VACUUM PVD Li COATER

Brief technical specification

Riga, 2025

1. Application and main features

1.1. Main application

1.1.1. Vacuum PVD Li coater 2FL500E (hereinafter – "the coater") is a pilot scale deposition system designed for production of uniform Li coatings on sheets in stainless steel frames applying thermal evaporation processes.

1.2. Main features of coater

1.2.1. The coater is a batch-operating tool with cartridge system that allows multiple substrates to be loaded simultaneously.

1.2.2. The coater is capable of processing foil that is fixed in stainless steel frames. In the base configuration, the coater can process rectangular foil-type substrates sized in length from 305 up to 310 mm and in width from 134 up to 152 mm, with thicknesses of 50 to 200 µm. Substrate size is approximately 6" x 12". Smaller, thicker (up to 1 mm) or substrates made of solid material can be used with customized holder frames.

1.2.3. Coating deposition is carried out by means of thermal evaporation from radiantly heated crucibles, that are replenished after multiple cycles.

1.2.4. The coater consists of 3 chambers – process chamber, input chamber, output chamber.

1.2.5. Process chamber contains 2 evaporators, 2 cooling drums and conveyor system. Input chamber contains cartridge lift and frame loading mechanism. Output chamber contains cartridge lift and frame receiving mechanism.

1.2.6. Cooling drums are designed to perform conductive cooling of substrates.

1.2.7. Conveyor system is designed to move frames from input chamber through coating and cooling stages to output chamber.

1.2.8. The area around the coater is split in two parts: dry room and service zone.

1.2.9. Coater design is ergonomically justified, and easy access to all coater components for operational and maintenance works is guaranteed as far as safety requirements permit such. All components and materials of the vacuum internals are compatible with process conditions (temperature, pressure, reactive environment).

2. Scope of delivery

2.1. Vacuum chambers
- 2.1.1. Process chamber with 2 sliding doors
- 2.1.2. Input/output chamber with 2 hinged doors
- 2.1.3. Rails and supports for sliding doors

2.2. Li evaporation device – 2 pcs.
- 2.2.1. Crucible
- 2.2.2. Set of heaters
- 2.2.3. Vapour chimney
- 2.2.4. Cooled platform with rollers
- 2.2.5. Evaporator lid
- 2.2.6. Liquid cooling system
- 2.2.7. Compressed air cooling circuit

2.3. Cooling drum – 2 pcs.
- 2.3.1. Set of cooling pockets
- 2.3.2. Liquid cooling system
- 2.3.3. Support legs with bearings and drive gear
- 2.3.4. Cooling liquid feedthrough
- 2.3.5. Gas feedthrough

2.4. Cartridge system – 2 pcs.
- 2.4.1. Cartridge
- 2.4.2. Lifting device
- 2.4.3. Support platform with rollers

2.5. Conveyor system
- 2.5.1. Set of nip roller assemblies
- 2.5.2. Horizontal guide rollers
- 2.5.3. Support frames for nip and guide rollers
- 2.5.4. Push device – 8 pcs.

2.6. Drive system
- 2.6.1. Electric motors for conveyor system rollers
- 2.6.2. Electric motors for push devices
- 2.6.3. Stepper motor actuators for push devices
- 2.6.4. Electric motors for cooling drum rotation
- 2.6.5. Electric motors for cartridge lifting device
- 2.6.6. Optical and inductive sensors for tracking and control of frame position.

2.7. Pumping system
  2.7.1. Fore vacuum pumping station – 2 pcs.
  2.7.2. Turbopump DN320 – 2 pcs.
  2.7.3. Turbopump DN250 – 2 pcs.
  2.7.4. Gate valve DN320 – 2 pcs.
  2.7.5. Gate valve DN250 – 2 pcs.
  2.7.6. Gate valve DN400 – 2 pcs.
  2.7.7. Vacuum gauges – 8 pcs.

2.8. Water cooling system
  2.8.1. Manifold
  2.8.2. Flow meters, gauges
  2.8.3. Manual regulating valves
  2.8.4. Manual shut-off valves
  2.8.5. Purge and isolation system

2.9. Cooling liquid system
  2.9.1. Chiller
  2.9.2. Manifold
  2.9.3. Flow meters, gauges
  2.9.4. Manual regulating valves
  2.9.5. Manual shut-off valves
  2.9.6. Purge and isolation system

2.10. Pneumatic system
  2.10.1. Circuit for lithium crucible cooling
  2.10.2. Circuit for pumping system valves
  2.10.3. Circuit for cooling manifold purging

2.11. Gas feeding system
  2.11.1. MFC for Argon – 4 pcs.
  2.11.2. MFC for passivation gas – 1 pc.

2.12. Electrical system and electrical cabinets

2.13. Set of technical documentation and user manuals

2.14. Set of accessories for maintenance
  2.14.1. Cooling drum removing rails

2.15. Set of spare parts

3. Optional Equipment

3.1. Additional replacement cartridges – 2 pcs.
3.2. Additional cartridge removal device – 1 pc.
3.3. Additional Li crucibles – 2 pcs.

