Specifications for an Ultra High Vacuum Thin Film Deposition System

The Naval Research Laboratory (NRL), Washington, DC, has a requirement for an ultra-high vacuum (UHV) thin film deposition system for the growth of multifunctional magnetic materials. The system must be designed to be a stand alone unit with a vacuum load lock chamber having a six position substrate cassette elevator for wafer and mask exchange and an appendage chamber equipped with an ultra violet lamp and heater for oxidation and wafer processing. The system must have a sputtering chamber to include seven 2" magnetron sputter sources for con-focal sputtering, each with integral isolation chimney, pneumatic UHV shutter and individual gas injection capability. The system must also include an e-beam evaporation chamber to accommodate a UHV linear e-beam source. The substrate holder must be able to be heated up to 850 C in an oxygen environment and accommodate up to a 4" wafer. The deposition uniformity must be better than +/- 2.5%, over a 4" diameter wafer. The substrate holder must be equipped with a minimum 100 Oersted in-situ rotatable magnetic field for up to 300 C. At least four mass flow controlled gas lines must be equipped with the system. The sputtering system must be computer-controlled and the base vacuum must be at least 5.0×10^{-8} Torr.

The magnetrons in the system must be a UHV design - no elastomers or polytetrafluoroethylene (PTFE), allowing baking to 200 C without disassembly UHV .

The magnetron sources must allow reconfiguration between balanced, unbalanced and magnetic materials mode depending on the application. The magnets for the magnetron sources must be located out of the cooling water. The magnets must be vacuum compatible to 10^{-11} Torr.

The substrate heater must allow simultaneous heating, rotation, biasing, z-motion and deposition up to 850 C in a pure oxygen environment. Temperature stability must be at least +/- 1 degree C.

The system must include (at a minimum) the following major components which must meet or exceed the following minimum specifications:

1.0 Main Deposition Chamber

1.1 Main Evaporation Chamber –must be at least 14" high x 14" outside diameter (OD), 1\8" thick stainless steel (S/S) vacuum chamber and consist of the following:

- Chamber Top – 16.5" ConfFlat (CF) flange with 8" CF flange on 6" tube in center
- Chamber Bottom – flat plate welded to chamber roll-up with (4) 2.75" spare ports

- Ports on Chamber Body for the following components:

    - vent valve
    - (4) 10” CF ports – UHV linear e-beam source, turbo pump, melt viewport system
    - (3) 2.75” CF ports – nude ion gauge, convectron gauge and vent valve

The chamber must be mounted to two (2) steel frames with dual instrument racks.

- heavy duty casters (for greater than 2000 pounds) and leveling feet
- table top
- water manifold with flow sensor

All unoccupied ports must be blanked off.

1.2 Main Substrate Chamber – must be at least 15.6" high x 14" OD, S/S vacuum chamber with flange each end and consist of the following:

- Chamber Top - Hinged with o-ring seal. Accommodates substrate holder.
- Chamber Bottom - 16.5" CF with copper gasket. Accommodates sputter sources.
- Ports on Chamber Body for the following components:

    - 4.5" CF viewport with shutter on 1.33" CF
    - (3) 8” CF for load-lock and spares
    - vacuum gauges ((2) 2.75" CF, (1) 1.33" CF)
    - process gas introduction (via sputter source(s) and substrate holder flange)
    - vent valve
    - angled ellipsometer ports - blanked ((2) 2.75" CF)
    - spare ports for future reflection high energy electron diffraction (RHEED) ((1) 2.75" CF and (1) 6" CF port opposite each other at transfer level)
    - additional spares: (1) 2.75" CF

The chamber must be mounted on top of the main evaporation chamber to allow for the proper distance that is necessary for evaporation to take place.

- hinge for chamber top

All unoccupied ports must be blanked off.

