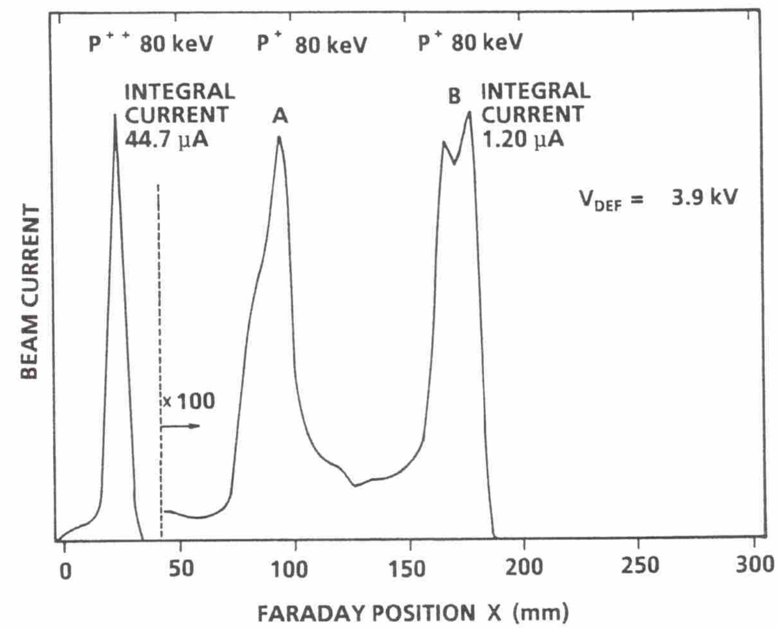

Fig. 7. Contaminant beam current measured.

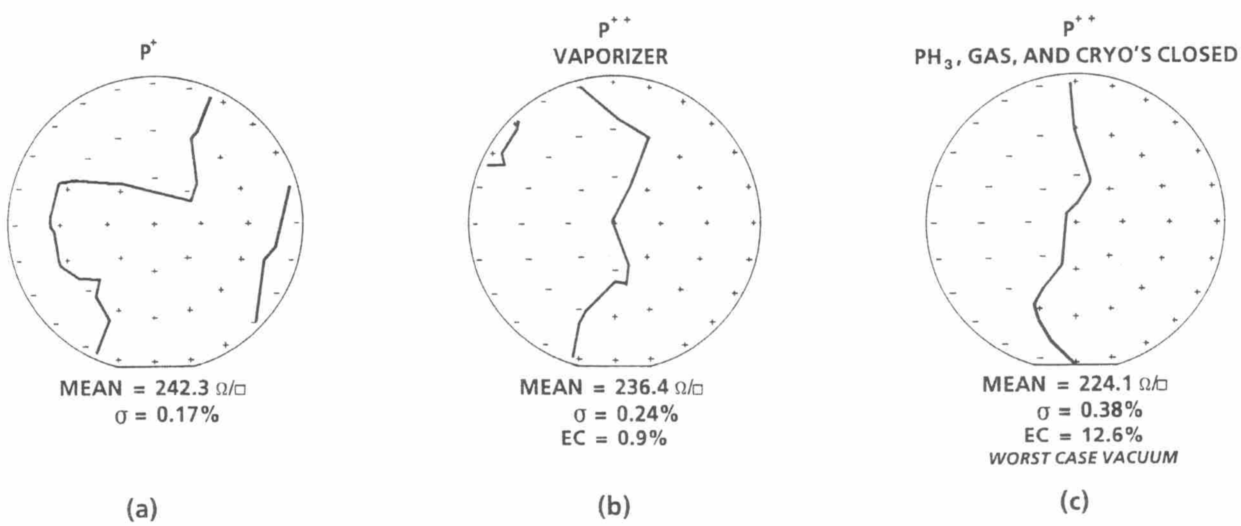

Fig. 8. Sheet resistance as a function of Energy Contamination.

