Review of Major Innovations in Beam Line Design

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***Abstract*—Since the beginnings of ion implantation in 1970, the beam lines used in ion implanter machines have undergone a long history of innovation and development not only for commercial manufacture of semiconductor diodes, transistors, ultra- large scale integrated circuits, and SiO2 insulating layers, but also in more recent years for making high resolution displays using thin film transistor (LCD/TFT) or active matrix organic light emitting diode (AMOLED) techniques. Also, high current proton implantation beam lines have been developed for induced exfoliation to make solar cell and other types of membranes. As wafer size has increased to 300 mm, dose range to 108 and energy range to 104, major innovations have been made in beam lines to meet these needs as well as achieving: high implant uniformity over the entire wafer surface; improved ion specie and ion energy purity; lower and lower particulate counts; small angular range of ion trajectories impinging on the wafer especially in medium current machines; high wafer throughput especially at very low energies; and the transition from high current and high energy batch implanters to serial implanters. Beam lines designed to transport and mass analyze uniform flood beams to implant large TFT and AMOLED display panels are also described.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

A precision ion implanter has three major, functionally quite different, subsystems - namely:

- *An Ion Source*
- *A Beam Line*
- *A Process Chamber*

In the most general sense the role of the *Beam Line* is to precondition and transport ions extracted from the *Ion Source* to uniformly irradiate substrates in the *Process Chamber.* A primary function of the beam line is to form the ions into a beam that has a high degree of purity in regards to the ion mass, energy and species. Generally this is implemented by filtering the ions through at least a bending magnet. The beam line may also have additional ion optical focusing elements such as quadrupoles, scanners or a collimator system in order to provide a uniform irradiance over the entire substrate surface. In addition, depending on the ion energy regime required of the implanter, there may also be a means of accelerating or decelerating the ions to higher or lower energy relative to the extraction energy from the ion source.

II. Historical Perspective

The first publication of the concept of using ion bombardment to dope semiconductors and dramatically change their electrical properties dates back to work at Bell Laboratories by Ohl in 1952 [1] and Shockley in 1954 [2]. However, it was not until the 1960's that ion beams were used to investigate semiconductor implantation. This work generally occurred in atomic and nuclear research laboratories at universities, institutes and corporate research entities. Perhaps most notable is the work performed at the UK Atomic Energy Research at Harwell, England. Here, Dearnaley [3] used an isotope separator and an ion source developed by Freeman [4] for generating and irradiating substrates with boron and phosphorus, the two main elements required for n-type and p-type doping of crystalline semiconductor silicon.

Around 1970, Lintott Engineering Limited, a Harwell spinout, and Accelerators Inc. in Austin Texas, formed by people from Picker Nuclear, delivered production type semiconductor ion implanters. However, these machines did not have an immediate impact on commercial semiconductor manufacturing because, as aptly pointed out by Mckenna [5] in his review article, ion implanter tools were at the time thought of as an unjustifiable additional cost because the furnaces used for doping were still required for annealing. Also, the ion implanters by nature were complicated. Furthermore, they were hazardous in a number of respects, including the use of high dc voltages, X radiation, rapidly moving mechanical parts, and vacuum locks. They most certainly had the appearance of something birthed from a low energy nuclear physics accelerator laboratory circa 1960. Generally, this was did not encourage easy adoption by commercial semiconductor enterprises.

The situation changed very quickly when Peter Rose and his associates founded Extrion Corporation in 1971 and developed what is regarded as the first really successful commercial ion implanter - the Extrion 200-20A (also there was a 150-20 model). The 200-20A was a purpose built, commercial medium current implanter. A Penning ion source produced an analyzed, scanned beam of few μA of dopant ions at energies up to 200 keV. Electrostatic X and Y scanners in the beam line provided a uniform dose over wafers up to 3.25 inch dia. The X scanner also provided a dc offset of 7° in order to prevent neutralized ions from reaching the wafer. The 200-20A was a precision machine with an entirely acceptable commercial appearance. The complex ion source system, beam line elements and process chamber were surrounded by modern looking box-like structure made out of hinged and folding doors for maintenance access. As needed, the doors were lined with lead for X-ray shielding. With out a doubt, this was the precursor to present day medium current implanters, of which one example is shown in Fig. 1.

Fig. 1. A Nissin Ion EXCEED, modern, medium current ion implanter.

The extra precision and versatility that could be achieved with these new ion implanters, compared with doping via thermal diffusion, quickly justified the added value for commercial semiconductor manufacture. In conjunction with the advances made in optical lithography and MOS development, ion implanters have had a profound effect in the world, leading to major advances, not only in computers, but also in medical science, communications, transportation, defense, agriculture and education. Driven by Moore's Law, these advances relentlessly continue today, as never previously perceived, even in the best of science fiction.

By 1975 Extrion Corporation had been acquired by Varian and also a number of other companies offering commercial ion implanters had emerged as extensively reviewed in various articles [5], [6], and [7].

In 1975, the Varian/Extrion Division offered two essentially different machines in order to address the different beam heating regimes associated with increased throughput that customers were requesting. The model 200-20AF was similar to the 200-20A except the throughput was increased by using a Freeman rather than a Penning ion source which generated up to 400 μA of scanned beam and implanting only one wafer at a time. By contrast, the model 200-1000 produced much higher beam currents, up to 1 mA of B^+ and 3 mA of P^+ and As^+. In order to disperse the beam power over a large effective area, Up to 26 wafers of 3 to 4 inch diameter were mounted on a rotating Ferris wheel and batch implanted. The peripheral motion and mechanical back and forth axial motion of the Ferris wheel substituted for and eliminate the need of beam line Y and X scanners.

