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Specification for Molecular Beam epitaxy with in-situ RHEED and UHV preparation chamber
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SPECIFICATION FOR "Molecular Beam epitaxy with in-situ RHEED and UHV preparation chamber"

INST invites tender bid for "Molecular Beam epitaxy (MBE) based deposition system with in-situ RHEED and UHV preparation chamber"

System Overview:

The deposition system must have two chambers. The first chamber is called *growth chamber* and the second chamber is called the *preparation chamber*. The two chambers must allow sample transfer using UHV compatible transfer arm. The growth chamber will allow for molecular beam epitaxy (MBE) based growth process involving deposition using effusion cells, and thermal cracker cells. The preparation chamber will be used to prepare samples before or after MBE growth procedures and will allow deposition of metal and metal oxide films using sputtering and e-beam evaporation methods. The preparation chamber must allow introduction of substrate into the deposition system either manually directly from air through appropriate flange or/and optionally through a load lock chamber.

1 GROWTH CHAMBER:

A. UHV stainless Steel (made of DIN 1.4406/SS 316LN or DIN 1.404/SS 316L or equivalent) chamber (of about 30 L volume) equipped with appropriate cryo-panel for effusion cells, thermal cracker cells and different ports for specific vacuum pumping. The growth chamber must be compatible to growth of chalcogenide materials like Te, Se, and Sb.

B. Growth chamber must be of vertical deposition geometry with substrate facing downward during film growth.

C. Appropriate arrangement of vacuum pumps should be provided to attain Base pressure $< 2 \times 10^{-10}$ mbar and $< 8 \times 10^{-11}$ (LN_2 cooling). The vacuum levels must be achieved within 72 Hrs or less time post system bakeout.

D. ***Pumping System***: The pumping system must include, turbo molecular pump (TMP), ion getter pump (IGP) with titanium sublimation pump (TSP) or other getter pumps and dry scroll pump.

(i) Turbo pump having capacity of ≥ 260 l/s with dry oil free scroll pump. Power supply and suitable cabling must be provided.

Manufacturer: Turbo Molecular Pump (TMP): Pfeiffer/Varian/Edwards or equivalent internationally reputed brands.

Dry scroll pump: Pfeiffer/Agilent/Edwards or equivalent internationally reputed brands.

Gate valve: A Pneumatically operated VAT gate valve between MBE and TMP must be provided with automatic interlock for safeguarding pump in case of vacuum failure

(ii) Ion pump (speed ≥ 300 l/s). Must have integrated cryoshroud and TSP. Power supply and suitable cabling to be provided alongwith.

Manufacturer: Pfeiffer/ Gamma/Agilent or equivalent internationally reputed brands.

Gate Valve: A Pneumatically operated VAT gate Valve between MBE and ion pump must be provided with interlock for safeguarding pump in case of vacuum failure

E. ***Pressure management***: High sensitivity Bayard-Alpert ion gauge assembly to measure the vacuum pressure ($1x10^{-3}$ to $1x10^{-11}$ mbar). Pressure gauge to measure atm to 10^{-3} mbar for pre-vacuum line. Power Supply, controllers and suitable cabling to be provided along with gauges. All the vacuum gauges and controllers must be from reputed company like Pfeiffer or Edwards or equivalent internationally reputed brands.

F. ***Vacuum Pump Protection***:

- Appropriate cryo shroud/trap/panel must be provided for ion pump and TSP, to trap Se, Te and Sb for protecting the pumps.
- Appropriate control and safety interlocked with the UHV measurement system.

G. ***Cooling Shroud (double walled)***: The deposition chamber must have liquid nitrogen cooling shroud to isolate all effusion cells (reduce the cross-talk between high temperature cells). Cooling shroud must be around the manipulator and must be encircling all the effusion and cracker cells. The cooling shroud must be compatible to both liquid nitrogen and water cooling. In case of integrated water cooling unit supplied for each effusion cells then the cooling shroud around the effusion cells may be water cooled.

