CLIN 0001 - Specification for an Electron Beam Writing System

The Naval Research Laboratory requires an electron-beam writing system for applications in nanoscale lithography. The system must be capable of accepting a variety of substrate sizes and exposing the substrate to a directed electron beam under computer control that, with subsequent processing, will allow features as small as 50 nanometers or less to be generated. The unit will be used by a small and qualified team of researchers exploring an array of problems in nanostructures and nanoscience. The system will be installed at the Naval Research Laboratory, Washington, DC (NRL).

The vendor must supply a response regarding each of the technical items listed below.

Abbreviations

CAD	computer-aided design
in.	inch
kV	kilovolt
keV	kilo-electron volt
mil	milli-inch = 0.001 inch
min	minute
mm	millimeter
nA	nanoamp
nm	nanometer
pA	picoamp
µm	micrometer
sec	second

Description

An electron-beam writing system allows a focused beam of electrons to be scanned over the surface of a sample in a controlled manner causing a overlayer polymer film, under the region exposed by the electron beam, to become more or less susceptible to chemical solvents. The system generally consists of a primary electron beam that operates in a high-vacuum environment and passes through a column containing electron accelerating and focusing optics, and impinges at the surface of a sample. Electron focusing, deflection and beam blanking controls are to be provided and integrated to a computer. This, combined with computer-aided design (CAD), allows transfer of computer-generated features to the polymer film atop the substrate. The system must be capable of transporting wafers and variously sized substrates from the laboratory to the vacuum chamber through a vacuum intro port and positioning them to a computer-controlled stage that provides gross positioning of the sample below the primary electron beam.

This specification provides the general requirements followed by requirements of the stage, the primary beam, scan/write control electronics and computer-aided design.

General Requirements

1.0. The system must be a commercially manufactured instrument. Developmental systems do not qualify for this purchase.
1.1. The instrument must have a user-friendly interface and sufficient interlock controls to prevent an operator from easily damaging the unit.
1.2. The system must be capable of operating as a scanning electron microscope (SEM) under computer control.

Stage requirements

2.0 Stage requirements. The stage unit is used to hold and translate the sample under the electron gun in x, y, z, and Φ directions. X-y motion is orthogonal to the primary beam direction; z motion is parallel to the primary beam direction; Φ is the rotational angle about the z-axis measured from the positive going x-axis.
2.1. Stage drive. Automated, computer-controlled stage drive is required with x-y-z-Φ motion.
2.2. Stage position measurement. Laser interferometer-based measurement in x-y.
2.3. Stage resolution. 2.5 nanometers or less in x-y.
2.4. Sample leveling. The stage must be capable of establishing a level surface to less than 2 micrometers over a 6 inch surface.
2.5. Position readout. The system must be capable of displaying x, y, z, Φ position of the stage.
2.6. Minimum stage patternable range in x-y. 150 x 150 mm.
2.7. Position control. The stage system must be capable of positioning to within 1.0 micrometers of x-y destination position under computer control.

2.8. Sample handling. The system must be capable of handling wafers between 2 inch – 6 inch diameter, mask plates 4 inch square x 90 milli-inch thick, and small pieces.
2.9. Faraday cup. The stage must have an integrated Faraday cup for use in accurate beam current measurement.
2.10. Field-field stitch accuracy. Misalignment of a line feature written from one field to an adjacent field must be 60 nm or less when written in both x and y directions.

Electron Beam and Column Requirements

3.0. Primary electron beam description. The primary beam is the source electron beam directed over the sample surface. The source must be of the Schottky field emitter or thermal field emitter type.
3.1. Primary beam energy range: Variable, minimum range 1 – 20 kV.
3.2. Beam-stage drift: The electron beam - stage drift must be 10 nm/min or less.
3.3. Beam shape: Gaussian round with x-y stigmation correction.
3.4. Spot size: 6 nanometers or less @ 1 kV beam voltage, 50 pA beam current.
3 nanometers or less @ 20 kV beam voltage, 50 pA beam current.
3.5. Beam current range. 10 pA – 10 nA, minimum
3.6. Beam current drift. 0.5%/hour or less.
3.7. Beam blanking method. Beam blanking refers to the technique used to turn off the primary beam under computer control. The electrostatic method is required for this system.
3.8. Beam blanking speed. 100 kHz or higher with beam operating at 20 kV.
3.9. Beam blanker rise time: 20 nanoseconds or less.
3.10. Field size range. Field size is the area of exposure for a fixed stage position. The system must be capable of operating with field sizes ranging between 25 – 200 micrometers, inclusive.