As advances were made in ion sources and process chambers to meet the commercial needs of higher dose and higher dose rates, as well as larger area substrates and more exacting implant characteristics, the beam lines themselves accordingly evolved via a number of different innovations depending on the dose versus ion energy regime being addressed by the particular implanter model. Interestingly enough, the merits of batch versus serial (one wafer at a time) carried on being debated for many years. Finally, aside from batch machines still needed for very high dose exfoliation applications and making buried SiO_2 layers, customer requirements and insistence resulted in serial implanters prevailing over batch implanters. Needless to say, this was only made possible because of corresponding significant advances made in all of the three ion implanter subsystems - namely:

- More efficient substrate cooling in the process chamber.
- Improved scanning techniques in the beam line.
- Improved mechanical scanning techniques in the process chamber.
- Beam line designs that could successfully form and transport to the process chamber, uniform flood beams originating from long aperture and various other types of ion sources.

III. Beam Line Innovations

Up until 1975 the techniques used in the beam lines were conventional and derived somewhat directly from those used in atomic and nuclear research laboratories. Thereafter, following widespread commercial acceptance and feedback, beam lines evolved in a number of different ways discussed below, in more or less in chronological sequence, but limited to commercially successful deliveries of fifty or more machines.

A. NV10-80

In 1978 Peter Rose and associates, whom had now departed from Varian/Extrion, formed a new company, Nova Associates, located in Beverly, Massachusetts. Their aim was to develop a high current (10 mA) batch ion implanter for pre-deposition. By 1982 sixty of these machines had been delivered [8]. The wafers (3 inch, 100 mm, 125 mm, and 160 mm) were mounted on a reciprocating spinning disc to provide X and Y scanning and a dose uniformity of 0.5% (1σ). The initial energy specification was 60 keV but soon was increased to 80 keV in the model NV10-80 and to 160 keV in the model NV10-160 by inserting a post accelerator after the resolving slits of the analyzer magnet. A Freeman type ion source was initially used and later replaced by a longer life Bernas [9] source.

High beam currents at the wafer were achieved because an unusually short beam path distance between source and wafer (see Fig. 2) resulted in nearly 100% beam transmission. However, such a short path length required a much more innovative analyzer magnet with an indexed field to provide much stronger ion optical focusing than hitherto used in ion implanters. Magnets with indexed poles already had widespread use in alternating gradient synchrotrons and their underlying theoretical principles were well understood and thoroughly documented by Enge [10] and Brown [11].

The analyzer magnet settled on for the NV10 implanters is shown schematically in Fig. 3. The pole gap dimension varies across the width of the gap in such away that if the field at the nominal bending radius R_0 is B_0 then at another radius $R = R_0 + r$ it is given to 2^{nd} order by the equation:

$$B(r) = B_0(1 - n\frac{r}{R_0} + \varepsilon r^2) \quad (1)$$

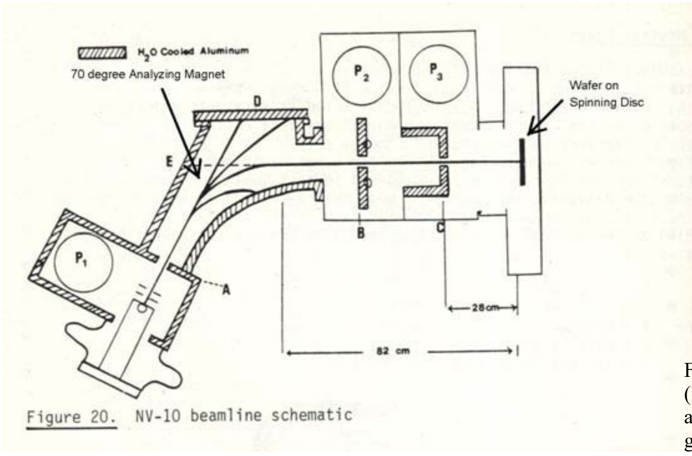

Fig. 2. NV10 beam line schematic.

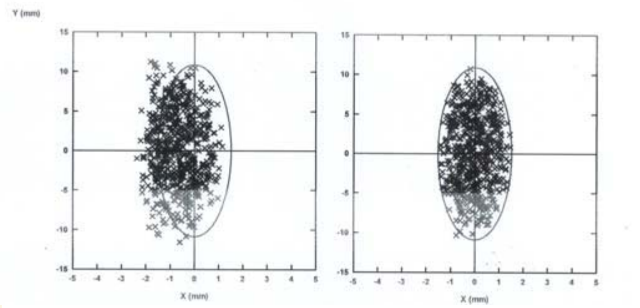

Fig. 4. The NV10 Beam emittance at the resolving slit with (right) and without (left) second order aberration corrections. The pole edge concave curvature at the entrance and exit, in conjunction with the second order term in the gap field, eliminates curvature in the image at the resolving slit and enables a mass resolution of 60-70 to be realized.

