Request for quote and Specifications of reactor for depositing doped and undoped heterostructures of Al, In and Ga nitride and their alloys on 2 to 8 inch substrates of Sapphire, SiC and Si

- The GEECI (Gallium Nitride Ecosystem Enabling Centre and Incubator) at SID-Indian Institute of Science is seeking bids from qualified industries for a MOCVD reactor for growth of the III-V nitrides as per the specifications below.
- Companies need to submit two bids, a technical bid and a commercial bid, in **two separate** sealed envelopes. The bids should be submitted no later than 30 days from the date of posting of this tender, as listed on the website date/time stamp, and by 5 pm on the 30th day or next weekday in case the 30th day falls on a weekend or a national holiday.
- Both technical and commercial bids should be addressed to "The Chief Executive, SID, IISc, Bangalore 560012, GST # 29AAATS5333E1ZJ."
- All quotations should be CIF Bangalore.
- Cost of last mile transportation, including any insurance, from port of shipment to IISc has to be quoted as an option.
- In case of courier shipments maximum permissible weight would be 70kgs.
- The envelopes should be addressed to "Prof. Srinivasan Raghavan, CeNSE, IISc, Bangalore, 560012" and submitted to the office at CeNSE, IISc in Room No. GF 15 between 9 am and 5 pm.
- All questions regarding this tender should be addressed to Prof. Srinivasan Raghavan at the email address sraghavan@iisc.ac.in
- Post such submission all vendors should send an email to sraghavan@iisc.ac.in with the subject line: "GEECI_Bidder's name_Tool Name" to intimate him of the submission within one day.
- Deviations from the technical specifications requested are allowed. Such deviations must be highlighted and justified. Their acceptance or rejection will be left to the discretion of the technical committee.
- The equipment sought will be placed at the Centre for Nano Science and Engineering (CeNSE), Indian Institute of Science (IISc). IISc is India's No. 1 institution on higher learning and the Center for Nano Science and Engineering is home to one of the best academic fabs in the world.
- The technical response, corresponding to the tool being offered, should be in the form of a compliance table with at least 5 columns. Serial number in column 1. Each of the items below should be addressed in a separate row of the table in column 2. Compliance to this requirement, in Yes/No, deviation from it and justification should be provided in the neighboring columns 3-5. Post the opening of a hard copy of the technical bid the committee will request for a soft copy of the files for further processing. Companies should **NOT** mail soft copies of the files unless specifically requested for.
- Detailed technical specifications of the tool being offered should be included.
- Any additional capabilities or technical details, that you would like to bring to the attention of the purchase committee, can be listed at the end of the technical table.
- If multiple systems can fulfill the requirements, vendors can submit multiple bids.
- Vendors are encouraged to highlight the advantages of their tools over comparable tools from the competitors.
- The commercial bid should be broken up to the maximum extent possible into separate items with a cost against each to enable better comparison of price for various configurations across the bidders. As an option, please provide itemized cost for any *suggested* accessories/add-ons that may enhance the usability, capability, accuracy or reliability of the tool. Vendors are encouraged to quote for as many add-ons as their tool portfolio permits.

1. Growth chamber:

A. Capable of controlling (closed loop PID control) and operating at temperatures from 100-1200°C (+/- 1°C) continuously.

B. The option of going up to higher temperatures, if available, should be quoted separately

C. Capable of controlling and operating at pressures from 10-650 Torr (+/- 2 Torr). If a larger pressure range is recommended that may be highlighted in the technical quote.

D. Capable of depositing GaN layers 5 microns thick at growth rates of at least 1 micron/hr across a 2 to 8" wafers of Si, SiC and sapphire with thickness variation not exceeding 5% (+/- 2.5% of average) on Si. FWHM of (0002) and (10-10) omega scans on Si shall not exceed 360 arc seconds.

E. Same as above for uniformity of thickness and composition of AlN and AlGaN layers with composition of AlGaN varying from 0 to 100% AlN.

F. Capable of depositing AlGaN layers of nominal thickness 30 nm across 2-8" wafer on a 4 micron GaN layer on the substrates above with thickness variation not exceeding 5% and composition variation in a $Al_xGa_{1-x}N$ layer not exceeding 1 % (+/- 0.5 of average). X to typically vary from 10 to 30%.

