HIGH CURRENT IMPLANTER
200KeV - SERIES 1090

TECHNICAL DESCRIPTION
TECHNICAL DESCRIPTION OF PROPOSED SYSTEM

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1. BASIC LAYOUT

The proposed ion implantation system includes the basic 200 keV implanter with main beam line and magnetic quadrupole lens and a switching magnet. The switching magnet provides exit ports for three beam lines, of which two are part of this proposal:

BL-I. A low current (< 0.5 mA) beam line for ion implantation of e.g. semiconductor wafers of up to 8" diameter.

BL-II. A high current (< 10 mA) implantation beam line with large area beam scanning magnets and a large implantation chamber for ion implantation of samples up to 40x40cm², as described in the Model 1090 High Current Implanter brochure.

The remaining exit port (0 degree) of the switching magnet may later be equipped with a third beam line.

2. ION SOURCE

The implanter is equipped with our MODEL 921A High Current Ion Source, in the gas/vapour and sputter configuration. Hence, both gases, vapours and solids may be used as charge materials.

The gas/vapour version is the basic version of the ion source system. The source operates well with gaseous charges, e.g. as noble gases, nitrogen and hydrogen, and with different compound gases, e.g. carbon dioxide, hydrogen sulfide and boron trifluoride (optional toxic gas handling system required) for the production of carbon
or oxygen, sulphur and boron ions, respectively. The gas/vapour version of the ion source also runs well with vapours introduced from a vessel outside the source, e.g. titanium tetrachloride for running titanium ions. The implanter is as standard equipped with one gas inlet.

The sputter configuration is particularly useful for the production of ions from medium and high melting point elements, such as Hf, V, Y, Zr, Fe, Ni, Nb, Ti, Cr, Ta, Mo, Be, Co, Er, Si, Zn, Al and W. This operating technique provides an ion beam without contamination from chemically aggressive ions. The sputtering mode also provides minimum of cross contamination of isotopes compared to Chlorination techniques.

With the sputtering configuration it is possible to change from gas ion beams to metal ion beam and vice versa without the need of opening the ion source.

The oven configuration is useful for the production of ions from low and medium melting point charge materials, such as Li, P, Ca, Sr, As, Sb, Mg, Se, Sn, Zn, In and Bi.

The gas system can be used in combination with both the oven and sputter mode so that it is possible to change between gas ion beams and ion beams from solids in a few seconds. Furthermore, this facilitates the use of carrier gasses or chemically activating gasses/vapours.

The operating parameters may be optimized for the production of doubly charged ions. In this way 400 keV ion beams may be produced. Doubly charged fractions are typically in the range from 5 to 20 % of singly charged. Beams of 600 keV ions may be produced from triply charged ions, which are typically 2-5% of the singly charged.

Because of the efficient plasma containment in the Model 921A ion source, heavy ions with even higher charge states (4+ to 6+) may be produced with this source.

The typical operation time between cleaning service and filament replacement is 100 hours. The removal/replacement time for the ion source is less than 1 hour.

3. **ACCELERATION VOLTAGE RANGE**

The ion beam is accelerated by means of up to 40 kV extraction voltage (ion source) and up to 160 kV post acceleration voltage. The operating range of the ion implanter is 20 kV to 200 kV. At acceleration voltage below approximately 75 kV the beam current is reduced.

The stability of the high voltage power supplies used is 0.1% per hour (of full scale value).

4. **BEAM CURRENT**

For the low current beam line (BL-I), typical beam currents for specific elements that have been demonstrated during acceptance tests can be found in the Appendix 1. Information regarding currents from other elements can be supplied upon request.