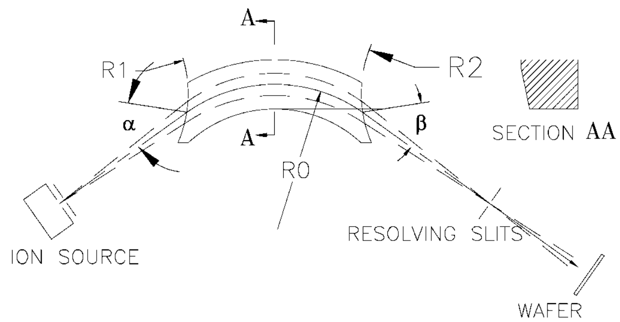

Fig. 3. Schematic of the NV10-80 analyzer magnet pole

In the particular design of the NV10 analyzer magnet, the bending angle is 70°, the CRT radius $R_0 = 500$ mm and the field index coefficient n has a value of approximately -1.34. This negative index value greatly enhances the transverse ion optical focusing power in the magnet dispersive plane (i.e. the plain of the paper in Fig. 3). Entrance and exit pole edge rotations α and β of approximately 48° produced sufficient vertical focusing to compensate for the vertical defocusing arising from the negative field index. In summary, this new analyzer design, shortened the beam path from the ion source to wafer by approximately 600 mm compared with the best that can be achieved using a conventional 70° uniform field bending magnet with the same bending radius.

Another important aspect of the analyzer design is the small second order aberration curvature in the beam waist that is achieved by applying a concave curvature to the entrance and exit pole edges corresponding to $R1 = R2 \simeq 400$ mm and contouring the transverse pole shape to set the coefficient ε in (1) to a value $\varepsilon \simeq -5.6E{-}6$ mm^{-2}. The result of introducing these field corrections is shown in Fig. 4. After ballistic drift to the wafer the beam shape is approximately circular with a diameter of ≈30 mm diameter.

The present authors personally recall the development of the NV10-80 in some detail. Marvin Farley joined Extrion Corporation in 1972 and was part of the Nova Associates start-up team in 1978. In particular, he developed the dose monitoring system for the NV10. Hilton Glavish designed the analyzer magnet to meet the short beam line specification. The magnet was built by ANAC Ltd, a New Zealand company that Hilton Glavish and associates formed in 1965 to make polarized ion sources for nuclear research laboratories around the globe. ANAC was a spin-out from the University of Auckland and continued to make ion implanter and other magnets until the beginning of 1980 when government funding for nuclear physics evaporated worldwide. Thereafter, Buckley systems, previously a key ANAC subcontractor, continued the manufacturing activity and is now the world's largest manufacturing company of implanter magnets.

By 1980 Nova Associates, owned by Cutler Hammer Corporation, became owned by Eaton Corporation and soon afterwards a joint venture was set up between Eaton Nova and Sumitomo Heavy Industries of Japan to form an implant company in Japan called SEN (Sumitomo Eaton Nova). For at least the next 20 years Eaton Nova and SEN shared ion implanter technology and engineering. This resulted in the NV10's being fitted with a serial process chamber developed by SEN. This was the birth of the Eaton NV-GSD in 1990-91. The GSD process chamber had dedicated vacuum load-locks to enter and remove wafers via cassettes from the process chamber as well providing a tilt and implant angle control.

Many hundreds of machines were delivered over the 20 year period from 1978 to 1998, all with the same basic ion optical beamline concept. The only notable change occurred in 1993 when the 70° analyzer magnet was fitted with a three segment indexed pole and a magnetic quadrupole singlet just at the exit of the analyzer. In addition, rather than using a beam guide the poles were inserted in an aluminum vacuum box containing graphite liners to reduce detrimental particulates from reaching the wafers.

B. NV2000

In 1984 Eaton Nova began the development of a commercial megavolt ion implanter. They received an order from IBM for two machines but based on a paper design that inserted an rf (radio frequency) linac (linear accelerator) as a post accelerator in the NV10 beam line, rather than using a tandem type accelerator as already used in semiconductor research laboratories. One amusing reason for this choice is described in the Peter Rose review article [6]. Another important consideration was that the successful NV10 platform (see III-A) had already been developed and offered much higher beam currents than a tandem type machine, an important consideration for a commercial implanter.

As for the rf linac, conventional drift tube machines as used in nuclear research laboratories, such as the Sloan Lawrence type [12] shown in Fig. 5 efficiently accelerated particles only according to a fixed particle velocity profile - i.e. for a given ion charge to mass ratio and rf frequency, there has to be a unique injection energy, final energy and rf electric field amplitude profile along the linac accelerating path. Other velocity profiles required at least an adjustable resonant frequency which is difficult to implement in practice.

The innovation adopted in the Eaton Nova rf linac was to vary the velocity profile using a sequence of independent phase and amplitude controlled, low power, two gap rf resonators described by Glavish [14], [15], [16]. There was no longer any need to change the resonant rf frequency. The idea of independent phase and amplitude control had already been used in research laboratories for universal heavy ion acceleration but only with superconducting resonators [13] because of the otherwise excessive rf power dissipation. However, the velocity profiles in a megavolt ion implanter are much lower than those required in nuclear physics accelerator where it is necessary to overcome the nuclear Coulomb barrier. As a result, it was realized that efficient room temperature resonators could be designed with an entirely acceptable power dissipation.