2.0 Vacuum Pumping

Vacuum Pumping must be mounted to main evaporation chamber and must consist of the following:

- 1080 l/s wide range, magnetically levitated, compound turbo pump with delayed vent valve
- 15 cubic foot per minute (cfm) mechanical backing pump.
- interconnecting plumbing and hardware

3.0 Magnetron Sputtering Sources

3.1 16.5" CF cluster flange to accommodate (7) UHV (2" target) magnetron sputter sources, (7) source shutters and (7) VCR (metal gasket face seal) gas injection fittings. Source angle must be optimized to achieve uniformity of +/- 2.5% on substrates up to 4" in diameter. Independent uniformity fine tuning must also be possible with each source. Cluster flange must include a spare 8" CF port in the center on 150mm inside diameter (ID) tube.

3.2 seven UHV 2” magnetron sputtering source(s) with integral isolation chimney(s), pneumatic UHV shutter(s) and individual gas injection capability via VCR port on cluster flange.

4.0 UHV linear E-beam source

NRL will provide a Thermionics (model 100-0030) 3KW 3 crucible (2.24 cc) linear e-gun source to the contractor to be integrated into the main evaporation chamber.

5.0 DC and RF Generators

- The contractor shall provide 3 750 Watt DC generator(s) with an integral.
- 3-way switchbox and cable set.
- 5kW variable frequency, pulsed DC power supply.
- 300 Watt RF generator(s), auto-matching network and cable set.
- 100 Watt RF generator, manual matching network and cable set.

6.0 Rotating Quartz Crystal Thickness Monitor

Single quartz crystal sensor, heat sink, controller, oscillator, cable, feed-through, and 10 crystals. Also must include rotary feed-through assembly to allow positioning of crystal in substrate position for deposition calibration.

7.0 Vacuum Gauge Package with Cables

Gauge controller that simultaneously displays three gauge head outputs:

- Nude ion gauge head
- Convectron gauge head
- 1-Torr Baratron gauge head

8.0 Substrate holder

- accommodates substrates up to 4" diameter
- mounts to top of chamber.
- confocal configuration on vertical center axis of chamber
- continuous motorized rotation (0-20RPM) with controller
- radiant heating to a maximum of 600 C with quartz halogen lamp(s)
- water cooled reflector box
- capable of being heated in an O_2 environment
- Proportional Integral Derivative (PID) controller with thermocouple (TC) input, overtemp protection, +/- 1 degree C temperature stability.
- (1) "wagon wheel" style transferable substrate carrier.
- (1) substrate transfer ring.
- RF/DC biasing capability while rotating / heating / depositing.
- substrate gas ring
- 2" substrate lift for load-lock transfer and working distance adjustment via edge welded bellows
- (1) transferable substrate carrier with transverse magnetic field, minimum 100 Oe, less than 2% skew, up to 300 C.
- (1) "wagon wheel adaptor to accommodate 4" substrate transfer ring at 10° angle for direct sputtering.
- Pneumatically controlled substrate shutter
- UHV construction

9.0 High Temperature (850 C) Transfer Plate Kit

- Inconel "propeller" to replace "wagon wheel" susceptor for high temperature applications.
- Inconel transfer plate with receptor for 4" diameter or smaller substrates - suitable for 850 C operation.

10.0 Gas Handling

(4) Mass flow controlled gas lines - 20 standard cubic centimeter per minute (sccm) with pneumatic isolation valves and filter.
(1) Ar gas line plumbed to one sputter source.
(3) Reactive gas lines plumbed to the substrate gas ring.

11.0 Pressure Control / Vacuum Valves

Downstream pressure control.

Closed loop, automatic pressure control / isolation gate valve. The throttle valve must be full ranged with1000 positions between the open and closed valve and must interface with the Baratron gauge via a PID controller. The controller must include pressure and position presets and battery pack which closes the valve within 3 seconds in the event of a power failure (8" CF size).

Manual vent valve.