G. Capable of depositing a AlGaN/GaN/buffer layer HEMT structure on 2 to 8" substrates with sheet resistance variation not exceeding 1% (100x 1 standard deviation/average value).

H. Vendor to include as part of the technical bid the feasibility of measuring thickness and composition uniformity across an 8" wafer as part of pre-shipment inspection.

I. Growth chamber shall be provided with a suitable load lock and mechanism for loading samples without exposing reactor to the site ambience provided. **Options**, manual and automated, may be suggested.

J. If loading is to be though a glove box, a mechanism of cleaning the box using vacuum to be provided **as an option**.

K. A recipe for cleaning, if required, shall be provided by the vendor to restore the growth chamber to a state that will ensure stable operation (also see point 8 for stability parameters).

L. Capable of depositing layers with the following characteristics.

L.1 Undoped GaN

a) Background concentration £ 1E16 cm^{-3}
b) Mobility @ RT ³ 350 cm^2/Vsec
c) Thickness uniformity £ 2%
d) FWHM of PL @ RT £ 60 meV

L.2 n- GaN

a) Doping level ³ 5E18 cm^{-3}
b) Mobility @ RT ³ 200 cm^2/Vsec
c) Sheet resistance uniformity@ RT £ 1%

L.3 p- GaN

a) Doping level ³ 2.5E17 cm^{-3}
b) Mobility @ RT ³ 10 cm^2/Vsec
c) Sheet resistance uniformity@ RT £ 1%

L.4 c-doping: Of the order of $1x10^{17} – 1 x 10^{19}$ cm^{-3}
L.5 Fe-doping: Of the order of $1x10^{17} – 1 x 10^{19}$ cm^{-3}
L.6 Mg-doping: Of the order of $1x10^{17} – 1 x 10^{19}$ cm^{-3}
L.7 GaN/AlGaN HEMT Heterostructure on Si and SiC:

a) 2DEG Mobility ³ 1800 cm^2/V-sec on Si and approaching 2000 cm^2/V-sec on SiC.
b) Sheet carrier density of 2DEG ~ 1E13 cm^{-2}
c) Thickness variation across an 8 inch Si wafer and 6 inch SiC wafer across at least 5 runs of less than 5% range.
d) Al composition variation in AlGaN variation across an 8 inch wafer across at least 5 runs of less than 2% range.
e) Edge exclusion in 6 inch and 8 inch wafers, to meet the above criteria, to be specified.
f) Vertical leakage of less than 1 micro-A/cm^2 at 900 V on Si as measured through Ohmic contacts.

At the time of submitting the bids, the MOCVD vendors should provide 6 and 8" wafers with HEMT layers meeting the specifications in k.7 above.

M) In-situ Monitoring:

a) Growth chamber shall be loaded with in-situ measurement tool or tools capable of measuring curvature, growth rate and **wafer surface** temperature.
b) The ability of the in-situ measurement tool to measure these parameters across a single wafer and on multiple wafers, when more than one are loaded in a single run, such as on a carrier, should be included in the technical bid.
c) The smallest curvature change from a reference flat that can be measured by the tool in the MOCVD growth environment and typical temperatures of operation should be specified.
d) A reference flat and a standard curvature reference, if required for tool calibration, should be provided.
e) The accuracy of **wafer surface** temperature measurement in the range of 500-1200 should be specified.
f) Details of temperature calibration on different substrates – for instance if it is by emissivity corrected pyrometry- if any, should be included in the technical bid.
g) Details pertaining to how the tool may be able to handle challenges associated with temperature measurement on non-opaque substrates such as sapphire and SiC should be included.
h) Any other capacity that the tool is capable of such as in-situ composition measurement, and real time control of process to alter composition may be mentioned.