Fig. 6 illustrates the utility of two-gap resonators for accelerating all particles, doubly or singly charged, from ^{11}B to ^{121}Sb. The first machine, Model NV1000, worked well and could deliver single charge beam currents up to 1.5 mA. In the latter part of the 80's it was upgraded to the Model NV2000 with an improved resonator power source, rf tuning, replacement of the final energy electrostatic filter with a bending magnet filter, fitted with the popular GSD process chamber and updated systems engineering. The rf linac structure of the NV2000 is shown in Fig. 7. By now it had become a very sound commercial machine but yet on the verge of extinction because by 1994 only a handful had been sold whereas many more Genus type tandetrons Fig. 8 had been delivered for commercial use

But then in 1995 the NV2000 suddenly became in high demand, particularly for memory manufacturing. Since then many hundreds have been delivered by Eaton Nova, now Axcelis Technologies. Over two hundred have also been independently built and delivered in Japan by SEN (now

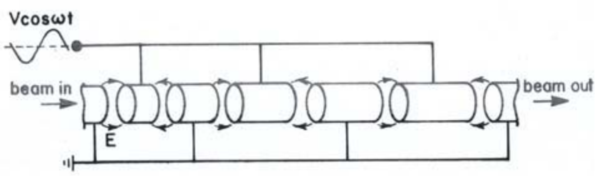

Fig. 5. Sloan Lawrence drift tube linac.

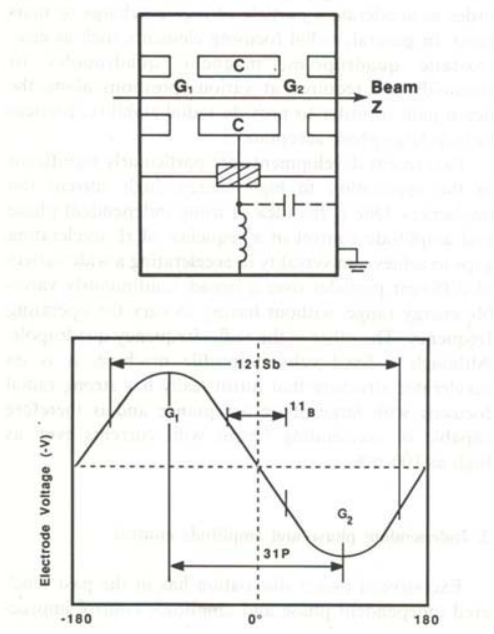

Fig. 6. The two-gap resonator - illustrating its broad velocity acceptance and ability to accelerate particles over a wide mass range.

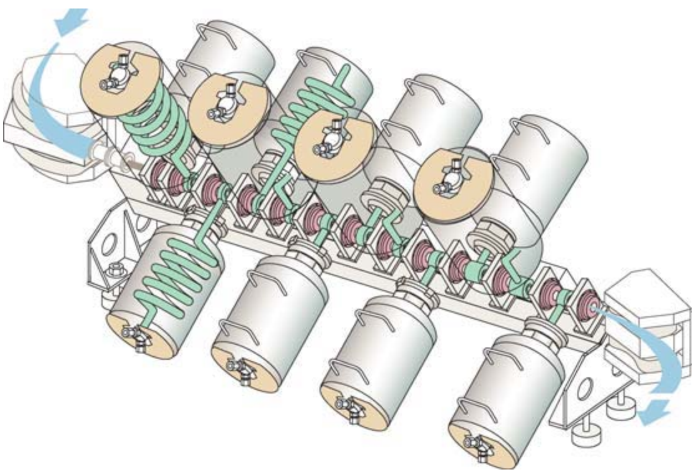

Fig. 7. Sequence of two-gap resonators used in the NV2000.

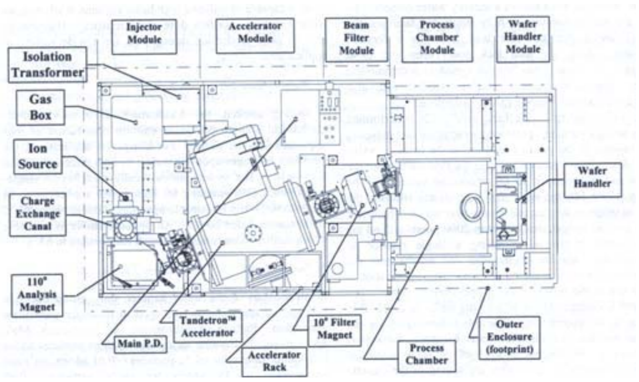

Fig. 8. Genus 1520 tandetron

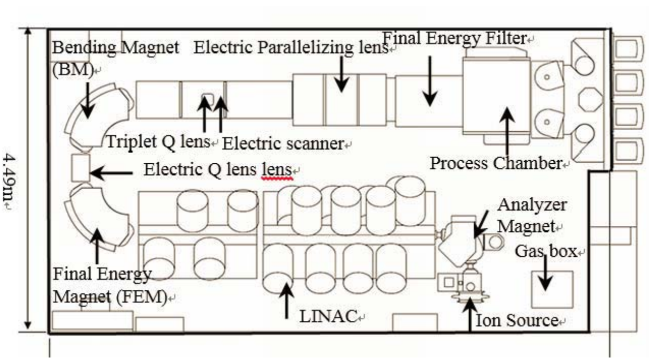

Fig. 10. SMIT ultra high energy S-UHE implanter.