12.0 Load-Lock

- Low volume (13.5 liters minimum) aluminum chamber body machined from single billet.
- Removable loading door.
- Extended magnetic transfer arm with susceptor for substrate transfer rings.
- Full range (from atmosphere to 10^{-9} Torr) vacuum gauge
- 70 liter per second wide range, compound turbo molecular pump with delayed vent and turbo mechanical pump (TMP) controller.
- N_2 purge on TMP for oxygen plasma processing with manual shut-off valve
- interconnecting plumbing and hardware
- Manual, 8"CF, isolation gate valve between load-lock and main chamber with load-lock adaptor flange.
- 4 cfm mechanical backing pump
- 6 position substrate/ mask cassette elevator with removable cassette
- linear / rotary substrate mask exchange tool
- (3) additional substrate transfer rings
- (3) mask rings
- Load-lock vacuum pumping system should be shared with oxidation appendage chamber

13.0 Power Distribution / Pump control

13.1 208V rack mounted master three phase power distribution box with:

- Main power switch
- Emergency OFF button
- Hoist up/down momentary switch with 4 pin output connector
- Main contactor with time delay or water interlock shutdown
- water and vacuum interlocks
- (2) 30A, high power, three phase (or single phase) outputs
- (4) 30A, 208/220 VAC single phase outputs
- Main power input (80A per leg + neutral + ground) with mating connector

13.2 Rack mounted master power distribution box with:

- Main Power Breaker
- 220 VAC, 30 A, 1 phase input
- water cooling / vacuum interlock input
- interlocks enabled output connector
- (2) interlocked 220 VAC receptacles
- (1) non-interlocked 220 VAC receptacle
- (2) non-interlocked 220 VAC receptacles for TMP and mechanical pump (MP)
- Integral TMP/MP on/off breaker (for main chamber vacuum pumps)

13.3 Rack mounted slave power distribution box with:

- Main Power Breaker
- 220 VAC, 30 A, 1 phase input
- water cooling / vacuum interlock input
- interlocks enabled output connector
- (2) interlocked 220 VAC receptacles
- (1) non-interlocked 220 VAC receptacle
- (2) non-interlocked 220 VAC receptacles for TMP and MP
- Integral TMP/MP on/off breaker (for load-lock pumps)

14.0 Pneumatic Controls

4-Way Solenoid & Manifold Assembly to actuate the following pneumatic devices:

- (8) shutter(s) for magnetron sources and substrate
- (6) gas line isolation valve(s)
- (2) future pneumatic device(s)

15.0 Computer Controls

- Lab-view based control software for sputtering system.
- Compact PC on heavy duty sliding drawer in instrument rack with ethernet connection, flat color display and CD burner.
- 7" x 19" rack mounted hardware module with input/output (IO) to allow field retrofits such as the addition of sputter sources, gas lines, and power supplies after system delivery.
- Interfaces with (5) DC & (4) RF generators for control of output mode, set-point, ramping & plasma detection
- Capable of interfacing with (1) 4 way DC switchbox and (1) 3 way RF switchbox
- Interfaces directly with solenoid pneumatics manifold, for control of shutters, gas isolation valves & spares
- Interfaces with throttle gate valve for: open / closed / throttle position
- Interfaces with heater controller for: on / off / temp. set-point / T/C temp. feedback
- Interfaces with up to (4) mass flow controller (MFC) for control of: gas correction factor / flow set-point / flow feedback
- Define and stack process layers to create processes
- Store and run processes
- 10 separate password protected accounts for process layer & process security
- Auto shutdown of power supplies if: plasma not detected
- Auto abort of process if: plasma not detected / gas flow set-point or temperature set-point not reached
- Displays and data logs: shutter position / DC power feedback, DC bias feedback (for RF), plasma verification, process pressure, gas flow feedback, T/C temperature feedback

16.0 Oxidation Appendage Chamber

- at least 8" diameter, 10" high appendage chamber opposite load-lock separated by 8" CF manual gate valve.
- substrate holder with Z motion for transfer via load-lock's magnetic transfer arm.
- 10” CF (top and bottom)
- (2) gas introduction via diverter valves from O_2 and Ar MFC lines.
- port for future Baratron vacuum gauge
- loading door
- pumping line with manual valve to utilize load-lock pumping system for evacuation after oxidation
- bearing support for extension of transfer arm.
- can accommodate future induction coupled plasma (ICP) source
- spare 8" CF port for future pump system upgrade
- 2.75" CF viewport

