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SI ALD

Atomic Layer Deposition

Product description

SENTECH Erfolg durch Leistung

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1 General description

The atomic layer deposition system **SI ALD** is designed for small scale production, research and development, and for use in universities. It allows the deposition of ultra-thin films of few nanometers with excellent uniformity and very good conformity to 3D surfaces. Precise control of thickness and film properties is facilitated by adding precursors in separate steps into the vacuum chamber during the process cycle. The characteristics of ALD offer many benefits in semiconductor engineering, MEMS, and other nanotechnology applications.

The **SI ALD** was developed and designed for a wide range of deposition modes and processes using flexible system architecture. It can be upgraded with further precursor lines, plasma source, in-situ monitoring, and many other options. The **SI ALD** enables the thermal and plasma enhanced (optional) deposition of oxides, nitrides, metals, and other materials on different substrate types and sizes.

Single wafers or carriers with a diameter of up to 200 mm can be loaded manually onto the wafer chuck. The substrate chuck can be controlled up to 400 °C and the reactor wall up to 150 °C respectively. The temperature range of the substrate electrode can be optionally extended to 500 °C. The precursor cabinet can be equipped with up to 4 heated precursor lines with separate inlets into the reactor. In total 6 precursors can be installed. Programmable heating and purging cycles for the reactor ensure operators safety and chamber cleanliness. Mass flow controllers (MFCs) provide highly constant flow rates of purge and carrier gases. The vacuum system is equipped with a dry pump for reliable low and medium pressure operation.

The system is controlled by advanced hard- and software with client-server architecture. A well-proven, reliable remote field controller (RFC) is used for the real time control of all components. Basic safety interlocks are realized by this RFC.

A state of the art PC with Windows operating system is used for the process control, for interlock against operator errors, for visualization and advanced data logging. It communicates with the RFC by Ethernet and optionally by LAN (local area network) with the clients. Via internet remote access to the PC system is available for quick support.

The **SI ALD** is operated by SENTECH software. The intuitive user interface allows the quick and flexible writing and monitoring of deposition recipes in the automatic mode.

Outstanding features of the **SI ALD** are the rugged design of the system, the reliability, and the flexibility of software and hardware.

The **SI ALD** system consists of the following modules:

- Reactor unit (containing reactor, electronics, gas and precursor supply system)
- Computer, monitor, and keyboard
- Roughing pump
- Mains connection box

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2 Reactor unit

2.1 Reaction chamber

The inner cylindrical process chamber is made from a monolithic aluminum ingot. The absence of welding seams contributes to the low leakage.

- Material: AlMgSi 0.5
- Upper flange DN 100 for the plasma source (plasma shutter optional)
- Side flange with door to the manual load
- Flanges DN 16 and DN 25 for in-situ monitoring (e. g. QMS, QCM …)
- Flange DN 63 for the vacuum system
- Vacuum system with flanges for Baratron, vent valve, and vacuum interlock switches
- Ellipsometer flanges (optional)

2.2 Substrate chuck

The process temperature, settable by software, is controlled by heating with a resistive heater. The temperature is measured with a thermocouple within the substrate plate. The substrate chuck has a diameter of 220 mm enabling the loading of wafers with a diameter of up to 200 mm.

- Wafer / carrier diameter: 4″, 6″, 8″ wafers; 2″, 3″ wafers or pieces on carrier
- Carrier: aluminum
- Chuck temperature: up to 400 °C (with optional Liner up to 500°C)
- Reactor temperature: up to 150 °C

2.3 Vacuum system

The vacuum system is equipped with a dry vacuum pump Alcatel ADS 602 P/H, resistant against corrosive gases. It is water-cooled and equipped with inert gas purge connection. The pump has a compact design with several sensors and controls to enhance reliability and operation.

- Base pressure in reactor 10^{-2} mbar
- Pressure sensor Baratron (heated), 1 Torr / 1 mbar

<u>Option 1:</u> Automatic throttle valve to control the residence time of the precursor material in the reactor, for plasma enhanced ALD processes, the automatic throttle valve is required

<u>Option 2:</u> Turbo pump for base pressure $< 10^{-5}$ mbar

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2.4 Gas and precursor cabinet

The gas and precursor cabinet contains the MFCs and the cut off valves as well as the different precursor pots with precursor lines and fast ALD valves.

The MFCs, used for the purge gases and for the optional plasma source, are equipped with particle filters. The control value of the MFCs is set according to the processes to be performed. The set points of the MFCs can be adjusted from the user interface. The screen visualizes the set points as well as the actual flow rates. Depending on the number of precursors the **SI ALD** is equipped with up to three MFCs for precursor delivery.

Depending on precursor properties different delivery methods can be used; direct draw for chemicals with high vapor pressure or bubbling for chemicals with low vapor pressure. Precursors may be purchased from different suppliers. They are supplied in cylinders or bubblers fitted with one or two manual valves respectively. Cylinders and bubblers with different sizes between 50 ml and 600 ml can be attached to the precursor lines of the **SI ALD**. The standard pot is the 300 ml vertical electro-polished stainless steel bubbler from STREM Chemicals. The precursor pots can be optionally equipped with heaters to heat them up to 200 °C.