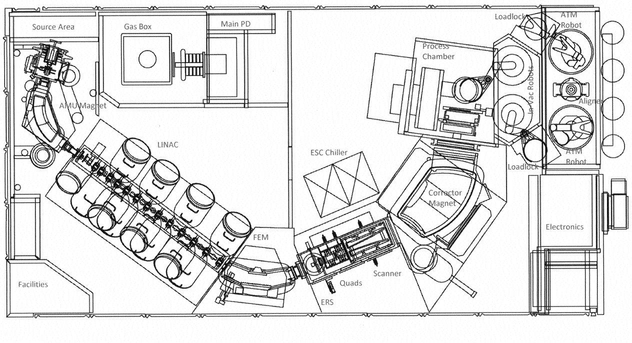

Fig. 9. Purion XE high energy implanter.

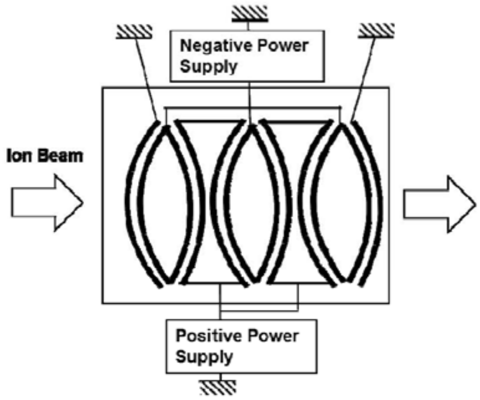

Fig. 11. The electrostatic parallelizing lens used in the SMIT S_UHE high energy implanter

SMIT). Both Axcelis and SMIT, although no longer part of a joint venture, continue to make these high energy implanters in quantity today. The present axcelis machine, Purion XE (see Fig. 9) delivers a parallel high energy scanned beam into a serial process chamber but otherwise retains the same basic rf resonators and front end as the NV2000. The present SMIT machine, the model S_UHE (Ultra High Energy - see Fig. 10), has 18 resonators delivering 1.7 MeV of $^{11}B^{+}$ and 2.2 MeV of $^{31}P^{+}$, uses a proprietary electrostatic parallelizing lens as shown in Fig. 11 and a serial process chamber.

C. E220

During the first half of the 1980's Varian/Extrion maintained their leadership for delivering medium current implanters, culminating in the model 300XP. Later in the 1980's, Eaton/Kasper of Austin, Texas (Kasper, formerly owned by Cutler Hammer, had became owned by Eaton about the same time as was Nova) began gaining market share in the US with their model 6200 as did Nissin in Japan with their model NH20 and the enhanced NH20SR. However, the development of these medium current implanters was not in the beam line but primarily in the process chamber to provide a greater range of implant angle control and also wafer handling with loadlocks, as more fully described by McKenna [5].

The first major medium current beam line innovation appeared in the model E220 in 1988, developed through 1985-86 by personnel formerly with Eaton and Varian in a start-up company called Eclipse Ion Technology [17] under financial backing from ASM. Shortly thereafter ASM became owned by Varian.

The beam in the E220 was scanned electrostatically in the horizontal direction and parallelized by an indexed dipole magnet (the "lens magnet" shown in 12) and a unique, balanced air-bearing assembly, executed a slow mechanical scan of the wafer in the vertical direction. In addition to providing continuously variable wafer tilt up to 60° and in-situ step-wise variable wafer twist, the scanning arrangement also accommodated 200 mm wafers. By the early 1990's hundreds of these machines had been delivered. With various enhancements, such as increasing the post acceleration to 250 keV and improved multiply charged beam currents for some high energy applications, it was a market leader into the first half of the 2000 decade for 200 mm wafers. For the case of 300 mm wafers the beam line architecture was substantially

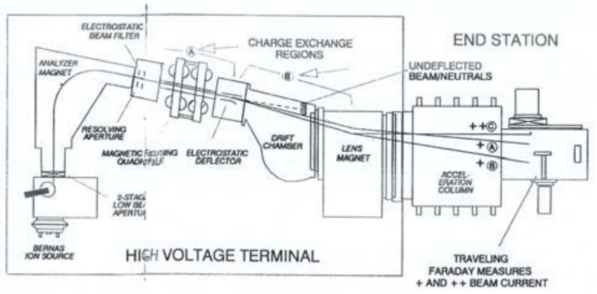

Fig. 12. Varion E220 medium current implanter.

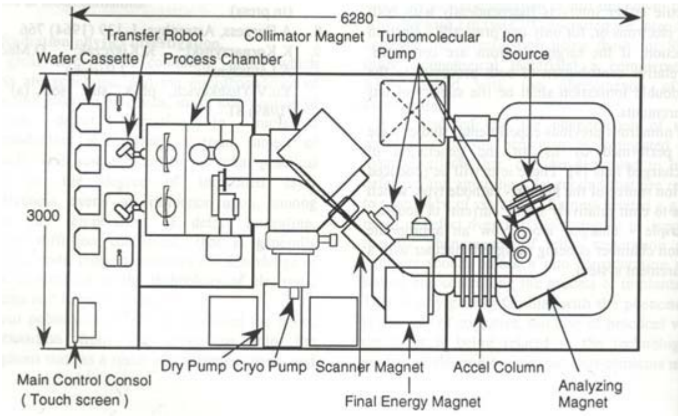

Fig. 13. Nissin Exceed 2000 magnetic scanning beam line.

changed and the E220 became superseded by Varians VIISta 810 and VIISta 900XP todays most commonly used medium current ion implanter.