H. ***View ports:*** (i) Atleast two dedicated view port to see the inside of the chamber during transfer. The view port must have manual shutter to protected against material deposition

(ii) One Dedicated view port to see the effusion and cracker cells inside of the chamber. The view port must have manual shutter to protected against material deposition

I. ***Effusion and Thermal cracker cells***:

(i) Number of effusion cells: 5, Number of cracker cells: 3.

(ii) The cells must be confocal arrangement in a way that the focus of deposition of all cells must coincide at the center of substrate on which deposition will be carried out.

(iii) All the cells must be separated by cell dividers made of Tantalum to reduce cross contamination. Details of cells are as follows:

(a) <u>*High Temperature effusion cells Qty: 1 Set*</u>

- Capacity: 10cc or better
- Temperature: Atleast upto 2000 C
- One Ta crucible to be provided
- Integrated pneumatically operated shutter or electric shutter with soft acting motion controllable through software should be provided
- Dedicated necessary power supply, thermocouple, pid control and cables

(b) <u>*High Temperature effusion cells Qty: 1 Set*</u>

- Capacity: 10cc or better

- Temperature: Atleast upto 2000 C
- One Ta crucible to be provided
- Integrated pneumatically operated shutter or electric shutter with soft acting motion controllable through software should be provided

- Dedicated necessary power supply, thermocouple, pid control and cables

(c) *High Temperature effusion cells Qty: 1 Set*

- Capacity: 10cc or better
- Temperature: Atleast upto 2100 C
- One Ta crucible to be provided
- Integrated pneumatically operated shutter or electric shutter with soft acting motion controllable through software should be provided
- Dedicated necessary power supply, thermocouple, pid control and cables

(d) *Medium Temperature effusion cells Qty: 1 Set*

- Capacity: 10cc or better
- Maximum Temperature: 1400 C
- One Ta crucible to be provided
- Integrated pneumatically operated shutter or electric shutter with soft acting motion controllable through software should be provided
- A hot lip or heating arrangement to avoid condensation at crucible orifice
- Dedicated necessary power supply, thermocouple, pid control and cables

(e) *Low Temperature effusion cells Qty: 1 Set*

- Capacity: 40 cc or better
- Maximum Temperature: 1000 C
- One Al2O3 crucible to be provided
- Integrated pneumatically operated shutter
- Dedicated necessary power supply, thermocouple, pid control and cables

(f) Thermal cracker cell for Sb Qty: 1 set

- Must have separate heating stage for evaporation and cracking of evaporated molecules
- The cell must have PBN insulator to save from corrosion and to minimize cross talk bet ween heating stages
- Cracker insert should be made of PBN
- Both the heating stages (evaporation and cracking) should be separately adjustable with individual
- PBN crucible must be provided with 60 cc or better nominal volume
- Integrated pneumatically operated shutter
- Dedicated necessary power supply, thermocouple, pid control and cables
- *Operating temperature range:*
  Heating stage for evaporation must be atleast between 100 C to 800 C
  Heating stage for cracking must be atleast between 300 C to 1000 C

(g) Valved cracker cell for Te Qty: 1 set

- Must have separate heating stage for evaporation and cracking of evaporated molecules
- The cell must have PBN insulator between the heating stages to minimize cross talk bet ween heating stages

- Cracker insert should be made of PBN
- Both the heating stages (evaporation and cracking) should be separately adjustable with individual
- PBN crucible must be provided with 60 cc or better nominal volume
- Integrated water cooling unit
- Must valve unit made of PBN with motoroized integrated shutter
- Dedicated necessary power supply, thermocouple, pid control and cables
- *Operating temperature range:*
  Heating stage for evaporation must be atleast between 100 C to 800 C
  Heating stage for cracking must be atleast between 300 C to 1000 C

(h) Valved cracker cell for Se Qty: 1 set

- Must have separate heating stage for evaporation and cracking of evaporated molecules
- The cell must have PBN insulator between the heating stages to minimize cross talk bet ween heating stages
- Cracker insert should be made of PBN
- Both the heating stages (evaporation and cracking) should be separately adjustable with individual
- PBN crucible must be provided with 60 cc or better nominal volume
- Integrated water cooling unit
- Must valve unit made of PBN with motoroized integrated shutter
- Dedicated necessary power supply, thermocouple, pid control and cables
- *Operating temperature range:*
  Heating stage for evaporation must be atleast between 100 C to 800 C
  Heating stage for cracking must be atleast between 300 C to 1000 C