4. The Customer provides

4.1. Dry room
4.2. Facilities for cleaning of Li parts
4.3. Electric power
4.4. External cooling water
4.5. Compressed air
4.6. Process gasses
4.7. Exhaust collection
4.8. Lifting devices
4.9. Substrates, Li rods and other consumables
4.10. Internet connection for remote support
4.11. Leak detection equipment

5. Technical parameters

5.1. Substrate	
5.1.1. Type	foil sheets in frame carriers
5.1.2. Material	Ni foils or equivalent
5.1.3. Substrate thickness	50 – 200 µm
5.1.4. Substrate length	305 – 310 mm
5.1.5. Substrate width	134 – 152 mm
5.1.6. Frame outside dimensions	317.5*158*3 mm
5.1.7. Frame inside dimensions	default 300*128 mm
5.2. Li coating	
5.2.1. Principle	condensation from vapour
5.2.2. Coated side	two-sided
5.2.3. Width	~ 128 mm
5.2.4. Thickness range	2 – 10 µm per side
5.2.5. Uniformity	± 10%, excluding edge effects
5.2.6. Passes	1 – 10 per side
5.2.7. Passivation	optional CO_2 or other gas
5.3. Li source	
5.3.1. Type	thermal evaporation device
5.3.2. Li evaporation temperature	500 – 600 °C
5.3.3. Estimated deposition rate	1 – 4 µm*m/min
5.3.4. Lid actuator	stepper motor
5.3.5. Crucible dimensions	~ 135*350*80 mm
5.3.6. Li fill	1.4 kg max
5.3.7. Li metal yield	> 90%
5.3.8. Li replenishment	batch
5.4. Transportation system	
5.4.1. Type	horizontal conveyor
5.4.2. Active conveying elements	nip rollers and pushers
5.4.3. Passive elements	idle rollers
5.4.4. Rotation transfer	belt- or cardan-coupled
5.4.5. Rotation feedthroughs	ferro-fluid
5.4.6. Drives	servo motors
5.4.7. Pusher actuators	stepper motors
5.4.8. Movement speed over Li sources	0.2 – 3 m/min

5.5. Cartridge	
5.5.1. Type	vertical stack on shelves
5.5.2. Capacity	50 frames
5.5.3. Outer dimensions	750*360*350 mm
5.5.4. Empty weight	25 kg
5.5.5. Loaded weight	40 – 50 kg
5.6. Substrate cooling system	
5.6.1. Type	rotating drum with pockets
5.6.2. Principle	conductive cooling
5.6.3. Medium	argon gas
5.6.4. Primary heat removal	liquid cooled pocket walls
5.6.5. Wall temperature	-15 – 20 °C
5.6.6. Capacity	10 frames per drum
5.7. Vacuum pumping system	
5.7.1. Ultimate pressure, all chambers	< $5*10^{-6}$ Torr (24 h, empty)
5.7.2. Base pressure, process chamber	< $2*10^{-5}$ Torr (~ 90 min)
5.7.3. Base pressure, input/output chamber	< $2*10^{-5}$ Torr (~20 - 30min, loaded)
5.7.4. Process pressure	~ $2*10^{-4}$ Torr
5.8. Electric power requirements	
5.8.1. Earthing system	TN-S
5.8.2. Nominal voltage	400 V, 3 phase
5.8.3. Frequency	50/60 Hz
5.8.4. Installed power	60 kW
5.8.5. Consumption	20 kW
5.9. Cooling water requirements	
5.9.1. Supply pressure	3.0 – 3.5 bar
5.9.2. Return pressure	< 0.2 bar
5.9.3. Filtration	< 75 µm
5.9.4. Hardness	< 5.5 °dH
5.9.5. pH value	6 – 8
5.9.6. Consumption	80 l/min
5.10. Compressed air requirements	
5.10.1. Supply pressure	5.5 – 7.0 bar
5.10.2. Particle size	< 5 µm
5.10.3. Dew-point	< 1.7 °C
5.10.4. Oil contamination	< 2 ppm
5.10.5. Consumption	up to 450 l/min