D. Exceed 2000

In 1994 Nissin launched their 200 keV Exceed 2000 medium current implanter [18] and [19] for 200 mm wafers. It used a hybrid scan beam line similar to the Varian E220 but using a magnetic rather than an electrostatic scanner in the beam line. The magnetic scanner which can operate up to 400 Hz [20] and [23] an exclusive technology to Nissin[1] for many years, reduces the loss of beam from space charge blow-up. The magnetic scanning is biased in order to prevent ion beam paths from crossing zero field regions in the scanner where anomalous space charge effects can occur. The collimator is a non-indexed field but carefully curved entrance and exit field boundaries produce precise uniform and parallel beams at the wafer (see Figs. 13 and 14).

The vertical mechanical scan is based on the previous Nissin electrostatic hybrid machine - Model NH-20SP - as is the in-situ uniformity and parallelism monitoring to enable precise dose control over the wafer.

Two other unique features of the beam line are:

[1]Licensed from Ibis Technology Corporation except for SIMOX oxygen implantation

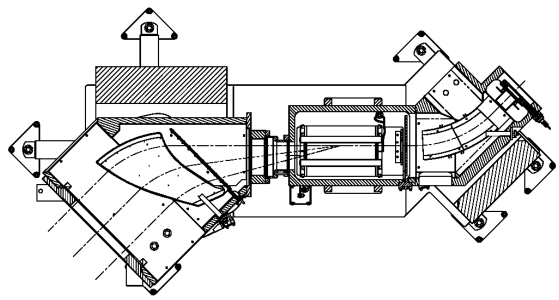

Fig. 14. EX2000 beam line after the post accel/decel lens.

- Adjustable focusing in the accel/decel post accelerator following the analyzer and mass resolving aperture.
- A Final Energy Magnet (FEM) after the accel/decel column in order to completely eliminate energy contamination, especially for BF3 operation.

All of the subsequent 300 mm implanters, released from the beginning of 2000, have a larger scanner but otherwise use the same beam line architecture as the EXCEED 2000. Sequentially, these machines are the 2300H, 2300V, 2300AH, 3000AH, 9600A, the Evo series for higher currents and the ultra low energy cluster ion beam implanter CLARIS^{TM}. In total, hundreds have been delivered since 1994. The distinguishing features of the 300 mm implanters have been more to do with improvements in the ion source, process chamber, wafer handling, wafer throughput, particulate reduction, and in the case of the 9600, extending the energy range from 250 to 320 keV (960 keV 3+ ions).

Nissin has also licensed the magnetic scanning technique for high current proton implanters used for thin film exfoliation applications.

E. NV8200

In 1980, Kasper in Austin, Texas was already owned by Cutler Hammer Corp. and now became part of the Eaton along with Nova Associates. At the beginning of the 1990's the NV 6200 became upgraded and superseded by the NV8200 shown in Fig. 15. The new, innovative feature adopted in the NV8200 was the curved electrostatic lens (see Fig. 16 used to parallelize the electrostatically scanned beam [21]. This was followed by a uniform field accel/decel column and an electrostatic final energy filter. This became the basis for the 300 mm Axcelis Purion M implanter and some machines continue to be delivered today.

It is interesting to note that this may have been the forerunner of the three stage parallelizing lens of Fig. 11 used in the SMIT (previously SEN) S-UHE high energy implanter.

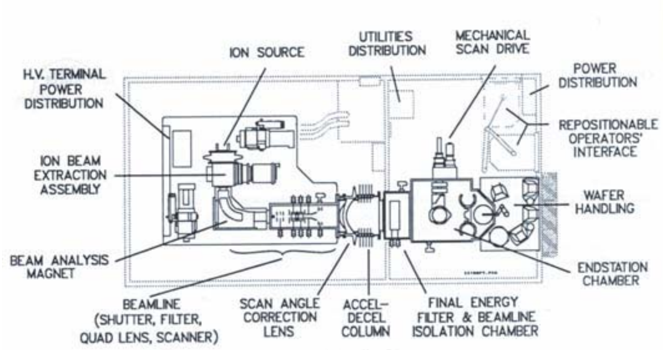

Fig. 15. Eaton NV 8200 medium current implanter

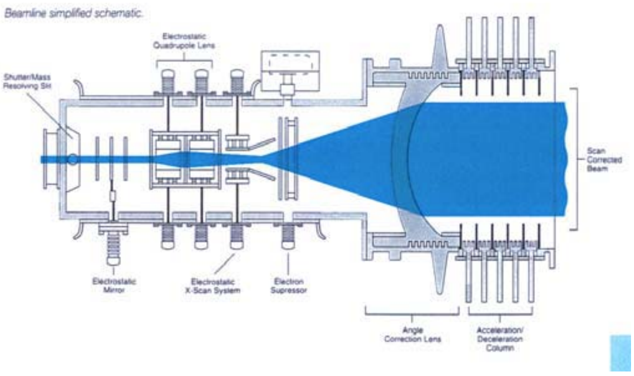

Fig. 16. Electrostatic scanning method used in the NV8200

F. xR80

The xR80 machine shown in Fig. 17 was developed by AMAT's ion implanter group in Horsham the during the mid 90's to specifically address the need to provide higher current B^+ beams at low energies down to 2 keV. The xR80 shares commonality of the process chamber, ion source and various sub-modules with those of the proven high current AMAT 9500xR implanter [22]. In particular, it uses the same small bending radius (230 mm) uniform field analyzer magnet, originally designed by Nicholas R White (see for example [24]), and considered to be an important aspect in obtaining higher beam currents before the onset of plasma instabilities. The xR80 the magnet was upgraded to bend 80 keV As^+ compared with the previous 60 keV limit. A very appealing feature of the machine is the very small 2m wide x 5m long footprint.

