

### 3. Chemical precursor source systems

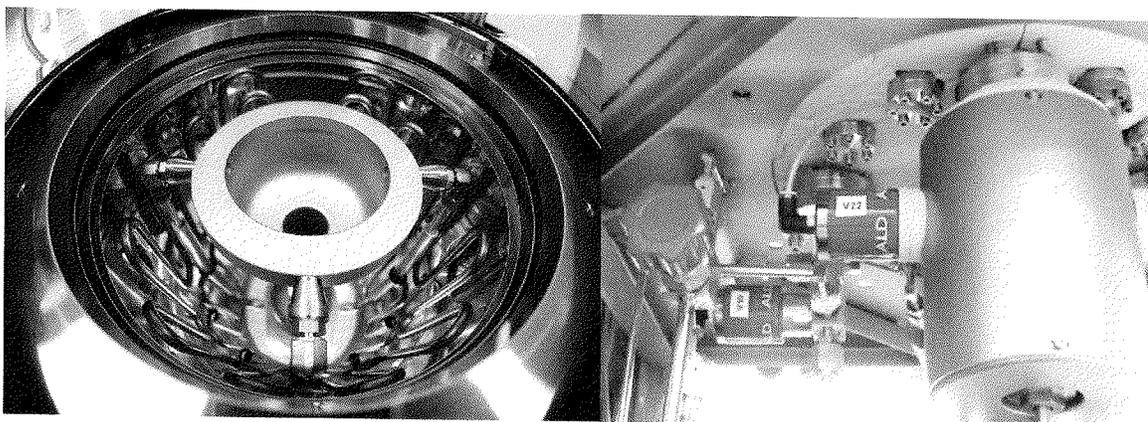
Four or six separate source inlets in the reaction chamber with option of connecting multiple precursor sources (12 precursor sources or more) controlled by separate mass-flow-controllers (MFC) and pressure transducers (PT)

#### Benefit of multiple, separate source inlets:

- Prevents cross-contamination and reaction between different precursors before they enter the reaction chamber
  - For example  $H_2O$  and  $NH_3$  have high sticking coefficient inside source lines. Separate source inlets helps avoid cross contamination for deposition of  $TiO_2$  and  $TiN$
  - Metal halides and organometallic precursors have separate source inlets. This is beneficial to avoid cross-contamination of metal precursors

#### Benefit of heated source for solid and liquid precursors systems:

- Integrated particle filter for solids/powders
- Replaceable cartridge for powder and liquids inside the source (no need to disassemble the source between different precursors)
- Up to 300 C can be used for solid precursors having low vapour pressure
- Innovative Booster technology maximize the delivery of low vapour pressure chemical precursors



**Figure** Separate source inlets (up to 6) minimize chemical cross contamination and maximizes deposited film quality.

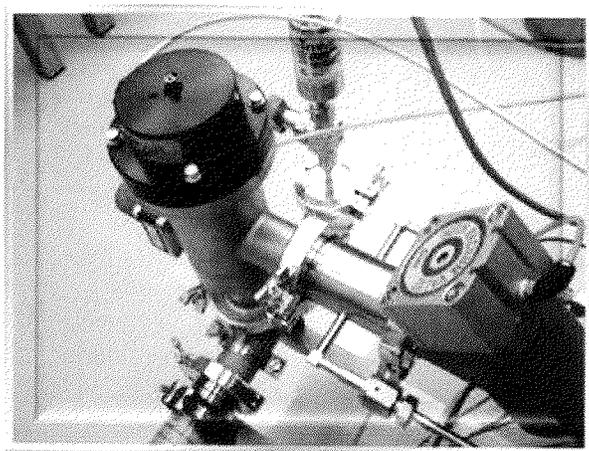
**Figure** A heated source PicoSolid™ for solid precursor delivery (max 200 °C). The chemical can be easily changed with a replaceable cartridge

## Other key features/benefits:

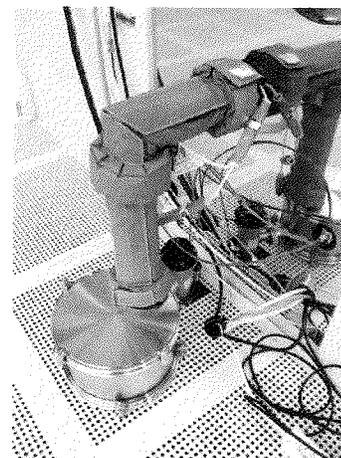
- All metal sealed (VCR) gas flow system for all precursor source lines
- Computer controlled high speed pneumatic ALD valves (Swagelok) for pulse and purge
- Temperature stabilization for high vapor pressure precursors
- Gas cabin for safe handling of high pressure gases and safe purging of gas lines