J. Manipulator and sample plate:

- Two axis (Z-axis and Rotation axis) UHV Manipulator
- Z-axis: must allow for 0-50mm motion
- Rotation axis: motorized continous rotation of at least 30 RPM
- Heating stage for reaching atleast upto 1200C with PID controller
- Radiation shield to protect manipulator against material coatings
- Molybdenum substrate holder (sample plate) compatible with the sample manipulator
- Appropriate sample plate style to handle sample size of upto 12 mm x 12mm (2 qty) and 10mm x 10 mm (4 qty). one blank sample plate to be provided

H. Analytical Instruments to be provided in the growth chamber:

(i) Quartz crystal microbalance

- Should be UHV beakable
- Must have shutter
- Thickness resolution: 0.01A or better
- Rate resolution: 0.01A/S or better
- Frequency resolution: 0.01Hz or better
- Linear feedthrough unit to adjust position the sensor position inside the UHV chamber
- All necessary measurement electronics, controller and cables to be supplied for reading out information into PC

- Atleast 10 qty of gold plated quartz plates to be provided
- Necessary water cooling unit to be provided

(ii) quadrapole mass analyzer/ residual gas analyzer

- Resolution 10^{-14} or better
- Must detect mass 1-200 AMU or better
- Software to control and analyze through computer
- Necessary power supply and cables to be provided
- Manufacturer should be reputed like SRS etc.

(iii) RHEED

- In-situ characterization facility with as RHEED with 15 keV energy gun. All associated electronic assembly packages, power supply and required cables should be included. Must be controllable through computer.
- Appropriate RHEED screen with manual shatter for protection against material deposition. Manufacturer: reputed brand like Staib or equivalent internationally reputed brand
- CCD camera and analysis software to be provided as option (cf option section))

I. ***Main Shutter:*** A main shutter infront of substrate to protect substrate surface from deposition during process stabilization/ flux measurement/ thickness measurements etc. The shutter must be made of tantalum.

J. other ***Requirements:*** All the effusion and cracker cells must have the individual power supply, control electronic and cables provided so as to use them simultaneously in co-deposition mode.

2. PREPARATION CHAMBER

The preparation chamber will be used to prepare the substrate by heating before introducing to the MBE chamber and deposit metal and metal - oxide layer. The deposition in the preparation chamber will be done using ebeam evaporation, DC or RF sputtering depending upon the nature of film to be prepared on top of MBE processed samples. The preparation chamber must have appropriate port that can allow direct manual introduction of samples without the requirement of a load lock and transfer arm arrangement.

A. Must be made of UHV stainless steel (DIN 1.404/SS 316L) (about 25 L volume)

B. Appropriate arrangement of vacuum pumps should be provided to attain Base pressure < 5×10^{-9} mbar

C. Vacuum gauges along with controller, and suitable cabling to cover the full range of vacuum operation.

D. Pumping system must include turbo molecular pump (685l/s or better pumping of N_2), dry scroll pump, any further vacuum pumps as deemed necessary to attain the base pressure. All pumps must have their power supplies and required cables for running. Pumps and gauges must be from Pfeiffer/Varian/Edwards or equivalent internationally reputed brands. In case of supplying other pumping speed of turbo molecular pump it must be ensured that Base pressure < 5×10^{-9} mbar vacuum is reached within 8 Hrs.

E. Must have an appropriate transfer arm for transferring sample from preparation chamber to growth chamber.

F. A VAT gate valve between preparation chamber and growth chamber

G. Must have appropriate port that can allow direct manual introduction of samples without the requirement of a load lock -transfer arm arrangement.