2. Gas Manifold:

Gas manifold will consist of

a) Separate run-vent stacks for metalorganic sources and ammonia/silane sources with active pressure balancing in both. Vent-Run stacks shall include suitable valves for fast switching of precursors and make-up flows between vent and run lines.
b) At least 3-metalorganic channels for TMA, TMG and TMI that incorporate necessary valves to divert flows through and bypassing bubblers, mass flow controllers for carrier and pusher flows, pressure controller of suitable range and flow rate to control total pressure in bubblers and baths equipped with PID temperature control of +/1 0.1°C and capable of cooling down to -20° and heating up to 100°C. The TMI line shall incorporate in addition a suitable device such as an Epison that serves to keep the flux of TMI constant. TMI lines shall be capable of being heated to a suitable temperature to prevent TMI deposition in the lines.
c) 3-metalorganic channels also called as double-dilution channels in previous Thomas-Swan nomenclature for dopants that incorporate in addition to the configuration in the previous item an additional final mass-flow controller that serves to control the diluted dopant stream. The difference between the flow through the final mass flow controller and the sum of flows through the carrier and pusher line will be diverted swept to the vent line through a suitable check valve.
d) 1 standard gas channel for NH_3 that incorporates the necessary valves, point of use filter and mass flow controllers for NH_3 and a push gas.
e) 1 gas channel for Silane in double dilution format as before that incorporates in addition to the source and push lines a final mass flow controller that controls flow of the diluted dopant stream, with difference as in item 2(c) swept to the vent line through a check valve.
f) 1 gas channel for carbon in double dilution format as before that incorporates in addition to the source and push lines a final mass flow controller that controls flow of the diluted dopant stream, with difference as in item 2(c) swept to the vent line through a check valve.
g) Make up lines for both the metalorganic and ammonia vent run stacks for balancing gas flow switching with necessary valves and mass flow controllers.
h) Suitable leak test manifold to enable He-leak testing of gas manifold
i) Gas manifold will be made out of welded (using orbital tube welding) SS316L electropolished tubing construction with Swagelok VCR type connectors for all fittings and leak tight to less than 4x10-9 sccs of He.
j) Gas panel should include a group-III manifold that enables simultaneous use of hydrogen and nitrogen as carrier gases when more than one source is being used for growth such as in the case of AlGaN or InGaN.
k) Dew point monitors on both the hydrogen and nitrogen lines at the inlet capable of going down to -130°C.

3. Computer control:

a) Valves, mass flow controllers, pressure controllers on metalorganic lines, pressure control of growth chamber and temperature control should be capable of being operated through an automated interface working in a stable software environment, MS Windows or otherwise. A graphic user interface should be provided to monitor process status during a typical run.

b) The automated interface should also allow a "manual" and a programmed mode. In the "manual mode" it should be possible to send set points to the MFCs, temperature controller, growth chamber pressure control system (most likely a throttle valve controller) and also operate valves when not running a pre-programmed growth recipe. The programmed mode will be used for running a pre-saved growth recipe.

c) Automated interface should also be sensitive to alarm sensors and interlocks required for the safe operation of the system.

d) Automated interface should also log and save process data and status of various alarms during the course of a process.

e) The following features are desirable in the run program. The ability to stall the growth process, the ability to abort the growth process to a safe abort recipe, the ability to end the process, the ability to reset the process, the ability to jump to a different or subsequent segment in the growth process and the ability to stall and edit non-executed portions of the growth recipe during a growth run.

4. Reactor Exhaust:

a) Growth chamber shall be evacuated through a dry pump capable of handling ammonia and pumping the growth chamber and the entire leak free gas manifold to below 1 Torr in less than 30 seconds in the absence of any gas flow. It should also be capable of handling any gases that may be used to either clean the chamber in between run and or bakeouts.

b) Exhaust system should feature a pump bypass line operated through a suitable check valve that prevents pressure build up in the system in the event of a power failure or in the event that the pump is not operational.

c) Exhaust system should feature a gas scrubbing system that reduces ammonia and metalorganics in the exhaust to safe level prior to final release into the atmosphere and also dilutes the hydrogen level to below 4 % (hydrogen+nitrogen+oxygen mixture). The nitrogen and oxygen component will be provided on site thorough in house nitrogen and air handling systems.

d) In the event that a wet acid scrubber is used for removal of ammonia, the scrubber should feature closed loop PID control of scrubber effluent pH. A mechanism should be provided for easy pump out of used scrubber fluid into the facility effluent drain and a safe mechanism of replenishing the scrubber with the neutralizing acid.

e) Vendor is also expected to provide two sets of spares for the acid pump that will be used in the wet scrubber.

f) Dew point monitor on the exhaust capable of going down to -130°C.

