TECHNICAL SPECIFICATIONS for Thermal Chemical Vapor Deposition unit for 2D Materials

Description and Technical Specifications:

The CVD Furnace with fully automated system should consist of

- a fused quartz tube furnace,
- a precision mass flow gas control station,
- atmospheric as well as low pressure station,
- exhaust port,
- safety interlocks,
- other components needed for the growth of 2D materials.
- user friendly graphical user interface for real-time monitor and control.
- provision for user defined recipes.

The maximum temperature of this workstation should be 1200°C or higher. The system should be able to achieve desired vacuum (10^{-3} mbar or lower) to grow monolayer materials. The mass flow gas control station should be able to mix two or more different gases together and input the mixed gas into a fused quartz tube inside the furnace. The individual gas flow rates should be precisely controllable. The system should offer a wide range of material depositions including those of chalcogenides, perovskites, oxides and other nanowires/2D materials. Inter-process contamination should strictly be avoided by providing appropriate replaceable parts.

The system should have the following general specifications and accessories.

S.No.	Item Specifications	
1.	**Tube Furnace**	
a.	General Features	High-quality Research-grade Split Tube Furnace with resistive heating-elements.
b.	Maximum Temperature	Max Temperature :1200 ºC or more. Continuous working temperature: At least 1100°C
c.	Number of Zones	Three or more
d.	Temperature Control and Stability	The temperature should be well within ±1°C of the set-point over entire operating range under steady-state isothermal conditions Even while ramping at rates δ ±5°C/min, the temperature should remain within ± 1°C of the set ramp profile
e.	Heating Rate	Programmable for each zone with at least 50°C/min up to 300°C, 30°C/min up to 600°C, 20°C/min up to 900°C and 5°C/min up to 1150 °C
f.	Cooling Rate	Programmable negative temperature ramps limited only by the natural cooling rate of the furnace.
g.	Heating Zone Length	300 mm or more with a constant temperature zone of at least 150 mm. A configurable zone length from a minimum of 150 mm to 450 mm or longer in multiple discrete steps would be preferable.
h.	Spatial Temperature Uniformity	Better than ±1 °C within each heating zone. A plot of the axial temperature profile with the zones at 3 widely different temperatures e.g. 600, 800 and 1000 °C should be provided as a part of the specifications.

i.	Temperature control and measurement hardware	Precision PID temperature controllers >30 ramp-and-hold programmable segments. Temperature measurement: Through K Type or N types thermocouples. One extra temperature monitor should be built in to shut down power when the temperature goes out of control by accident.
j.	Skin temperature	Should not exceed 25° C above ambient
k.	Power regulation	Through duty cycle controlled solid state relay (SSR) or phase angle fired thyristor
l.	Electrical Power	Single Phase 200-230 V, 50 Hz
2.	**Sample Holder** The system should be capable of handling different substrates such as silicon and quartz wafers, glass plates of given dimensions etc.	
a.	Reaction Chamber	Quartz Reaction Tube of suitable size with ID in the range of 45mm - 80mm and length in the range of 1000 mm -1300 mm to enable laminar flow and growth of 2D materials on 1 inch × 1 inch specimens. Two spare quartz tubes should be provided. Additional quartz tubes may be quoted for (optional). Provision for using a different size (diameter) quartz tube is a must. The flange temperature should not exceed 50 °C above ambient. The precise chilling/cooling mechanism used to achieve this must be clearly specified. If a water cooling system is used to control flange temperature, then customized water-cooled flanges and water chiller should be provided. Water tank with 10-20 liters capacity and appropriate pump with over flow protection should be included. The water chilling plant should be constructed with wheels to move the equipment easily. Automatic on/off Digital temperature controller with set temperature, automatic cooling on/off facility 5-10 ^{o}C for secondary coolant (water) ~10 lit/min. Independent control for chilling plant and water circulation pump.
b.	Sample/ component size	Variable, between a maximum size of 100 mm (L) × 20 mm (H) × 30 mm (W) and minimum size of 10 mm (L) × 10 mm (H) × 2 mm (W). Reduction of working zone size either by decreasing the tube diameter (see point 2.a) and/or the zone length (see point 1.f) should be possible for carrying out coating deposition on small-sized samples.
c.	Sample placement and labware	Stainless steel sample-positioning tool should be provided (2 numbers) Alumina Crucibles/Trays 10 units of 50 × 25 × 10 mm in dimensions Two pair of Thermal Gloves
3.	**Vacuum Station:** Vacuum station should consist of Double Stage Rotary Vane pump with complete accessories including vacuum gauge, SS vacuum bellows, digital display, ball valves etc. The system should be able to run at both low pressure and atmospheric pressure.	
a.	Pump-1	Heavy duty rotary pump. To evacuate process chamber to ~ 10^{-2} mbar (Ultimate Vacuum 10^{-3} mbar). Pumping Speed 250 liters per min.
b.	Cleaning of Chamber (Purge Line)	A vacuum station should enable N_2 or Ar purging/cleaning of the process tube (reaction chamber) . A separate line should be provided to flush with Ar/N_2 after deposition.