H. Must have a UHV Planar magnetron source 2": Qty 1

- Target Diameter: 2"
- Must be bakeable upto 200C
- Water cooling
- Pneumatic shutter.
- Must allow for DC, RF and AC operation
- Must allow both magnetic and non-magnetic target for deposition
- Must be compatible O_2, N_2, and Ar

I. DC Power supply for magnetron source with 1000 W or better power. Cabling to be provided. Power supply must be of internationally reputed brand

J. RF Power supply for magnetron source with match box.
Power 300W, Frequency: 13.56 MHz, RS232 interface and set of suitable cables to be provided. Power supply must be of internationally reputed brand

K. Gas dosing system for sputter sources: Must have appropriate mass flow controllers, necessary leak valves and gas capillary connections and tubings compatible with O_2, N_2 and Ar

L. UHV Electron-Beam Evaporator for high purity evaporating of different kind of materials by electron-beam evaporation.

- Maximum Temperature range 2700C or better
- Must have X-Y beam deflection
- Necessary Power supply , controller and suitable cable to be provided
- Crucible size: 5cc or better
- Tantalum crucible to be provided
- Pneumatic shutter

M. Sample stage/manipulator with rotation (0-30 RPM or better) and heating upto 1000C
Necessary power supply, PID controller and cabling to be provided.

N. Quartz crystal microbalance

- Should be UHV bakeable
- Must have shutter
- Thickness resolution: 0.01A or better
- Rate resolution: 0.01A/S or better
- Frequency resolution: 0.01Hz or better
- Linear feedthrough unit to adjust position the sensor position inside the UHV chamber
- All necessary measurement electronics, controller and cables to be supplied for reading out information into PC
- Necessary water cooling unit to be provided

O. Viewport: There should be a view port to see the evaporator and sputter source and sample transfer inside of the chamber. The view port must have manual shutter to protect against material deposition.

P. Ports: Additional ports should be available for future integration of atleast two more sputter source or one sputter source and one ion source/ebeam evaporator

3. PROCESS CONTROL SYSTEM AND COMPUTER PACKAGE

- State-of-the-art PC unit must be provided
- Software control of Valve cluster and modular expandable electrical terminal to interface analog and digital signals, such as:
  - Valves and Shutters (pneumatic or electric)
  - Temperature sensors
  - Analog signals from other devices
  - Digital signals from other devices (
  - Heating lamps or similar
  - Motion (intelligent servo motors)
- Appropriate I/O computer interface via Ethernet TCP-IP where necessary must be provided
- Appropriate software for control exclusively from PC that should include
  - For system control (venting, evacuating and bake-out)
  - Incl. functions like ramping, logging and conditional sequence
  - Graphical user interface with completely interactive elements for a best view over the system
  - Capable of running growth recipes and complex sequences with high time resolution through a graphical editor/ graphical user interface
  - Must have appropriate Continuous data logging capabilities
  - Complete control for devices with communication interface must be integrated
  - Note: Implementation of further instruments via remote access must be done for free within the first two years after delivery

4. FRAME

- Made from stainless steel
- To keep all chambers and necessary accessories

5. RACK and MEDIA DISTRIBUTION

- Appropriate arrangement must be provided for mounting
  - Water cooling distribution
  - Central distribution of the different gases for the preparation chamber, pressed air etc.
  - Central distribution of the power and the thermocouple connections to the effusion cells, the manipulator heaters etc.
- Free space for further mounting of valve banks for shutter and pneumatically gate valves etc.
- Free space for further mounting of additional units, mounted to the media panel
- Appropriate rack must be provided for PID controllers, computers power supply, main switch, power distribution box etc. There must be flexibility on positioning and layout of racks to enable optimum working practice in our laboratory.