5. Input Gas Handling systems:

a) Ventilated gas cabinets shall be quoted <u>as a separate item</u> along with suitable manifolds that include pressure regulator and are provided with cross purge assemblies for ammonia, hydrogen and nitrogen gas **<u>as an option</u>**.

b) Gas purification system shall be quoted as a separate item provided for purifying all the above gases of oxygen containing species down to ppb levels as an option in the

quote. Vendor is requested to quote for point of use purifiers, life time end-point detectors and purifiers that can be regenerated **as an option**.

c) All three gas lines will have inline sub-1 micron particle filters.

6. Safety features and interlocks:

a) System shall contain safety features and interlocks for safe operation of the reactor.

b) In particular, safety interlocks and alarms should include among others.

i. Inability to open the reactor chamber during a run process.

ii. Inability to open the reactor chamber when it is connected to the pump and at sub-atmospheric pressure.

iii. Inability to open the reactor till it has cooled down to less than 100°C, all NC valves are closed, the reactor has been purged with nitrogen for a preset time and pressure is at atmospheric pressure for a preset time.

iv. Reactor over pressure alarm and pressure release mechanism.

v. Low cooling water pressure alarm if water cooling is used.

vi. High pressure alarm for reactor and gas cabinets to ensure that they are being properly vented.

vii. At least two hydrogen gas alarms in the reactor cabinet and gas manifold cabinet.

7. Installation and commissioning:

a) Quote should include **as an option** the cost of shipping the system and locating it **AT THE SITE** specified by the client. This includes the final mile transfer from the airport or dock to the site. IISc will provide documents for customs clearance.

b) The technical bid should include details of utilities required – power, water, gases and vacuum- for the stable operation of the reactor.

c) Quote should also include **as an option** a turnkey contract for installing the system on site:

i. Connecting lines from location of source gases, N_2, H_2 and NH_3 to the inlets in the reactor using electropolished SS tubing, welded construction and VCR fittings. For ammonia and Silane coaxial tubing to be used.

ii. Connecting lines from exhaust to scrubber using electropolished SS tubing, welded construction and VCR fittings

iii. Connection dilution nitrogen stream from nitrogen source to scrubber if warranted

iv. Incorporating point of use purifiers and end point detection systems into gas manifold if purifiers are provided by client and are of dimensions that can be included inside the gas manifold

v. All other SS tubing construction as deemed by manufacturer that is warranted for the safe operation of the system

vi. Connecting vents from gas cabinets, scrubber, pump cabinet, reactor cabinet, gas manifold cabinet and other vents to the building exhaust provided by client on site.

vii. Making hardwired electrical connection if required from electrical outlets provided by client on site:

viii. Hooking up cooling water systems from points provided by client on site

ix. Connecting in house dry compressed air supply at required pressures to the system for operation of pneumatic valves

x. All other hooks ups as deemed by manufacturer that is warranted for the safe operation of the system

d) System shall be He leak tested after installation on site either with leak detector provided by the client or by turn key contractor and certified to not have leaks greater than 4×10^{-9} sccs of He

e) Commissioning shall also involve training of a certain number of personnel agreed upon between the client and vendor.

f) Trained personnel will run the reactor independently and be certified by vendor representatives that they are satisfied with the level of training. **The vendor will not be held liable for such certification.**

8. **Clean Room Compatibility**: Tool should be compatible with a class 1000 clean room or better.
9. **SEMI Standards:** The technical bid should include details of the SEMI standards the tool confirms to.
10. **Recipes:** Vendor should list recipes for GaN HEMTs, both depletion and enhancement mode, on Si and SiC respectively that can be shared with the customer in the technical bid. Vendor should also indicate if whether such recipes can be part of the tool qualification and acceptance criteria if device fabrication and characterization can be made available within mutually agreed upon time frames.
11. **Tool Qualification and Acceptance**: Commissioning shall involve demonstration of growth of hetrostructures mutually agreed upon between the client and vendor and characterized by the client within time frames agreed upon and based on the details given in point 1 of this document. Details of the stage wise certification protocols to be pursued

for tool acceptance pre-shipment at the vendor's location and at IISc post installation should be included in the technical bid. The PO will include a mutually agreed upon set of tool qualification criteria.