## 4. Vacuum and abatement system:

- Base pressure at  $10^{-2}$  torr with standard dry pump,
- All metal sealed flanges integratable with ultra-high-vacuum (UHV) chamber for demanding thin film and substrates.
- Two stages tandem evacuation with combination of low speed pre-evacuation followed with high speed, high conductance main pump valve
- PicoFlow™ Diffusion Enhancer technology with extra stop-valve for thin film deposition of porous substrates with ultra-high aspect ratio
- In-line after-burner and particle trap minimizes reaction gas emission and prolongs pump life



**Figure** Innovative PicoFlow™ Diffusion Enhancer technology integrated with two stage tandem pumping valves



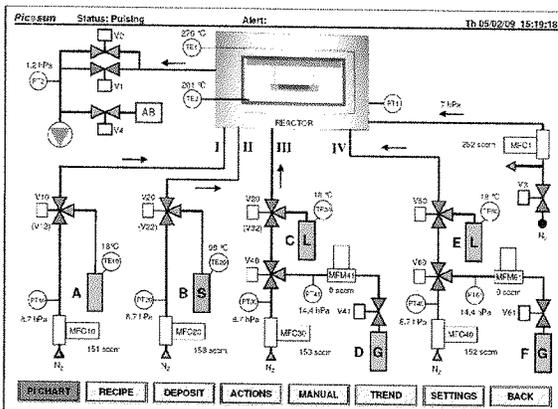
**Figure** Heated pump line with a particle trap is particularly suitable for high volume manufacturing

## 5. Electronics and software

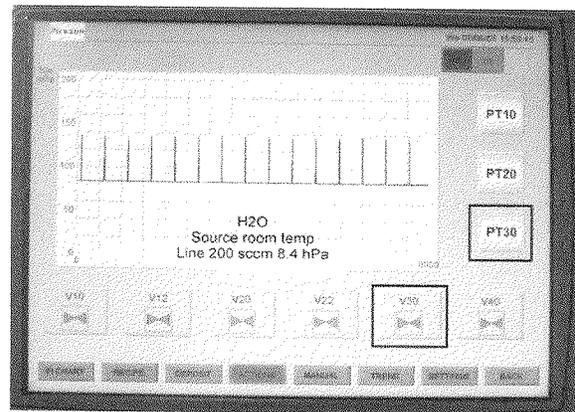
SUNALE™ ALD systems provides the best quality and reliable electronics package for handling the electrical power feeds and input/output signals related to the instrumentation and precursor sources

### Key Features/benefits:

- Advanced control program with fully programmable pulsing sequences for the deposition of conventional binary compounds as well as advanced thin film systems such as nanolaminates, doped thin films and ternary thin films
- Real time display of process status and PC data logging of all key process parameters.
  - Innovative PT setup with software comprises pulsing monitoring (easy start-up of new precursor)
- Possibility to save log files on an USB stick or a flash card memory.
- Individually programmable process parameters including reactor temperature, precursor source temperature, gas flow rate, etc.
- Multiple user levels allows customized data security
- Complete fail-safe operation with warning/error messages and history records
- Human Machine Interface (HMI) PLC system with a touch screen panel



**Figure** Advanced control program with fully programmable pulsing sequences for advanced thin film deposition.



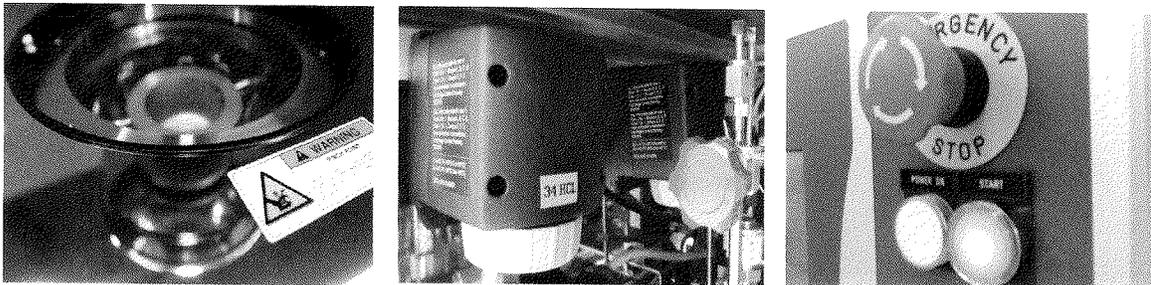
**Figure** Real time display of process status and PC data logging. Innovative PT setup with software comprises pulsing monitoring

