Annex No. 1 -**Technical Specification**

**Technical Specification**

**ALD system with inductively coupled plasma**

**Introduction:**

The subject is the delivery of a system for atomic layer deposition (ALD). The aim is to acquire an advanced device for atomic layer deposition, which will enable the implementation of both thermal and plasma ALD processes, including plasma diagnostics and advanced control of process parameters. The system will be used in the research and development of advanced materials at the level of single atoms and thin films for applications in the field of nanotechnology, photocatalysis and electrochemistry.

**General requirements**

* The system must allow both thermal and plasma processes with the possibility of combining them within one cycle.
* The device must have a fully automated control system with support for remote monitoring and control.
* High stability of process conditions and repeatability of deposition cycles.

**Reaction chamber**

* Made of a single block of aluminium, heated to 150 °C to prevent condensation of precursors.
* Smooth internal shape with no dead zones for fast flushing.
* Easily removable inner compartment for cleaning (2 sets).
* Quick opening of the chamber (1 minute after venting). After opening the chamber, there must be full access to the electrodes and chamber. This requirement is necessary due to the planned research activities.

**Performance of vacuum system and vacuum pumps**

* Limit pressure in reactor at least: < 5 \* 10⁻⁶ Torr
* Duration of depletion from atmospheric pressure to 1 \* 10⁻⁵ Torr: less than 20 minutes

**Plasma source**

* Remote plasma source based on inductively coupled plasma (ICP) with a diameter of <= 75 mm.
* ICP type - helical
* Direct-coupled plasma generator with automatic matching unit with vacuum capacitors
* 13.56 MHz auto-tuning radiofrequency (RF) source with min. 600 W output
* The positions of the capacitor values of the matching unit are adjustable as parameters of the deposition process
* Advanced atomic mass unit (AMU) analyser with datalogging.
* Vacuum capacitors are controlled by DC servo motors
* The plasma source can be generated at a minimum pressure of 10 mTorr.

**Substrate**

* Diameter: 240 mm, electrically grounded, suitable for placing substrates up to 200 mm in diameter using the loadlock system (see below). Possibility of open placement of substrates. Open loading of the chamber is possible without interruption of gas or vapour supply.
* Thermal surface homogeneity of the substrate < ±2.0 °C at 400 °C.
* Substrate temperature control: < ±1.0 °C.
* Bias electrode (BIAS) at 550 °C, RF generator 300 W, 13.56 MHz, direct connection with matching unit. Capacitive condenser positions: Selectable as process parameters. Advanced AMU with data logging.
* Air-cooled capacitors controlled by a DC servo-motor.

**Loadlock system**

* Independently pumped vacuum loadlock with automatic wafer transfer.
* Fully automated loadlock for single wafers with low volume (< 7 litres).
* Supported wafer sizes: 3" to 8" wafers can be directly handled in the loadlock.
* Smaller wafers and samples: They can be placed on carrier wafers or boards.
* Maximum substrate height: 9 mm.
* MonoVAT valve: Industry standard for wafers up to 200 mm diameter.
* Dry process pump: Capacity >= 15 m³/h.
* Wafer sensor: Deactivation option.
* Wafer handling: 200 mm wafer can be loaded/unloaded using vacuum tweezers.

**Gas system**

* Gas module: Separately located for a maximum of 10 MFC-controlled gas lines for plasma gases and gas precursors for thermal processes.
* Gas line configuration: H₂S or SF₆; N₂; H₂ (with bypass and internally metal-sealed MFC); Are; O₂.

**Pressure measurement**

* Capacitive pressure gauges: Range: 250 mTorr and 5 Torr Protective deflector against deposits during deposition for long-term stability
* Process pressure measurement: The capacitive pressure gauge must measure the pressure during the ALD process.
* The system must include a Penning pressure gauge for accurate measurement of low pressures.