12. **Tool Training:** The bid should include as an option the cost of training personnel on site before shipment and at IISc post installation.
13. **Tool footprint and utilities**: A floor plan should be part of the technical bid. A list of utility requirements should be part of the technical bid. The system should be compatible with 240±10V, 50 Hz single phase or 415±20V, 50 Hz 3 phase supplies. The **MINIMUM** set of utility requirements needed are provided in Table 1. If there are additional utility requirements please include them in the technical bid. **Please list connector types for all utilities.**
14. **Cost of Ownership and supply of spares:** The quote should include a listing of spares that need to be replaced periodically to ensure that the system is in operation in a stable fashion – the stability parameters being defined by the vendor and agreed to by the client – the cost of such items, the ability to guarantee their availability at this cost for a period of 5 years from the time of procurement. The aim of this exercise is to compare cost of ownerships between reactors.
15. **Maintenance**: The cost of an annual maintenance contract and cost of emergency technical support that may involve an engineer being on site should be quoted for in the commercial bid and addressed in the technical bid. The availability of trained engineers in India for servicing the system will be preferred. If more than one type of maintenance contract is available they should be listed as separate line items in the commercial bid.
16. **Maintenance:** On all systems a set of basic tools required -non-standard screw or spanner head that is required for routine tool maintenance should be mentioned- for performing routine maintenance should be included.
17. **Maintenance:** System operation, process and troubleshooting manuals and detailed drawings are a must. Their inclusion must be indicated in the technical bid.
18. **Online support:** System should have the capability for online diagnostics from a remote location in case of tool problems.
19. **Post sales service and Indian Presence:** Bidders should provide details of after sales service and support available in India. If not India, the nearest geographical location should be specified. Please provide details of the number of trained personnel in India who can service the machine, the number of tools sold in India and the corresponding number in the southern region or in Bangalore.
20. **Payment Terms and Conditions:** On all systems the payment terms should be specified in the technical and commercial proposal and is subject to negotiation.
21. Bidder shall have to submit audited accounts of financial year 2017-18, 2018-19 and 2019-20. Audited statement must be signed and stamped by qualified chartered accounted. Income Tax return for assessment year – 2017-18, 2018-19 and 2019-20.
22. **References:** Bidders should provide details of other locations in India with similar tool installations.
23. **References:** Bidders should provide details of at least 3 other locations globally where similar tool installations have been deployed for device fabrication in a clean room preferably for production purposes.
24. **III-V nitride processing:** Please include information on whether the tool and its fixturing has been used for deposition of the said metals on GaN on Si wafers of 6" diameter for power applications.
25. **Shipping:** On all systems the cost of shipping up to IISc should be included. IISc will help with customs clearance at Bangalore Airport. Please include your payment option.

IISc would prefer to retain at least 20% of payment till instruments have been commissioned and successfully demonstrated.

26. **Company financials:** Bidder shall have to submit audited accounts of financial year 2017-18, 2018-19 and 2019-20. Audited statement must be signed and stamped by qualified chartered accounted. Income Tax return for assessment year – 2017-18, 2018-19 and 2019-20.
27. The following documentation should be provided. ISO9001 quality certification. CE marking confirmation.

Details to be provided in addition to other utility requirements the tool may require. If not applicable mark as NA: Not applicable.

				Electric		**Chilled Water**		**Gases**																**Exhaust**	**Thermic load**
Tool Foot Print, (LXBXH)			Area	Power consumption average	Peak power	Cooling capacity	Cooling Water Process	UHP Nitrogen	UHP Hydrogen	Dopant Silane	Pure Silane	Ammonia	Chlorine	He	Oxygen	Regular Nitrogen	CF_4	CHF_3	SF_6	NO_2	BCl_3	Argon	Forming Gas		Thermic load to clean room
L (mm)	B (mm)	H (mm)	Sq. M	kW	kVA	kW	l/h	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	slpm	m^3/h	kW