Ion Beam Etch & Deposition System

1.0 Scope

This specification describes the minimum requirements for an Ion Beam Etch & Deposition System to be installed by the contractor at the Naval Research Laboratory (NRL), Washington, DC 20375. This system will be used by trained NRL personnel to ion mill thin film coatings and provide for the sputter deposition of thin film materials onto wafers or substrates under high vacuum conditions. The system will be installed in a multiple user class 100 cleanroom facility.

2.0 Installation Site

The contractor shall install the system at the Naval Research Lab, Bldg. 250, at a specific location to be designated by the Authorized Government Representative (AGR). NRL will provide process cooling water, pressurized air, pressurized dry nitrogen gas, argon and nitrogen process gases, liquid nitrogen and 208 VAC single and three-phase electrical power. The system must operate on 208 VAC single or three phase power and/or 120 VAC single phase power. Mechanical pumps and cryogenic pump compressors associated with the system will be located in a utility corridor up to 30 feet distant from the milling system; the contractor is responsible for providing the vacuum tubing and compressed helium lines (if a cryo pump is used), and electrical cables necessary to connect these components to the main chamber. The contractor shall install the system in a manner consistent with typical cleanroom operating procedures.

3.0 Description and Primary Components

This system is to be composed of a high vacuum system that includes an Ar^+ ion beam source to perform ion milling, a sputter deposition capability to deposit thin films onto a freshly milled wafer, and a water-cooled sample stage capable of rotation of the sample about the sample's normal axis and adjustment of angle of incidence of the ion gun and sputter gun under vacuum. A vacuum load lock with rapid pump down and sample transfer are required to minimize operator time. The system must be must be computer controlled via menu-driven software with the capability of being monitoring from a remote location via TCP/IP network protocols.

3.1 Vacuum System

3.1.1 The vacuum chamber must be constructed of 304 stainless steel using high vacuum and/or ultra-high vacuum fabrication techniques.

3.1.2 Vacuum requirements. The pumping system and chamber must be capable of reaching a vacuum of $1x10^{-6}$ Torr in 30 minutes or less and less than $5x10^{-8}$ Torr within 12 hours after exposure of the main system chamber to atmosphere.

3.1.3 High-vacuum pumps for the main chamber are to be of the turbo-pump or cryogenic pump type. Diffusion pumps are not allowed. Dry pumps are preferred as backing pumps for all turbo pumps. Turbo pumped systems must be configured with automatic vent valves to safely spin down the turbo during shutdown and emergency power outage. Cryo pumps, if used, must have automatic regeneration controls with dry nitrogen purge. Cryo-pumped systems must have a capacity of at least 1000 liters argon.

3.1.4 Loadlock. The system must be provided with a load-lock and vacuum sample transfer device capable of handling at least one 4" diameter wafer. The load-lock pumping must be provided by a dedicated turbo-pump with mechanical backing pump capable of reaching $1x10^{-5}$ Torr from ambient in < 4 minutes.

3.1.5 Vacuum gauging. The system must provide minimum one ion gauge and one convectron gauge within the main chamber to monitor pressure conditions. A capacitance manometer gauge is required to monitor gas pressure during ion milling and deposition and provide electronic signal to downstream pressure control unit. The load-lock must be configured to measure pressure between $3x10^{-5}$ Torr to atmospheric pressure (760 Torr.)

3.1.6 Downstream pressure control. The system must be configured with automatic pressure control during ion milling and sputtering. The system must be of the downstream type that modulates the opening of a valve to the main turbo or cryo pump to maintain constant pressure. The system must be capable of programmable operation at 1.0×10^{-4} – 1×10^{-3} Torr (minimum) for ion milling and $1x10^{-3}$ – $5x10^{-2}$ Torr (minimum) for sputter deposition. Pressure gauges used for downstream vacuum control are to be of the capacitance manometer type.

3.2 Ion Source

The ion source will be used to accelerate Ar^+ ions to the sample stage to provide sample milling.