Up to 4 precursor lines with separate input into the reactor can be installed in the precursor magazine. At maximum 6 precursors can be installed in the cabinet; two times two of them in series with a common input into the reactor. The precursor lines can be shut off separately by normally closed pneumatic valves directly at the reactor. The stainless steel electro-polished lines (6 mm outer diameter) are welded orbitally and coupled with VCR connectors. The individually heated precursor lines are connected to the lid of the reaction chamber and can be heated up to 200 °C, the temperature of the precursor line has to be higher than the temperature of the precursor pot.

3 Control system

3.1 Hardware

A remote field controller (RFC) is used for the real time control of all system components via the serial field bus (interbus). Basic safety interlocks are realized by this RFC.

Bus nodes in the control rack and in the reactor module convert the bus commands and the input / output signals of the components respectively. The architecture enables quick addition or removal of components and extended error diagnostics. The interbus is one of the fastest and most noise-immune serial bus systems and has a protocol stable over years.

The PC with Windows operating system is used for process control, for interlock against operator errors, for visualization, and for a lot of comfortable tools. It communicates with the RFC by Ethernet and is equipped for communication with the clients by LAN. It is located next to the reactor unit. For improving the service of our instruments and products, the remote access to the PC system for quick support is available via internet.

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3.2 Software

The SENTECH software is based on Windows. The user-friendly interface enables quick and comfortable process development and recipe generation. Commands and input data that are important for safety are controlled by the RFC independent on the PC.

The system can be used in the recipe mode or the manual mode. In manual mode all elements can be operated and set directly whereas in the recipe mode a predefined sequence of single steps is performed automatically. The control program enables the operator to control the command execution, the process run, and to follow the schematic flow and the graphical data logging. The current recipe step is marked and the current state of the system is displayed. The settings and the current values of all analog parameters are displayed.

A process runs automatically until the end of the recipe. It will be automatically interrupted when a parameter is beyond the set limit. Lower and upper limits can be defined for all parameters to assure additional safety and reproducible processes. A process can also be manually interrupted.

To organize ALD cycles a special device, called “sequencer”, is used. The 16 channel sequencer is able to call up different hardware components like (ALD) valves and MFCs within one sequence (cycle). Time intervals and flow rates can be chosen arbitrarily. The minimal time step is 10 ms. A cycle is repeated a number of times, as defined in the recipe.

A separate window supports the operator in creating or changing recipes or parameter values. The recipe may contain jumps as well as loops. The completed recipes can be stored in a recipe list. Support is given for a closed loop control of process parameters in dependence on in-situ measurement of plasma or deposition parameters. In the manual mode each step can be executed by mouse click. A flexible password management defines the access of every user.

An extended data logging records all analog parameters on the monitor and in ASCII files.

4 Options

In order to account for customer needs the **SI ALD** allows the upgrade of the system with different options.

4.1 Plasma source for PEALD

In addition to thermal ALD processing, the system can be extended with a plasma source to enable low-temperature ALD processes. The plasma assisted atomic layer deposition system uses radical gas species rather than water as oxidizer during the deposition process.

For the **SI ALD** system a capacitive coupled plasma source (CCP source), driven by a 13.56 MHz generator, is attached as a remote source to the upper flange of the reactor. An external matching box matches the plasma load to the 50 Ohm output impedance of the RF generator. The CCP source includes one gas line equipped with a particle filter and controlled by a MFC. In case of oxygen or hydrogen sensitive precursor materials, a second gas line is required. The plasma source can be expanded with up to 4 non-corrosive gas lines.

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- Pressure range 7 Pa to 100 Pa
- RF power supply 13.56 MHz, 300 W
- External matching box 13.56 MHz
- Water cooled
- 1 gas line with particle filter, pneumatic valve, and MFC

Option 1: More gas lines for plasma source (maximum 4 noncorrosive or 2 corrosive lines)

Option 2: Isolation valve between reactor and plasma source (plasma shutter)

4.2 Further options

- Additional precursor lines (direct draw or bubbler)
- Additional gas lines for plasma source
- Ozone gas supply
- Liner for the reactor (needed for 500°C sample chuck temperature)
- Vapor trap
- Automatic throttle valve to control the residence time of the precursor material in the reactor
- Turbo pump Oerlikon Leybold Turbovac 151 C with isolation valve for base pressure $\leq 10^{-4}$ mbar
- Isolation valve between reactor and plasma source
- Penning and Pirani vacuum gauges
- Ellipsometer flanges with two isolation valves for in-situ monitoring, 65 deg incident angle
- Glove box for inert sample handling

5 Mechanical dimensions and utility requirements

Approximate dimensions (width x depth x height)

- ALD unit 680 x 1,080 x 1,840 mm^3
- Mains connection box 500 x 300 x 500 mm^3
- Backing pump(s) 390 x 830 x 875 mm^3

Utility requirements

- Power 3 x 400 V ± 5 %, 32 A, 50 Hz
- Compressed air 5 to 6 bar (oil and water free)
- Cooling water max. 4 bar (filtered), 2 to 3 l/min, temperature 15 to 25 °C, colorless, free of oil and grease, see installation manual for details
- Nitrogen 4 to 5 bar, 25 liters per run, 25 slm purge gas for dry pump
- Exhaust of gas box $Ø_{outer}$ 80 mm
- Exhaust backing pump DN 40 KF
- Gas-lines to cabinet electro-polished stainless steel tube, 4 VCR

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Approximate mass

- Reactor unit 250 kg
- Pump module 380 kg
- Mains connection box 30 kg

The equipment can be installed “through the wall” between clean room and service areas.