The Quantum X version of the xR80 was fitted with a serial in place of the batch process chamber and a variable three electrode cylindrical aperture accel/decel lens to enhance the beam current in the 5-80 keV range and operation down to 1 keV with greatly reduced beam currents. Improvements were made to the lens but only a few were delivered prior to AMAT exiting the ion implant business in 2006 and not re-entering until 2011 after acquiring Varian Semiconductor Equipment.

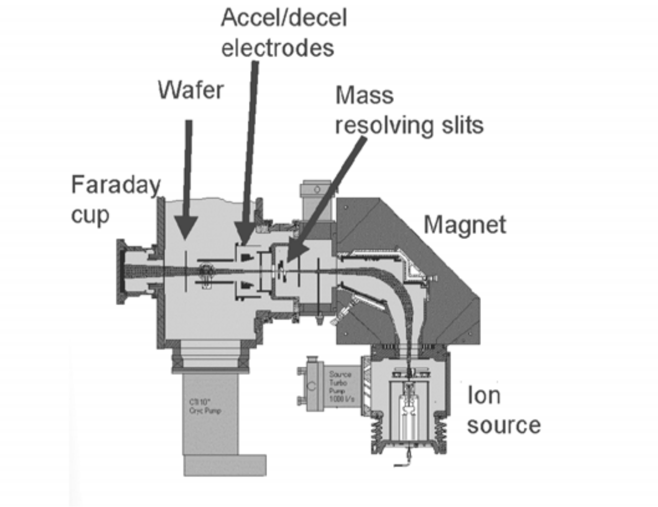

Fig. 17. AMAT xR80 ion implanter

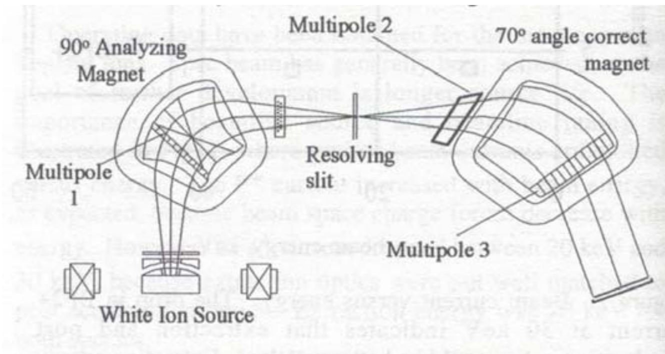

Fig. 18. Beamline schematic of the Varian SHC-80 high current flood ion implanter

G. SHC-80

Varian Ion Implant Systems introduced the first high current flood beam ion implanter in the mid 1990's. The beam line architecture shown in Fig. 18 is very coordinated with the specially developed White ion source [24] shown in Fig. 19. The divergent, substantially uniform beam extracted from the ion source, at full energy up to 80 keV, is essential for finally producing a uniform flood beam at the wafer. The divergent beam is analyzed in a small radius bending magnet with a very large pole width and gap to accommodate the tall and very divergent beam from the ion source. A second bending magnet after the mass resolving slit performs the function of making the expanded beam precisely parallel and uniform.

A great advantage of a flood beam is not only to reduce the degrading effects of space charge because of the reduced charge density in the beam for a given beam current, but also it eliminates the necessity of having a second scan direction either in the beam line or the process chamber. The SHC-80 uses a simple vertical mechanical scan of the wafer in

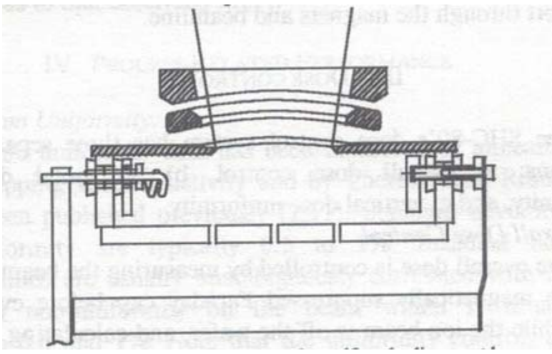

Fig. 19. White ion source producing a substantially uniform diverging beam

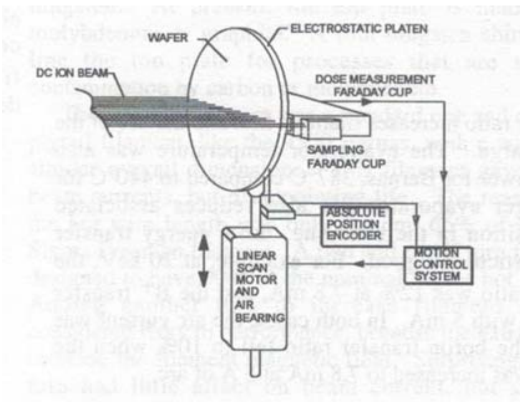

Fig. 20. 1D mechanical scanning in the process chamber of the Varian SHC-80 high current flood beam ion implanter

the process chamber, with closed loop dose/angle control as illustrated in Fig. 20.