6. BAKE-OUT TENT and/or arrangements for the Chambers and ion pump

- Bake-out equipment to bake out the system including the growth chamber, ion-pump, and preparation chamber
- appropriate radiation heaters must be part of bake out package alongwith fan for a homogeneous temperature distribution inside the bake out area
- Proper bake out controller for the chambers

7. UTILITIES/SPARES

A. Utiliies

Tool case for minor maintenance work incl. helpful accessories:

- Various suitable wrenches, screwdrivers, Allen® keys, pincers etc.
- Torch light, graduated metal rule, level, glass fiber pencil etc.
- High temperature grease for lubrication of air-side mechanics
- Set of spare sealing

B. Spares

- Complete set of gaskets (15 no. of each type/size of flanges, Silver coated)
- Spare filaments (4 nos. for RGA, each ion Gauges)
- Fuses (20 nos. For each type)
- TSP filaments (10 nos.)

OPTIONAL ITEMS:

1. Load lock:

UHV stainless steel chamber with flanges for connection to the preparation chamber, a transfer rod, fast loading door, pumping system including appropriate turbo pump and vacuum gauges wide range gauge. Must attain base pressure of 10^{-8} mbar. VAT valve for putting in between preparation chamber and load lock. Must have sample storage for atleast for three samples. IR heating for special lamp heating unit to bake out the samples and remove water quickly.

2. UHV Planar magnetron source 2”

- Target Diameter: 2”
- Must be bakeable upto 200C
- Water cooling
- Pneumatic shutter.
- Must allow for DC, RF and AC operation
- Must allow both magnetic and non-magnetic target for deposition
- Must be compatible O_2, N_2, and Ar

3. **Beam Flux Monitor**

- Mounted to a UHV linear feedthrough
- Must include filament protection tube as shielding in home position
- He leak checked, tested in UHV
- Bakeable up to 200°C
- With power supply
- With connection cables and suitable connectors

4. CCD camera for imaging RHEED data and RHEED analysis software

5. Appropriate Water Chiller

6. Appropriate Air compressor

7. Cryo trap/baffle for TMP

8. Wobble stick for substrate manipulation in growth chamber

9. LN2 Deewar of 100 liter and/or 150 liter to be quoted

10. MBE grade source materials (6N or better purity): Fe, Te, Se, Mn, Cr, Nb, Ge, Co

Other required terms & conditions:

i. Layer growth training/material specifications.
ii. The vendor must have the proven capability to provide a thorough epilayer demonstration programme. Installation and Training at user site should be provided.
iv. Prospective suppliers must provide training for epitaxial growth for at least three days on the fully installed instrument. The source material and substrate for training to be provided by customer.

v. It is essential that the scientist(s) delivering the programme is (are) a full – time employee(s) of the system vendor and is (are), as such, expert and fully conversant with every aspect of machine operation, functionality and the philosophy of the design that led to its development. Further, the training manager(s) must be accessible for consultation beyond the completion of the scheduled epi-layer demonstration.

vi. **Utility power**: 230 V single or 440 V three phase, 50Hz. Total power consumption of the system under full operation should be mentioned. UPS requirements for the system should be mentioned.
vii. **Applications support**: The vendor must provide evidence that there lies embedded at the core of the company, a true applications culture that has evolved and continues to evolve with the companies technology interests. Application support that is void of heritage and pedigree will be viewed less favourably than otherwise.
viii. User reference list worldwide should be attached. A minimum of 5 successfully installed MBE system of similar type worldwide in the past 7 years.
ix. Hard and soft copies of all relevant documentation including operating manual, service manual etc., run up to epitaxy, source loading, installation should be provided.
x. Warranty for one year after the date of installation. Additional AMC for 4 years beyond the warranty period should also be quoted for.
xi. System Functionality to be demonstrated

- Functionality of water cooling and media distribution
- Functionality of effusion cells, PID controllers and shutter mechanisms
- Functionality of sputter guns
- Functionality of sample transfer, sample heating and sample rotation
- Achievement of Vacuum levels as per tender requirement for all the chambers
- Simultaneous co-deposition functionality of effusion cells

xii. Layer homogeneity

Achievable film homogeneity better than 1% over 10x10mm wafer must be demonstrated after showing the vacuum specification. A maximum of 2.5% edge area of the substrate may be excluded from this measurement. All required materials, and homogeneity measurement tools for characterization will provided by the customer in state-of-the-art quality. The customer covers all costs for materials and characterization for the growth.