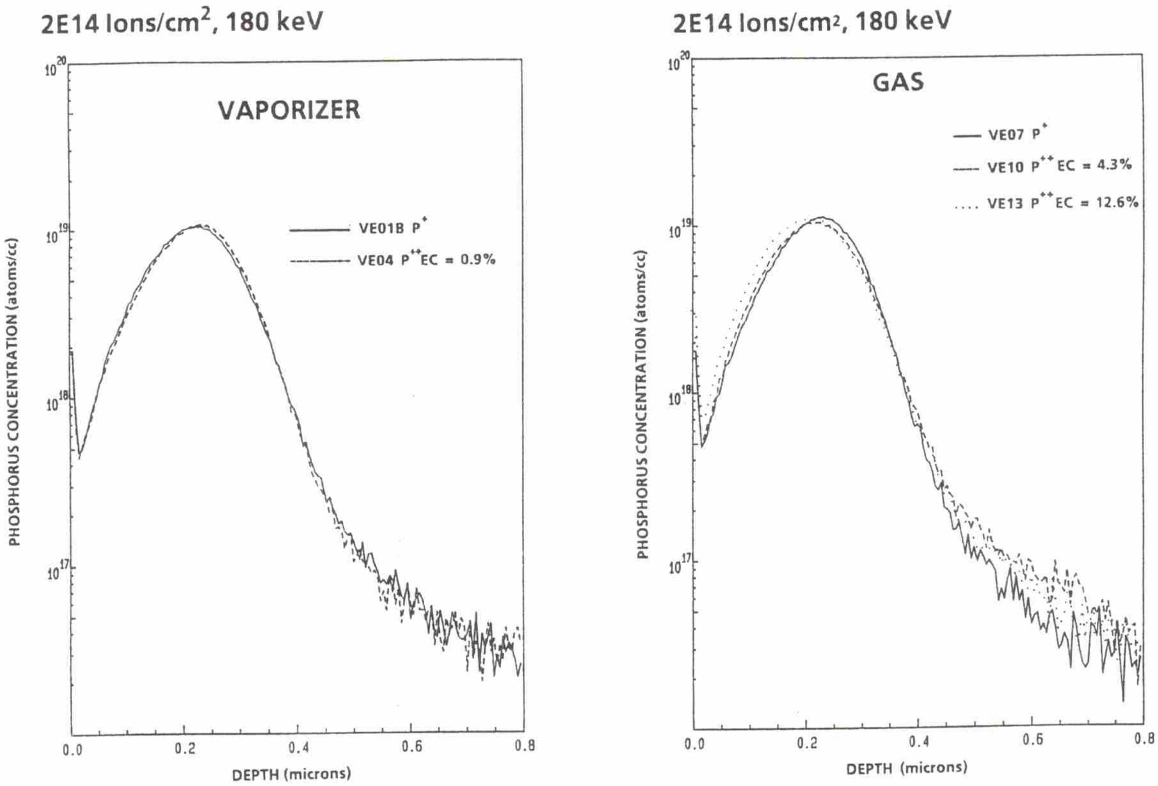

Fig. 9. Energy contamination and SIMS depth profiles.

4. Particle Control

Extensive engineering effort has gone into the reduction of particle contamination in conventional medium current ion implanters where wafer handling is performed in atmosphere and each wafer was individually pumped and vented [13]. The Extrion 220 was designed with high vacuum wafer handling techniques [14]. The philosophy is summarized below:

1. Two cassettes (50 wafers) will be pumped and vented as a batch.

2. All handling of wafers will be in high vacuum.

3. Handling will be by backside pick and place methods.

4. All handling mechanisms and moving parts stay below the wafer plane.

5. Handler and process chambers remain in high vacuum during normal operation.

It was found that in the Extrion 220 configuration, the largest contribution to particles added comes from the vent cycle of the load lock chambers. Substantial improvements were obtained after installing a point of use filter and polished baffle (Fig. 10). In figure 11, particulate measurements on 200mm wafers at 0.3 um particle site are presented. The average number of particles added during a four-day experiment was 4.6 (0.016 particles per cm^2). This is well below the Extrion 220 specification of 0.05 particles added per cm^2 at 0.3 um.

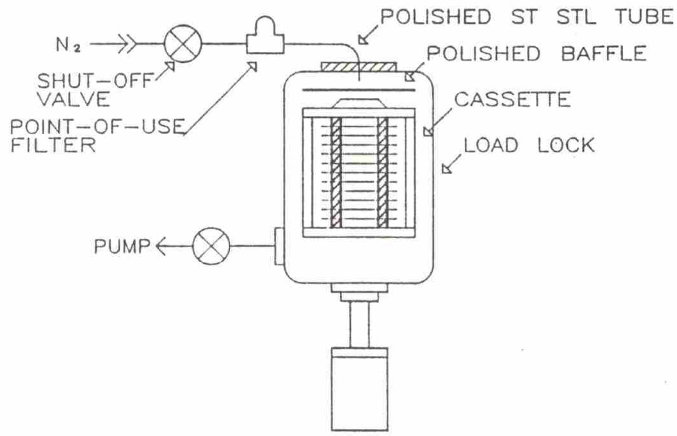

Fig. 10. Particle reduction in the Extrion 220 load lock chamber.

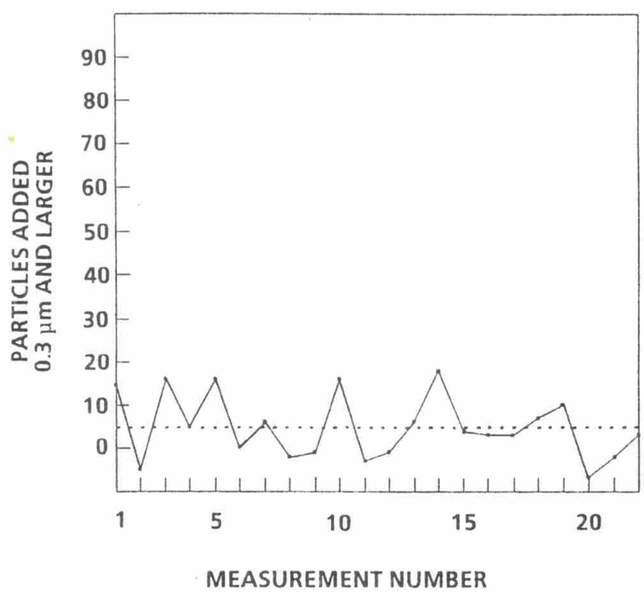

Fig. 11. Particulates added on 200mm wafers in production environment.

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