Typical currents obtained by users on the 1090 high current beam line (BL-II) can be found in a user produced data base at: [http://www.fzd.de/pls/rois/Cms?pOid=108778&pNid=306http](http://www.fzd.de/pls/rois/Cms?pOid=108778&pNid=306http)

5. **MASS RANGE**

The ion source can produce ions from all stable elements of the periodic table. The analyzing magnet has a magnetic rigidity of 12.5 MeV·amu corresponding to a maximum ion mass of 250 at maximum extraction voltage. The machine is equipped with a system for display of mass.
6. **MASS ANALYSIS**

The 90 degree double focusing analyzing magnet has a mass resolution better than 1 amu and all isotopes can be clearly separated.

7. **BEAM FOCUSING QUADRUPOLE MAGNET**

The magnetic quadrupole triplet lens is used to shape the beam on target in BL-II and to match beam transport conditions in BL-I.

In the high current implantation chamber the beam can be focused to 10-20 mm diameter, FWHM, depending on beam current and energy. This is possible with total acceleration voltages of more than 50 kV. In combination with the subsequent beam scanning this ensures that optimum dose homogeneity is achieved. The lens can also be used to shape the beam into horizontal or vertical ellipses or larger cylindrical beam profiles if it is required, e.g. because of sample geometry or sample heating or for minimizing the effect of neutrals.

When BL-I is in operation, this lens is used to make an approximately parallel beam entering the electrostatic quadrupole triplet lens.

8. **SWITCHING MAGNET**

The switching magnet provided with the implanter has three exit ports at ± 30° and 0°. Due to the large bending angle it is possible to add a third beam line at the 0° port at a later stage. The magnetic rigidity of the switching magnet is 50 MeV·amu, corresponding to a maximum ion mass of 250 at 200keV.

9. **LOW CURRENT BEAM LINE (BL-I)**

In order to allow fast electrostatic scanning, the maximum beam current in the low current beam line is limited to 0.5mA. It will be possible to obtain doses of $10^{19}$/cm² over 10 cm² within one hour. Maintaining the stable operational mode of the implanter, the beam current can be reduced down to 10 nA by adjusting the operational settings of the ion source and the apertures in the slits: a remote controlled analyzing slit and a manually controlled beam limiter at the entrance of this beam line.

9.1 **ELECTROSTATIC QUADRUPOLE TRIPLET LENS**

In order to focus the beam in a small spot, an electrostatic triplet lens is provided in BL-I. With this lens it is possible to focus the beam to diameters as low as 2.5 mm, FWHM, depending on required beam current and energy.

9.2 **ELECTROSTATIC SCANNING SYSTEM**

The fast electrostatic scanning system in this beam line can be used to scan the beam over an area corresponding to an 8" wafer. The scanning voltages (x and y) follow triangular waveforms and their frequencies can be set individually to values from 100 Hz to 1 kHz.

In order to avoid the influence of neutrals on the dose homogeneity a separate 7° deflector and a neutral trap is provided. Dose uniformities better than ±5% are produced with the Danfysik 1090-200 implanter.

9.3 **TARGET CHAMBER FOR IMPLANTATION OF WAFERS**

The low current beamline target chamber includes individual carrousels for 2", 4", 6" and 8" wafers.
A retractable Faraday Cup and beam profile monitor is used to set up the un-scanned, focused beam. A four Faraday cup system at the entrance of the chamber is used for dose measurements and for check of the dose homogeneity. Aperture discs for implanting 2", 4", 6" and 8" wafers are included. When the wafer carousel is used a single Faraday cup mounted behind the target position may be used for dose calibration if one wafer position is left open.

A camera will be provided, connected to a monitor at the control desk. Two extra vacuum ports are provided for optional diagnostic equipment, e.g. for temperature measurement (IR-detector).

An optional sample holder mounted on the target chamber allows heating (20-500°C) or cooling with liquid nitrogen of a single wafer.

The dose repeatability is better than 5% run to run.

10. HIGH CURRENT BEAM LINE (BL-II)

The high current beam line will be used for implantation of materials which require high dose implantation. It is designed to handle beam currents in the 1 to 10 mA range. With a beam current in this range, implantation for 30 min. will produce a dose of \(10^{17}/\text{cm}^2\) to \(10^{18}/\text{cm}^2\) over an area of 100 cm².