3.2.1 The ion beam diameter measured at the gun output must be between 11 – 16 cm diameter.

3.2.2 Ion beam current range: 50 - 350 mA, minimum.

3.2.3 Ion energy range: 200-1000 eV minimum.

3.2.4 The ion source must be capable of neutralization of the ion beam under all operating conditions. Configurations in which the neutralizer minimizes radiant heat generation or filament wire contamination are preferred.

3.2.5 The power supply must have manual, automatic and remote operating modes and must be capable of displaying all control parameters.

3.2.6 The ion gun must be capable of achieving etch rates greater than 10nm/s for copper and with 5mm edge exclusion, provide ± 5% uniformity across a 4 inch DIA wafer.

3.3 Sample Mount and Stage

The sample stage is used to mechanically position the wafer or substrate under the ion mill or sputter gun. It is to be configured with a sample chuck to hold the wafer and allow transfer of the wafer to the sample stage through the load-lock assembly, provide cooling to the wafer to dissipate heat generated during the milling process, mechanical tilt and rotation, and allow operation of a shutter to protect the sample from the ion mill and sputter gun.

3.3.1 Substrate size. The sample chuck must be capable of holding silicon wafers up to 4" diameter wafer and variously sized smaller pieces.

3.3.2 Rotation. The stage must be capable of continuous rotation about the sample normal axis by use of computer control. Rotation speed is to be settable from 0 - 7 RPM, minimum, and operate during both ion milling and sputter deposition processes.

3.3.3 Stage tilt angle is measured as the angle between the sample normal and the ion beam axis during milling or the sputter gun axis during deposition. The stage must be capable of implementing a tilt angle from 0 – 90 degrees under computer control. The tilt axis is to be coincident with the sample surface so that the sample remains centered in the ion beam or sputtering plume during rotation.

3.3.4 Water cooling. The sample stage and chuck must be equipped for water cooling to dissipate heat generated during the ion milling process. The sample temperature is to be maintained below 50 degrees C under all operating conditions. This condition will be tested using temperature tabs placed on a 4" silicon substrate and milled at 1000V, 350 mA for 30 minutes. (NRL will provide cooling water at or below 68 degrees Fahrenheit, up to 1 gallon per minute for this requirement.)

3.3.5 The stage must accept transfer of the sample chuck to and from a load lock transfer arm.

3.3.6 Shutter. Sample isolation from the ion beam and sputter deposited material must be achieved by a pneumatically operated, computer controlled sliding stage shutter.

3.3.7 The sample holder assembly must connect to system electrical ground to minimize charging effects.

3.3.8 Sample chucks are to be provided to hold 4 inch DIA and 3 inch DIA silicon wafers.

3.4 <u>Sputter Deposition Requirements</u>

The system must be capable of *in situ* deposition of dielectric or metal films on substrates immediately after they have been ion beam etched. The sputter deposition system must be configured as follows:

3.4.1 The variation of film thickness across a 4” wafer must be less than 5%.

3.4.2 The sputter gun must configured such that no sputtered material is deposited onto the ion gun during sputtering or that no material from the ion milling process is deposited onto the sputter gun target during ion milling.

3.4.3 Power supply. NRL will provide a sputter gun power supply for integration to the system. The power supply is an ENI Corp Model RPG-100 requiring 208 VAC/45 Amp, 4-wire, 3 phase power. The sputter gun power supply is to be integrated into the computer control system in a manner that will permit full computer control of the deposition process.

3.4.4 Interlock. Water cooling of the sputter gun is required with interlock to the power supply. Power is not to be delivered to the sputter gun unless cooling water is flowing into the gun.

3.4.5 Sputter target. A silicon sputter target is to be supplied with the sputter gun for reactive sputter deposition of silicon nitride. The vendor must demonstrate the ability to reactively sputter 100 nm thick films of silicon nitride on silicon wafers with the nitride film having a refractive index of 2.0.

3.5 <u>Gas Handling</u>

The gas delivery component provides argon and nitrogen process gases to the ion gun and sputter gun.

3.5.1 The gas delivery must be controlled with 3 elastomer-sealed digital mass flow controllers (MFC), one for the ion gun calibrated for argon and two for the deposition gases calibrated for nitrogen and argon. The mass flow controllers are to be sized for 0 – 50 SCCM argon or nitrogen operation.