- appendage chamber support hardware
- 8” CF manual gate valve for chamber isolation

17.0 Complete UV Lamp / Substrate Heating Package

- UV lamp source mounted to bottom 10" CF of appendage chamber.
- UV lamp source power supply.
- Substrate heating to 300°C with quartz lamps, Z motion, water cooled reflector and PID controller.
- RF/DC biasing capability while rotating / heating / depositing. Shares 100 Watt RF generator from main system.
- Baratron gauge with display for process control

18.0 Water chillers

- (1) 8000 British Thermal Unit (BTU)/hour (HR) water to water Chiller
- 3/4 HP water-cooled condensing unit with full controls for automatic operation
- digital temperature controller / display
- automatic expansion valve and hot gas bypass
- stainless steel immersion coil, coolant tank and drain plug
- 1/3 horse power (HP) rotary vane type pump with 4 gallons per minute (GPM) @ 60 pounds per square inch (PSI) capacity
- interlock connections for "Low-Flow" and "High-Low Temperature" fault indication
- configured for 220V input power
- includes rubber castors and aluminum air filter

19.0 Residual Gas Analyzer (CLIN 0002) (Option Item)

The contractor shall provide a residual gas analyzer for inline process monitoring and diagnosis. The gas analyzer must meet or exceed the following minimum specifications:

a) The system must be able to monitor the base vacuum with 5×10^{-14} Torr detection limit and the process at operating pressure of up to 10 Torr for atomic mass unit (amu) of up to 300 amu with better than 1 amu resolution,
b) The system must have two paths, one is to the residual gas analyzer (RGA) to monitor base vacuum and the other path is a pressure reducing path for monitoring the process at operating pressure.
c) The system must be equipped with a hybrid oil-free turbo molecular pump and an oil-free diaphragm pump to maintain a pressure drop from the working gas pressure to about 10^{-6} Torr pressure.
d) The system must contain a micro-hole orifice to operate at four different inlet pressures of 0.01, 0.1, 1.0 and 10 Torr.

e) The system must use both Faraday cup (FC) and electron multiplier (EM) detectors.
f) The system must be able to cover 6 orders of magnitude dynamic range in a single scan.
g) The system must come with software to operate the instrument in various modes, including analog scan, histogram mode, and pressure vs. time mode.

20.0 General Requirements

20.1 Used Equipment

Offers of used equipment will not be accepted.

20.2 Installation Site, Installation, and Training

.
The contractor shall deliver and install the UHV sputtering system to the Naval Research Laboratory, Washington DC 20375, at the location specified by the authorized government representative. NRL will be responsible for providing the necessary facilities and utility hook-ups at that location for proper installation and operation of the sputtering system. The contractor shall provide a pre-installation guide with its proposal submitted in response to the solicitation. The pre-installation guide shall indicate, in detail, all of the site requirements including, but not limited to: utility hook-ups (e.g. electrical, air, water, gas, etc.); required space (e.g., doorway passage, floor space, operating space, maintenance access space, etc.); required ambient environment (e.g. temperature, vibration, air flow, etc.); procedures for receiving the equipment and placing it in its laboratory location for use and communication hook-ups (e.g. Ethernet, portable media connections for data retrieval, etc.) The sputtering system shall be ready for immediate use following installation/set-up by the contractor. The contractor shall provide a minimum of two days of setup/training for up to three people at NRL-DC following the installation and set up of the sputtering system.

20.3 Warranty

The contractor shall offer the Government at least the same warranty terms, including offers of extended warranties, offered to the general public in customary commercial practice. These warranty terms must be included in the system price. The period of the warranty shall begin upon contractor installation and calibration of the test system.

20.4 Documentation

Written documentation customarily provided to the public with a commercial item shall be provided. This shall include user manual(s) or equivalent as well as copies of any software, and any manuals for the software included with the system, if customarily provided. This documentation must be received at NRL

with the system hardware, unless other arrangements are agreed to by the authorized Government representative.