5.11. Process gases requirements
- 5.11.1. Supply pressure — 2.0 – 2.5 bar
- 5.11.2. Argon purity — ≥ 5N6
- 5.11.3. Estimated consumption — 50 l bottle per 3 months

5.12. Exhaust collection requirements
- 5.12.1. Inlet pressure — < 0.2 bar
- 5.12.2. Extracted flow — > 100 m^3/h

5.13. System dimensions
- 5.13.1. Footprint of the coater in the dry room — 7.5*4.0 m
- 5.13.2. Footprint of the service zone equipment — 9.0*2.5 m
- 5.13.3. Total system weight — ~ 20 ton
- 5.13.4. Recommended dry room size — 10*5*2.7 m

5.14. Operating conditions
- 5.14.1. Service zone
  - 5.14.1.1. Temperature — 15 – 25 °C
  - 5.14.1.2. Relative humidity — ≤ 60%
- 5.14.2. Dry room
  - 5.14.2.1. Temperature — 18 – 22 °C
  - 5.14.2.2. Relative humidity — ≤ 3%

6. General description of the coater

6.1. Dry room, service zone, cleaning room

6.1.1. The area around the coater has two parts: dry room and service zone. The chamber is opened within the dry room, where the substrate loading and unloading is carried out. The dry room houses the whole vacuum chamber, there must be space available for product handling and packing. The service zone is a non-clean room environment separated from the dry room. It contains the pumping station, cooling manifolds and electrical cabinets.

6.1.2. The dry room and air-drying systems are supplied by the Customer.

6.1.3. The Customer prepares a well-ventilated room with the necessary safety measures for cleaning the shields and parts of Li evaporators.

6.1.4. The coater is designed as a single-level plant, maintenance can be done from the ground.

6.2. Vacuum chambers

6.2.1. Vacuum chambers are stationary, rectangular in shape, with doors, with flanges for vacuum feedthroughs, rotary feedthroughs and with viewports. Internal illumination is provided.

6.2.2. Chambers are made of stainless steel. They are placed on mild steel supports. The chamber doors and walls have strengthening ribs, also made of mild steel. The outside surface of chamber walls is painted and the inside surface has polished finish.

6.3. Lithium evaporation devices

6.3.1. The Li evaporation device is built around a rectangular crucible that is batch-replenished using Li ingots, rods or granulate.

6.3.2. For heating purposes two heaters are installed – one under the bottom surface and one around the crucible side surface, consequently it is possible to differentiate power input.

6.3.3. For Li cooldown, a compressed air loop is located in the crucible.

6.3.4. For cooling and excess heat removal, the entire evaporation device is encased in liquid cooled shields.

6.3.5. A motor-activated lid ensures minimal Li vapour loss while there are no frames moving over the coating zone. This lid can be manually tilted upwards to provide access to the crucible for Li replenishment.

6.4. Cooling drums

6.4.1. Cooling pockets – 18 pcs. per drum, active at once – 10 pcs.

6.4.2. Pockets are individually replaceable.

6.4.3. Doors on both sides of each pocket, that open automatically on approach of operating position, and close after leaving said position.

6.4.4. On both long edges of the frame, there are multiple rollers for supporting the frames from bottom, top and sides.

6.4.5. Support legs with bearings and drive gear retain the drums in position and have openings for drum installation and removal using the supplied accessory.

6.4.6. Cooling liquid feedthrough with leak diagnostics provides cooling of each pocket wall, removing the heat from the coated substrate out of the vacuum chamber.

6.4.7. Gas supply into each pocket provides pressure rise in the pocket enabling conductive heat transfer.

6.5. Cartridge system

6.5.1. A removable cartridge unit with shelves for frames is fixed to a vertical lifting device.

6.5.2. Lifting device consists of two shaft guides, a platform with consoles for the cartridge, and a ball screw actuator.

6.5.3. Support platform with rollers for frame transfer is mounted to the base of the chamber, and allows for friction-free removal and insertion of frames in the cartridge. At most, misaligned frames may touch the sides of the shelves during movement.

6.5.4. Swivel-type pusher device on a vertical axis moves the frames out of the input cartridge. The pusher arm itself can be folded away during cartridge removal.

6.6. Conveyor system and substrate transfer during the process

6.6.1. A horizontal conveyor transfers the frames between the main elements of the coater – input/output chambers, cooling rolls and deposition zones.

6.6.2. Movement is accomplished by a combination of rollers and pushing devices. Actively driven conveyor rollers, holding the frames in a nip-roller configuration from top and bottom, cover most of the transfer distances. Retractable pusher devices finish or initiate the movement into or out of cartridges and cooling drums, as the idle rollers in those zones are not actively driven.