3.5.2 Controllers must have a bellows sealed isolation valve on the vacuum side of the controllers and each MFC must be connected to a particulate filter on the inlet side.

3.5.3 All gas lines must be electropolished 316 stainless steel with VCR fittings. VCR fittings must be used throughout the gas distribution system

3.6 System Automation

The system controller must provide automatic operation and sequencing of the ion beam etching and deposition system.

3.6.1 .System control is to be provided using a dedicated computer operating under Windows XP Professional. The computer must have a 17" flat-panel monitor, minimum 512 MB memory, minimum 1 GHz processor speed, minimum 80 GB hard drive, optical mouse, Read/Write CD capability, network interface for 100-Base T network operation, TCP/IP protocol.

3.6.2 Full pump down control. Venting and sequencing of pump operation must be accomplished through a PLC controller with a Labview or equivalent front end software.

3.6.3 The computer software must provide for display of all significant system parameters, including pump on/off status, main system and loadlock pressure, gas flow, ion beam parameters and status of all valves.

3.6.4 The controller must operate all etching and deposition power supplies and must be capable of chaining steps and recipes for etch and deposition.

3.6.5 The system must have data logging and recipe files handled through a LabView or equivalent interface.

3.6.6 The software must be capable of supporting multiple users with individual accounts.

4.0 On-Site System Training

Upon completion of installation the contractor must provide training at NRL. Training must include at least system operation, review of maintenance procedures, troubleshooting, software control, recipe editing and run data archiving.

5.0 Warranty

Contractor must provide a standard commercial warranty from the date of installation and acceptance at the NRL site.

6.0 OPTIONAL ITEMS. (Note: Price each optional item separately). These items may or may not be made part of any resulting contract.

6.1 End Point Detection System

The contractor shall provide and install an analytical end point detection system. The end point detector system must be interfaced with the system controller to enable the termination of the milling process within 10 Å of a newly exposed interface. The system must be capable of sensing this change using a 99% (minimum) masked, 4 inch DIA wafer.

6.2 6" Sample Stage

6.2.1 Must provide a wafer capacity of at least 6” diameter with sample load lock. Etch and deposition uniformity is required to be +/- 10% or less.

6.3 Spare parts kit.

6.3.1 The vendor must supply an additional grid set for the ion gun and a spare parts kit for items requiring regular maintenance. This is to include filament wire (for filament type ion guns), replacement seals and fuses. One spare mass flow controller unit is required.

6.4 Rate Monitor

6.4.1 A quartz-crystal rate monitor system is required. It must be mounted in a position where it can accurately measure the deposition rate on the sample.

6.4.2 The quartz crystal sensor part of the monitor must be equipped with a shutter to prevent deposition on the crystal.

6.4.3 The rate must be displayed on the system computer screen.

6.5 Ion Beam Current Probe Assembly

6.5.1 A probe is to be provided to allow accurate determination of the ion gun beam current at the sample. The probe is to be mounted on a retractable arm to remove it from exposure to the ion beam.

6.6. Sample Chuck Holder

6.6.1 Sample holders capable of holding 1 inch DIA and 2 inch DIA silicon wafers are required.

6.7 <u>Leak Detection System</u>

A stand-alone leak detection system for use in testing HV and UHV vacuum systems is required. The unit must include the following:

6.7.1 Must include a dry helium leak detection system.

6.7.2 Must operate at 110 volts and 60Hz.

6.7.3 Must include a turbomolecular pump with pumping speed of at least 60 liters/sec.

6.7.4 Must provide a dry diaphragm backing pump with pumping speed of at least 1.3 cubic meters/hour.

6.7.5 Must include an ultra sensitive 180 degree magnetic sector mass spectrometer.

6.7.6 Must be capable of detecting a leak rate of at least $5X10^{-12}$ sccm with a response time of less than 0.5 seconds.

6.7.6 Must have a maximum inlet pressure of at least 16 torr and an effective pumping speed of at least 2.1 L/sec.

6.7.7 Must allow for fast testing cycles.

6.7 8 Unit must be ready for operation in no more than 3 minutes after start up.

6.7.9 Unit must be able to detect masses 2, 3 and 4 and contain an internal calibrated leak standard.