The main components of this beam line are described below.

10.1 BEAM SCANNING

When operating with high current ion beams (≥ 0.5 mA) at the energies used for ion implantation it is essential to use electromagnetic beam scanning. With electrostatic scanning the beam pattern would be strongly influenced by space charge effects. With the electromagnetic two-dimensional beam scanning system of this beam line the ion beam can be scanned to produce a homogeneous exposure over large areas. The maximum beam scanning area depends on the magnetic rigidity of the beam particles. For singly charged ions at 200 keV it is 40 cm x 40 cm for ions up to mass 200 (amu). The maximum scanning frequency is 8 Hz at maximum amplitude.

The beam scanning system also provides a beam offset possibility of +/-20 cm in both X and Y direction within the scanning area.

10.2 IMPLANTATION TARGET CHAMBER AND MANIPULATOR

The target chamber consists of a "conical" beam entrance tube with a square cross section, and a large (0.7 m x 0.7 m x 0.7 m) cubical target chamber. The entrance tube contains a moveable Faraday cup for beam current measurement and a large (40cm x 40cm) water cooled beam stop for setting up of the beam pattern.

The target chamber contains a directly water cooled sample manipulator for wafers and samples up to 40 cm x 40 cm. The holder disc may be rotated continuously around its axis of symmetry, and the disc axis may be rotated continuously from parallel to the beam to perpendicular to the beam. Finally, the sample can be moved linearly in the vertical direction. The beam scanning system may be used to off-set the beam horizontally. All movements may be performed independently or simultaneously via computer control. Water cooling can easily be adapted to the sample holder system.

The vacuum system on the target chamber is dimensioned such that implantation may start approx. 15 minutes after start of pump down.

As an option the chamber can be provided with an infrared detector for sample temperature monitoring and control. Control is based on relay signals from the detector which can be used as target overheating interlock and will cause the beam stop to intercept the beam at a preset maximum temperature.
11. **VACUUM SYSTEM**

The implanter is delivered complete with vacuum system including monitors and controls. We have based our proposal on our experience in design and operation of the implanter, and we propose the following high performance vacuum pump systems (clean-oil free), which will guarantee the best operating conditions for the research and service implantation work anticipated with the implanter.

11.1 **ION SOURCE/EXTRACTION REGION**

Because of the "rough conditions" with high gas flow, metal vapors and chemical compounds, we propose to use an oil diffusion pump (φ160mm) in this region together with corresponding fore pump.

11.2 **MAIN BEAM LINE**

One turbo pump (φ100mm) with corresponding fore pump.

11.3 **LOW CURRENT BEAM LINE (BL-I) AND TARGET CHAMBER**

One turbo pump (φ100mm) with corresponding fore pump in the beam line and one turbopump (φ160mm) with corresponding fore pump in the target chamber.

11.4 **HIGH CURRENT BEAM LINE (BL-II)**

One turbopump (φ200mm) with a corresponding roughing/backing pump in the target chamber.

The base pressure without beam will be in the $10^{-7}$ mbar range in the beam lines and target chambers.

During beam operation, the pressure in the target chambers will rise to a value below $5 \times 10^{-6}$ mbar in the high-current beam line and below $5 \times 10^{-7}$ mbar in the low-current beam line. The exact levels depend very much on the amount of gas present in the ion source region and the extend and nature of collisions occurring at and around the target.

12. **ACCELERATOR CONTROL SYSTEM**

The implanter is delivered with a control system. The system allows complete control of all parameters from a PC. It is based on fiber optics control and is insensitive to high voltage transients and electromagnetic interference.

The system features graphic user interface, display of measured values, display of control values, adjustment of control values, data logging for historical analysis, alarms to highlight error conditions, and control algorithms for automatic control using fibre optics loop controller.