6.6.3. First conveying zone is transfer from the cartridge in input chamber, through the load-lock tunnels and gate-valve, towards the cooling roll Nr. 1. The insertion in the pocket is finished by a pusher device.

6.6.4. In this roll, as it indexes by each pocket, the frames are accumulated and the circular motion of the roll also rotates the frames.

6.6.5. Next conveying zone is started by a pusher, moving a frame out of the drum, until it is captured by the nearest rollers and accelerated such that the front of this frame reaches the end of the previous frame in the rollers where the next zone starts – the constant speed coating zone.

6.6.6. In coating zone, the frames travel in a continuous, near gap-less que over the Li evaporator, at a constant speed. During this, a partial thickness coating is deposited on the “A” side of the substrate.

6.6.7. After coating zone, as soon as the frame has left the rollers after the evaporator, starts the next zone, where the frame is quickly moved towards the roll Nr. 2. The insertion in the pocket is finished by a pusher device.

6.6.8. Frames are, again – accumulated, cooled, and flipped over.

6.6.9. The sequence continues as from point 6.6.5, only in the opposite direction and over the other Li evaporator coating the “B” side.

6.6.10. These coating sequences can continue for a multiple number of times until the full required coating thickness is obtained. Estimated number of such cycles for optimal coating is 5 – 8 passes.

6.6.11. A total of up to 22 frames are being processed at once.

6.6.12. Once the coating step is completed, frames are pushed out of roll Nr. 1 and conveyed towards the output chamber, finally pushing them in place in the cartridge.

6.6.13. Lateral movement of frames is limited by horizontal guide rollers.

6.7. Drive system

6.7.1. Drive system is a complex of motors, drive electronics, sensors and control units that actuates the cartridge, conveyor and cooling drum systems.

6.7.2. This entire system works in synchronization, and the period of all cyclic movements is determined by the constant movement speed of frames over the deposition zone, which can be adjusted, and the length of frames, which is nominally constant.

6.7.3. Presence and movement progress of the frames is controlled with sensors along the conveyor system. Correct positioning of cartridges and drums is also electronically controlled.

6.7.4. Local speed corrections in the zone just before the evaporator are made to ensure minimal possible distance between the frames passing through the coating zone.

6.8. Pumping system

6.8.1. Pumping system is based on oil-free vacuum pumps to avoid contaminating the lithium coating.

6.8.2. One of input/output chambers can be pumped from atmosphere while the other part of the coater is operating and under high vacuum. During that time, the input/output chamber under vacuum is backed by the process chamber backing pump.

6.8.3. Fore-vacuum pumping stations are based on a Roots-type booster backed by a dry scroll-type fore-vacuum pump.

6.8.4. High-vacuum pumping is based on turbomolecular pumps installed on corresponding gate valves directly on the chamber.

6.8.5. Vacuum gauges for high- and fore-vacuum ranges are installed on each vacuum chamber. Pumping lines are equipped with fore-vacuum gauges.

6.8.6. High-vacuum gauges are operating on the inverted magnetron principle.

6.8.7. Fore-vacuum gauges are combined units with a Pirani-type sensor for fore-vacuum range and capacitive sensor for intermediary pressure between atmosphere and fore-vacuum. They include pressure correction to take into account the increased pressure in the dry room.

6.8.8. Process chamber fore-vacuum line includes a leak-testing port with a manual valve.

6.9. Cooling system

6.9.1. All cooling lines are equipped with flow meters connected to the controls, manual isolation and regulating valves.

6.9.2. The cooling lines for equipment located within the dry room are also equipped with:

6.9.2.1. For routine maintenance and servicing needs – with 3-way valves for purging and drying the cooling lines using compressed air;

6.9.2.2. For safety purposes – with solenoid and non-return valves to isolate the cooling circuits while the process chamber is open.

6.9.3. Supply and return manifolds are equipped with analogue pressure and temperature gauges, as well as with temperature transducers.

6.9.4. Cooling drums are temperature-controlled by means of a closed-loop chiller.

6.9.5. The Customer provides the primary plant cooling water connected to the water manifolds of the coater.

6.10. Pneumatic system

6.10.1. Compressed air system is split into these functional circuits:

6.10.1.1. Li crucible and lid cooling;

6.10.1.2. Pumping system valves;

6.10.1.3. Cooling manifold purging.

6.10.2. Compressed air system includes isolation and pressure relief valves and pressure regulators with status outputs for each circuit.