A complication is the need to have active ion optical, multipole control elements in the two magnets to adjust and control the final beam uniformity to around 2% full range. Algorithms for doing this have proved to be manageable and this same basic architecture continues to be used today in the Varian VIIsta HCP (Fig. 21) which additionally has two decel lenses to provide beams down to 200 eV.

H. iG6

In the mid 2000's Nissin began introducing implanters for FPD are used to manufacture Low Temperature Polycrystalline Silicon (LTPS) and Organic Light Emitted Diode (OLED) high resolution displays on large, thin glass panel substrates. Of course, as the size of the substrate became larger, accordingly, the implanters also become larger, but they all have a simple concept as shown schematically in Fig. 22. The only significant beam line element is the analyzer magnet itself, needed to purify the ion species and enable the making of sufficiently small critical dimensions for low power transistors and gates. An important role of the analyzer magnet is to transport the vertically long ribbon beam from the ion source to the substrate and uniformly irradiate the latter.

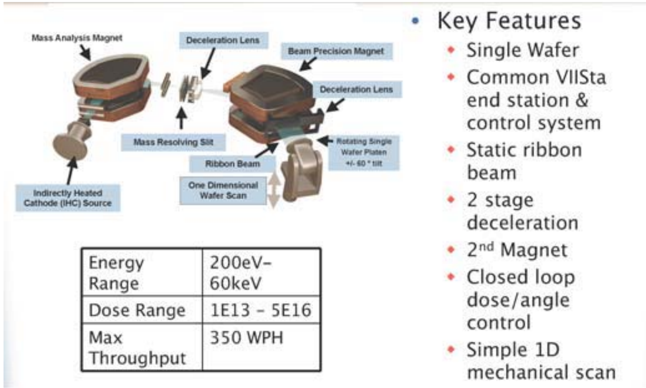

Fig. 21. VIIsta HCP

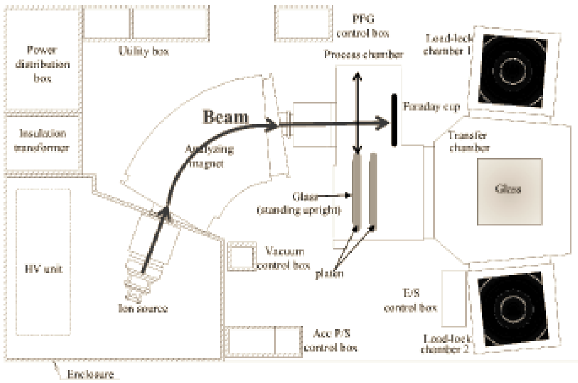

Fig. 22. Nissin FPD Implanter

The iG4, introduced in 2005, is for FPD generation 4.5 with a substrate size of 730 mm x 920 mm. The iG5 is for generation 5.5 (1300 mm x 1500 mm) and the iG6 for generation 6 (1500 mm x 1800 mm). Typical performances are shown in Fig. **??**. In all cases the substrate is mechanically scanned in the horizontal direction and the ion energy range is from 10 to 80 keV.

Some of the novel and innovative beam line features of the iG6 will now be described. Some customers have dubbed it the "flying saucer magnet" as evident in Fig. 23. A diamond shape yoke structure. is used in order to minimize the weight and yet allow a larger copper volume in the coils to achieve a lower overall coil power and a substantially uniform field with compact fringing fields at the entrance and exit. Field clamps at each end of the magnet minimize field penetration into the ion source and process chamber.

Fig. 23. Nissin iG5 FPD implanter for 1300 x 1500 mm substrate size

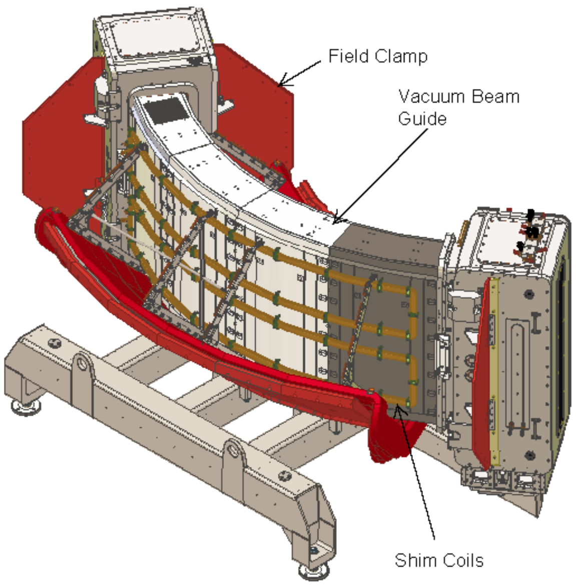

Fig. 24. iG6 with upper yoke segments and coils removed

	iG6
Energy range	10 – 80 keV
Max beam (B^+ / PH_X^+)	850 / 550 uA/cm
Convert to total current	130 / 83 mA @150cm
Mechanical T/put	60 sheets/h
Floor space	7.5 x 13.0 m

iG6 typical performance

The magnetic return yokes are made from twenty-four similar, relatively light weight segments that can be easily removed as shown in Fig. 24 and simplify on-site maintenance of the magnet if ever required.

Better than 3% full range uniformity over a distance of 1500 mm is achieved.

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