The control system includes automatic start-up procedures including automatic out gassing of the filaments and automatic shut-down. The automatic start-up includes setting of the magnet power supplies, high voltage supplies and electrostatic devices, opening valves etc.. Parameters for a specific run can be saved to a database and recalled for later use.

All parameters (input or output, digital or analog) including alarms are logged to a file.

The software platform is InTouch from Wonderware. Optionally, the development program may be included to allow the users to add their own applications.
13. **INTERLOCK SYSTEMS**

The following interlock systems ensure the safe operation of the implanter:

**Software controlled interlocks**

- Vacuum gauges, pump and valve control and interlock units, which protect the vacuum system from improper operation.
- An interlock system, which protects the gate valves from being hit by the beam.
- An interlock system shuts off the beam extraction in case of lack of cooling of the ion source.

**Hard-wired interlocks**

- Key activated door interlocks and a failsafe grounding system ensure a reliable high voltage interlock system.
- An interlock system which turns the accelerating voltage off in case the x-ray level increases above a preset value.

14. **X-RAY SAFETY**

The implanter is designed in a manner so that the radiation level outside the HV-enclosure is below 0.6 µSv/hr. The source point for most radiation inside the platform is shielded by lead. Similar installations have been tested by the Danish authorities whose regulations are based upon EEC/EURATOM norms 80/836 and 84/467 and have been found "fully satisfactory", and the operating personnel do not need to wear film monitors. The above-mentioned x-ray safety interlock is provided as an extra precaution.

15. **FACILITY REQUIREMENTS**

The following facilities are required for the operation of the proposed implanter system:

- Typical overall dimensions of implanter equipped with two beamlines:
  10.0 m (long) x 6 m (wide) x 2.7m (height)
- Typical space requirement of implanter equipped with two beamlines, including free space for service and operation: 11.5 m (long) x 7.5 m (wide) x 3.2m (height)
- Typical installation/transportation dimensions:
  The access to the installation site should allow the high voltage platform to enter without the need to break down the platform in individual components. The high voltage platform has the following minimum dimensions during transport and installation: 3.00 m (wide) x 2.50 m (long) x 1.75 m (height).
- Total weight:
  Approx. 12,000 kgs. Max. floor loading 1000 kgs/m².
- **INSTALLED ELECTRICAL POWER:**
  Three phase, 400V Y, 50 Hz, 100 kVA. Consumption under normal operating conditions considerably smaller, typically 30% of the above maximum values.
- **INSTALLED WATER SUPPLY:**
  Min. 5 bar pressure drop, approx. 6 m³/hr. at 20°C inlet temperature. A closed circuit cooling system with heat exchanger for the high voltage platform is part of the system.
  For direct cooling of implanter components de-mineralized water or pure water with an electrical conductivity of less than 10μS/cm should be used.

- **INSTALLED PRESSURIZED AIR:**
  Min. 7 bar for pneumatic valve operation.

16. **TRAINING**

Training of two operators in maintenance and use of the implanter is included in the delivery. We recommend that one of the operators has a background in electronics.

The training will take place partly during the final factory acceptance test and partly during the installation and commissioning phase.

17. **DOCUMENTATION**

The implanter comes with all 3rd party user manuals. Also included is a description of the accelerator control system.

18. **TEST**

The implanter will undergo a Factory Acceptance Test (FAT) at Danfysik before shipment. An Ar beam will be used to test the general performance (component performance, alignment and optics) of the system. Further tests in the FAT are customer specific and will be agreed upon in the contract.

After delivery, part of the FAT is repeated in the Site Acceptance Test (SAT) to ensure that the implanter has been properly assembled and has not been damaged during transport.
### APPENDIX 1: BEAM CURRENTS

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<th>Ion Source Mode</th>
<th>Beamline</th>
<th>Beam current @ terminal FC</th>
<th>Beam current @ target FC</th>
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<tr>
<td>Ion Source Mode</td>
<td>Ion Source extraction voltage</td>
<td>Acceleration voltage</td>
<td>Total energy</td>
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