**Process control**

* **Swagelok ALD valves:**
  + Temperature-controlled up to 200 °C
  + Valve control with a minimum resolution of 10 ms ± 1 ms
* **Rapid automatic pressure regulator:**
  + Open/close response time: 150 ms
* **Argon mass flow control:**
  + MFC linked to a rapid camber system for short bubbling and flushing
  + Including diversion to the exhaust chamber (foreline)

**Pumping configuration**

* **Pumping pipes:**
  + Diameter >= 100 mm, heatable up to 120 °C
* **Turbomolecular pump:**
  + Corrosive environment compatible
  + Pumping capacity 450 litres/s, with system heating
* **Dry pump:**
  + Minimum pumping speed 450 m³/h, chemical series
* **Automatic standby mode for nitrogen flushing.**
* **Automatic Pressure Controller (APC):**
  + Diameter >= 100 mm, response time 150 ms
  + Allows different process pressures in one ALD cycle
* **High vacuum shut-off valves:**
  + 100 mm to turbomolecular pump
  + 100 mm to dry pump
* **Process pump selection:**
  + Both pumps can be used as process pumps
* **Pump duct heating:**
  + Electric duct heating for increased process efficiency

**Analytical chamber ports**

* **Port configuration:**
  + The system must be equipped with two ports at an angle of 70° to the norm for ellipsometry.
  + One 40 mm port for connecting the RGA directly to the chamber (not to the exhaust line).
  + Optical Emission Spectroscopy (OES) port.
  + Possibility of simultaneous connection of ellipsometry, RGA and OES.
* **Port specifications:**
  + **1 × KF40 (40 mm diameter):** Analytics port for QMS, RGA and other applications.
  + **1 × KF16 port:** Positioned vertically above the centre of the wafer for optical emission spectroscopy.
  + **2 × KF16 ports:** For in-situ spectroscopic ellipsometry, placed at an angle of 70° to the norm.

**Control system and software**

* **Automated recipe control:**
  + Fully flexible control of all valves including safety interlocks.
  + Controls with timing up to 10 ms with 1 ms resolution.
* **Temperature control system:**
  + Multi-zone PLC (industrial logic computer) temperature system with a control interface located in one clear menu.
  + Controls all temperature zones from one place.
* **User access management:**
  + Fully protected access levels for different users.
  + Possibility of management of user rights by the manager.
* **PLC system:**
  + Ultra-fast PLC with digital and analogue inputs/outputs (I/O).
  + Precise precursor dispensing with up to 10 ms increments and 1 ms resolution.
  + Automatic leak check and automatic MFC check.
  + Plasma discharge confinement function between process steps.
* **User interface:**
  + Computer based on Windows 10 LTSC or higher.
* **High-speed distributed I/O:**
  + I/O data transfer up to 400 µs.
  + I/O diagnostics by individual channels (on/off status, OK status, short circuit, circuit interruption).
  + Option of adding, removing and upgrading digital and analogue I/Os without the need for additional PLCs.
  + Possibility of placing I/O controllers close to sensors and actuators for higher efficiency.
  + Direct connection: One channel per sensor or actuator.

**Security and connectivity**

* **Hardware safety connection:** Essential for the safe operation of the device.

**Processes for demonstration**

* **Reference process specifications:**
  + **Plasma and thermal ALD Al₂O₃:** Cycle time < 5 seconds.
  + **Plasma ALD TiN:** Resistivity uniformity over 200 mm wafer < ±4%, cycle time < 30 seconds.
  + **Plasma ALD HfO₂:** Thickness uniformity < ±3% over 200 mm wafer.
* **Data requirements:**
  + The Contractor must provide data for ALD SiNx at 350 °C with an oxygen content of less than 5%.
  + The Contractor must provide data for ALD SiO₂ with a wet etching rate of < 2 nm/s (in 30:1 buffered HF) with a plasma of < 10 s.
* **NbN**
  + **NbN deposition by ALD:**
    - Bed temperature: 250 °C
    - Thickness inconsistency over 200 mm wafer: < 3% (1σ)
    - Resistivity: < 200 µΩcm
    - Non-uniformity of resistivity over 200 mm wafer: < 3% (1σ)
    - Cycle time: < 20 seconds
    - **Superconducting transition temperature (Tc):**
      * Tc > 13 K for film thickness > 30 nm
      * Tc > 10 K for film thickness > 10 nm
* **TiN**
  + **TiN deposition by ALD:**
  + Bed temperature: 250 °C
  + Thickness inconsistency over 200 mm wafer: < 3% (1σ)
  + Resistivity: < 150 µΩcm

**Laboratory and process support of the Contractor**

* **Process support:**
  + The Contractor must offer process support throughout the lifetime of the system.

**Other requirements**

* **Compliance with CE regulations:**
  + Machinery Directive - 2006/42/EC
  + Low Voltage Directive - 2006/95/EC
  + EMC Directive - 2004/108/EC