Scan/Write Control Requirements

4.0. Scan/Write Control description. The scan and write control describes the manner in which the electron beam is rastered over the surface as a function of CAD-generated patterns.
4.1. Scan mode: vector scan mode, minimum. In this mode, the scan control system implements scans parallel to the longest edge in a feature. For circular features it executes a spiral pattern to fill the circle.
4.2. Basic Pattern Shapes. The beam control electronics must be capable of writing the following patterns:

1) Rectangles, triangles, and polygons of any shape and orientation.
2) Lines and curves with single or multiple pixel wide resolution at any orientation.
3) Dots, circles and cones.
4) Shapes generated by mathematical functions.

4.3. Minimum dwell time. Dwell time is the time the beam can be directed at a pixel on the sample surface. The minimum dwell time must be 100 nanoseconds or less.

4.4. Dwell time increment. 10 nanoseconds or less.

4.5. Dose control. Each structure defined in CAD must be capable of being assigned an electron dose. (Dose is the product of beam current and pixel dwell time.)

4.6. Writing speed. The system must be capable of writing random pixels at 1 MHz.

4.7. Scan resolution. The resolution of the scan control electronics must be at least 16 bit x 16 bit in XY.

4.8. Overlay registration. The scan control electronics must work in conjunction with computer software to provide local field mark registration. Registration is done by generating an image of feature(s) within subfield(s) in the field of view, implementing a comparison of the imaged alignment feature to a reference CAD feature, and correction of the image coordinate system to the CAD coordinate system by x,y offset parameters, x, y scale parameters, and rotation.

4.9. Overlay accuracy. The system must be capable of performing a local field alignment to an accuracy of 60 nm or less within the field within a 100 μm image field.

4.10. Field size. The system must be capable of writing a 100 μm square field region with electrostatic deflection of the primary beam.

4.11. Current measurement. The system must be capable of automated beam current measurement to an accuracy of 1 pA or less and to provide this measurement to system software for electron dose correction control.

Pumping System Requirements

5.1. System vacuum. The sample chamber must be capable of producing oil-free vacuum to a pressure of $5x10^{-7}$ Torr or less. (Note: Diffusion pumping systems are not allowed for pumping the primary or the intro chambers).

5.2. Intro port. The system must be capable of insertion and removal of samples through an intro port while maintaining the main chamber under vacuum.

5.3. Vacuum gauging. The system must provide readout of vacuum at the e-beam source and within the main chamber and vacuum of the main chamber.

Computer, Software and CAD Requirements

6.0. The system requires a computer for automated control of feature imaging, CAD development and electron-beam writing functions. The system must be capable of running a post-1998 Windows, Macintosh, or Unix or Unix-based operating system.

6.1. Duplicate license. A second license to operate the CAD software on an offline computer must be available.

6.2. CAD features. It is necessary for the CAD to generate circular and polygon structures. Structures must be capable of being duplicated and copied to other regions or as arrays having user-defined x-y spacing. Electron dose assignment is necessary for each structure.

6.3. CAD file format. Computer-aided design files are used to generate and store pattern information. The software must be capable of saving data in the Calma GDS-II file format. It must be capable of reading Calma GDS-II, DXF (AutoCAD) and bitmap formatted files.

6.4. Network interface card. A network interface card with industry standard RJ-45 connection is required as part of the computer system. If more than one computer is required, each computer will be configured with a network interface card.

6.5. Image archival format. SEM image storage in electronic format is required. Image format can be in TIFF (tagged image file format) and/or JPEG or other high resolution storage formats.

6.6. Portable data storage. The computer must be provided, at minimum, with a ZIP drive having 250MB storage capacity.

CLIN 0001AA - Training and Documention

7.0. The vendor must provide on-site (NRL) training for up to 10 NRL personnel.

7.1. The system must include User's Manuals appropriate to fully operate the system at the highest performance level.

CLIN 0001AB - Warranty

8.1. Warranty. The contractor shall provide a standard commercial warranty. Include an offer of extended warranty as provided in customary commercial practice.

Options

Option I - CLIN 0002

9.0. Water-to-water heat exchanger. The installation site has a centralized water cooling system for heat removal. The electron beam writing system must include a water-to-water heat exchanger (e.g. Neslab System Series or equivalent) to allow interface to the building cooling system.

Option II - CLIN 0003

9.1. Uninterruptible power supply. The electron beam writing system must be equipped with an uninterruptible power supply that can maintain 1 minute of power if building power is lost. Electrical utilities having 208 VAC, single phase , 208 VAC 3-phase, and 120 VAC single phase power will be available at the installation site.

Option III - CLIN 0004

9.2. Alternate resolution standard. The system must include a gold/carbon resolution standard.

Option IV - CLIN 0005

9.3. Vibration isolation table. A vibration isolation table will be provided to support the electron column and provide additional mechanical isolation from the laboratory environment.

Option V - CLIN 0006

9.4. Optional scan modes. The scan control electronics must be capable of operating in a Bit map/raster scan mode and/or scanning under polar coordinates.