d.	Pressure gauges	Anti-corrosive pressure gauges in the range of 0.001-1000 mbar with digital display, high accuracy and reproducibility at atmosphere, easy to exchange plug & play sensor element.
4.	**Gas Supply System**	
	Gas Supply Chamber	A gas feed system shall be provided with Mass flow controllers, Regulators, Valves, 316 steel corrosion-resistant tubing and flow monitoring devices and digital read-out. Gas handling system should be non-corrosive and catering to feed and exhaust by products. The make and model of all these components should be given with relevant documents of their specifications.
a.	Mass flow Controllers	4 Precision MFCs (Provision for 2 Extras). MFCs should be calibrated for N_2, He, Ar, H_2, O_2 and CH_4. Should have a response rate of <1 sec to a flow-controlled mass of gases and the minimum specs as follows: Flow ranges: 1000 sccm (1 no.), 100 sccm (2 no.), 10 sccm (1 no.) Accuracy: ± 1% of Full Scale or better Flow stability: 0.1% of set point + 0.1% of full-scale Material: Aluminum or Stainless Steel, Non Magnetic. Closed loop fast response solenoid Readout and display for set point and actual flow. A control panel for operating MFC should be provided in the graphical user interface. Detailed specifications of each MFC along with their make and model model are a must.
5.	**Vacuum readout, control and exhaust system**	
	1. Springless diaphragm or butterfly valve for vacuum port 1. Digital Pirani gauge and/or diaphragm based pressure sensor in the range of 0.001 mbar to 1000 mbar 2. Optional pressure control in the range of 10 mbar to 1000 mbar using a closed-loop electronic back pressure regulator. 3. Purge: To let out process gases in a controlled fashion. The system should prevent backflow of air into the system from the atmosphere by maintaining a positive tube pressure while purging. 4. Exhaust: An exhaust pipe should be provided to dispose off process gases safely. Traps should be provided to arrest sulfur/selenium fumes	
6.	**Automation and Computer Control**	
	Graphical User interface	• Monitor: The system should be able to display and record the following parameters digitally in real time. (a) Furnace temperature profile and individual heater powers (b) Gas flow rates and supply pressure (c) Tube pressure (d) Vacuum pump and purge status • Interactive control: The user should be able to set the following parameters from a computer interface in real-time. (a) Heating zone temperature set-point (b) MFC gas type and flow set-point (c) Vacuum pump on/off (d) Purge valve on/off The user should be able to save the entire process as a recipe, which can be later executed to repeat the growth results.

	Automation	(a) Fully automated PC control with Linux/Windows Operating System. For a Microsoft-based system, a Windows license should be quoted for and provided. (b) Unattended operation: The system should be capable of controlling all process parameters sequentially through user-defined recipes. (c) Remote access: User should be able to monitor, interact and run recipes on the system remotely over LAN.
7.	Clear documentary proof of synthesis of high-quality graphene and MoS_2 carried out using the CVD quoted for should be provided as part of the technical bid.	
8.	**Safety and other requirements** 1. The entire system should be thoroughly checked for leaks (All leak rates should be less than 10^{-3} cc/s). This should be shown at the time of inspection 2. Suitable audible/visual alarm should be provided in case of malfunction of CVD furnace like temperature shoot-up, excessive withdrawal of power, vacuum loss and/or deviation from the chiller-water/gas flow rates. 3. The vendor should specify the maximum power rating and weight of the furnace. 4. All the emergency procedures should be clearly spelled out in a detailed document to be provided to IIT Madras.	
9.	**Installation and training** Complete installation should be done by the supplier at IIT Madras and the expense associated with installation and training should be included in the quoted price. All Electrical Power Distribution and control panel accessories required for installing the CVD need to be provided. On-site one week training for operation and application should be given free of cost. This should cover in some detail the installation and maintenance of the system by the user and a basic recipe for synthesizing MoS_2 as completely solved example demonstrating all the functions of the system. **The machine should be commissioned at the company itself before shipping to IITM.**	
10.	**Warranty and maintenance** The complete instrument should be under warranty for a period of at least two years from the date of installation. The vendor should be agreeable to entering into a Comprehensive Annual Maintenance Contract with IIT Madras at a reasonable price, for maintaining the equipment in proper working condition, after the warranty period is completed. A Quote for the cost of onsite annual maintenance for two years after the warranty period should be provided. The CVD system provider/vendor must have a service centre in India. In case of breakdown during the warranty period, a competent service engineer of the supplier should make as many visits as are necessary to rectify the problem and replace the faulty parts, without any liability of cost. The supplier should ensure the supply of all spares required for making the instrument operational. Spares recommended for keeping in inventory along with the instrument may also be quoted.	
11.	**Spare parts** The supplier should provide the list of accessories required for smooth running of the machine for 3-5 years and should quote for all the necessary accessories. The supplier of the instrument must confirm in writing that the spares for the entire instrument will be available for a period of at least ten years after the model of equipment supplied has been phased out. For frequently required spares, there should be adequate inventory with the Indian agency.	

12.	**Manual** One set of operating manual and service manual including detailed drawings and wiring diagrams (in English) should be provided with the instrument.
13.	**User list with contacts** The supplier must have installed similar equipment in at least 3 IITs/NITs/IISERs/National Labs. The supplier should provide the contact details (address, email id, phone number) of all these users so that IIT Madras can approach them for any feedback. Supplier should provide Performance certificate(s). In case of any doubt about the capability of the machine, the vendor will have to arrange a demonstration at any site, bearing the cost including the travel and other expenses of the IIT Madras representative.

Compliance Statement:

The supplier must submit technical brochures and proper application notes adequately explaining and confirming the availability of features in the model of the equipment being quoted for. **The offered specifications should accompany all Makes & Model Nos.**

The supplier must submit a table indicating the compliance of the features of the model being quoted for with those given in the indent. Features not matching – must be clearly indicated and **all deviations must be clearly specified.** Additional features and features in the quoted equipment which are better than those in the indent – may be explicitly highlighted and explained.

A detailed compliance statement should be included.