6.10.3. Circuit for pumping valves is equipped with a reservoir for emergency closing of pneumatically-actuated valves.

6.10.4. The Customer provides the primary plant compressed air connected to the pneumatic system of the coater.

6.11. Process gas system

6.11.1. Pure argon gas is used for these functions:

6.11.1.1. To increase substrate cooling in the cooling drum pockets;

6.11.1.2. To purge the cooling pockets during pumpdown;

6.11.1.3. To purge input/output chamber during pumpdown;

6.11.2. Pure CO_2 or other gas can be used optionally to passivate freshly coated Li surfaces.

6.11.3. Process gasses are supplied by MFCs and lines have shut-off valves.

6.11.4. The Customer provides the supply of process gasses connected to the gas control panel of the coater.

6.12. Utilities

6.12.1. Most electric power and control cables, as well as the lines of cooling, process gas and compressed air systems are organised in covered cable trays.

6.12.2. Cable tray locations and means of passing through the walls are decided jointly by the Customer and the Contractor.

7. Electrical and control systems

7.1. Electric power

7.1.1. Electrical part of the coater is fed from industrial 3-phase network.

7.1.2. Control voltage is 230V AC and 24V DC.

7.2. PLC and visualization software

7.2.1. Main control system is based on a Siemens Simatic S7-1500 PLC, Simatic ET200SP I/O stations and modules.

7.2.2. The control system for loading, unloading and transporting of the frames is based on a Lenze c550 PLC and i750 servo drives for servo-motor control and stepper motors with controllers.

7.2.3. Process visualization is based on Siemens WinCC SCADA system.

7.2.4. Communication between the PC and PLC is based on Industrial Ethernet.

7.2.5. The coater is managed via a SCADA control interface from the Operator’s PC.

7.2.6. Remote access for service and maintenance of the PLCs and SCADA PC is based on an industrial secured VPN gateway.

7.2.7. Operator’s desk is equipped with the following:

7.2.7.1. Control PC,

7.2.7.2. Ethernet switch,

7.2.7.3. LCD displays, keyboard and mouse,

7.2.7.4. Push-button control panel,

7.2.7.5. UPS unit.

7.3. Main functions of the control system

7.3.1. The coater controls are used for monitoring and management of the processes and systems, in particular:

7.3.1.1. Control of cartridge loading/unloading in input/output chambers,

7.3.1.2. Control of chamber pumpdown, venting and opening of load-lock valves between input/output and process chambers,

7.3.1.3. Control of frame feeding into transfer system, operation of conveyor zones, push actuators, rotation of cooling drums,

7.3.1.4. Control of Li evaporation zones, heating/cooling of Li, lid activation,

7.3.1.5. Control of gas inlet system,

7.3.1.6. Control of cooling system, chiller for cooling drums,

7.3.1.7. Semi-automatic control of the coating process,

7.3.1.8. Logging of process data,

7.3.1.9. Management of alarms,
7.3.1.10. Monitoring of state of internal components (circuit breakers etc.),
7.3.1.11. Access level control.

7.4. Safety interlocking

7.4.1. Complex of software or hardware interlocking is provided, ensuring both personnel and equipment safety and prevention of emergency situations caused by any actuation system failure or Operator's error.

7.4.2. All hardware interlocking has software duplication and state control.

7.5. HMI Screens

7.5.1. The following screens are displayed on the control PC:

7.5.1.1. Process – management of main system components – Li heaters, transfer system, gas flows, readings of pressures, temperatures;
7.5.1.2. Gases – management of process gas flows and shut-off valves;
7.5.1.3. Transfer – control of loading, unloading and movement of frames, control of deposition process speed and number of passes over coating zones, indication of position sensor readings;
7.5.1.4. Vacuum – management of vacuum system devices, state control, readings on pressure in all compartments;
7.5.1.5. Cooling – status of flow in each cooling line, chiller control;
7.5.1.6. Trends – display of measured parameters in graphic form on multiple tabs;
7.5.1.7. Alarms – recording of all errors and warnings;
7.5.1.8. Service – engineering and maintenance functions, information.

7.6. Control system delivery set

7.6.1. Delivery set includes the following:

7.6.1.1. Operator's PC with the installed software
7.6.1.2. Fully equipped control cabinets
7.6.1.3. All external connection cables
7.6.1.4. Electrical schematics
7.6.1.5. Operator's manual

8. Safety

8.1. The design of the coater will consider the following safety regulations and rules:

8.1.1. 2006/42/EC (Machinery Directive)

8.1.2. 2006/95/EC (Low Voltage Directive)

8.1.3. EN60204-1:2006+A1:2009 (Safety of Machinery)

8.1.4. Customer specific requirements (to be provided by the Customer within one month after contract signing date)

8.1.5. ISO 12100:2010 “Safety of machinery - General principles for design - Risk assessment and risk reduction”

8.2. The coater will have CE marking.