## 6. Hardware and software interlocks and safety features

SUNALE™ ALD system provides complete safety features through both hardware and software interlock systems

### Key features/benefits:

- Complete fail-safe operation with warning/error messages and history records
- Hardware interlocks for vacuum chamber over pressure, over heating (touch safe at ~60 °C), pneumatic lift crash, etc.
- Software interlocks for reactor and vacuum chamber pressure, precursor source lines and ALD valves, etc.
- Emergency Off (EMO) buttons
- Chemical source cabinet with gas sensors to detect hazardous and pyrophoric chemical leaks
- Lock-out, tag-out of reactor cover and source/gas cabinets
- Normally closed pneumatic valves (all valves closed if the pneumatic line fails)
- Complete safety user manual with safety assessment made for the gas cabin of flammable and poisonous gases
- Earthquake support of the reactor



**Figure** Hardware and software interlocks and safety features are not compromised with SUNALE™ ALD systems

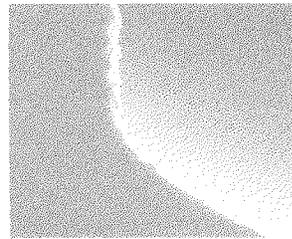
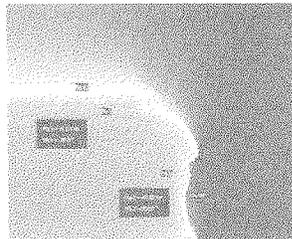
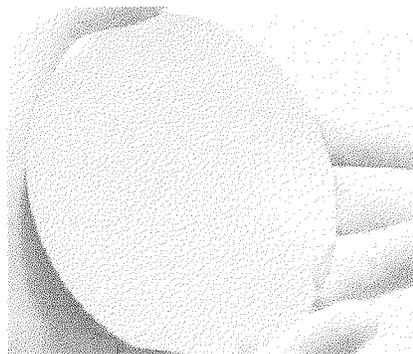
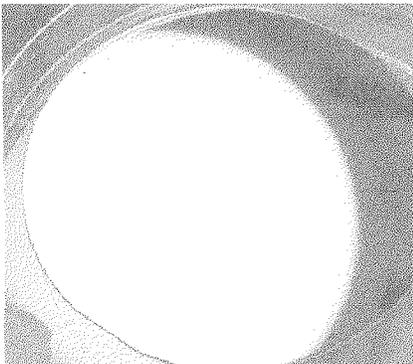
# PICOPLASMA™ Source System

Picosun's innovative PICOPLASMA™ source system for plasma-enhanced ALD (PEALD) is based on a tunable, highly advanced remote ICP plasma source, proven by key customers around the globe to be capable of low temperature depositions. Various excited species such as oxygen, nitrogen, and hydrogen radicals can be generated to broaden the range of ALD process chemistries. Due to very low ion count, the remote source enables the processing of even the most sensitive substrates without plasma damage, all while retaining high reactive species flux.

The PICOPLASMA™ source system can be mounted on existing PICOSUN® ALD reactors or the whole PEALD system can be installed as one compact, small footprint deposition unit capable of easy implementation, quick maintenance, and low cost-of-ownership. The system can also be fully automated by integrating it into the PICOPLATFORM™ cluster tools.

## The key advantages of PICOPLASMA™ technology

- No plasma damage to the substrate
- No short-circuiting with conductive materials
- No precursor back-diffusion → no film formation in the plasma generator
- No pressure oscillation during plasma ignition → no particle formation
- No gate valve between the plasma source and the substrate → no particle formation
- No etching of plasma source materials → low metal and oxygen in-film impurities
- Easy and fast service and chamber change through maintenance hatch
- Possibility to run thermal and plasma process steps during the same deposition without hardware modifications



*Examples of film uniformity values of some PEALD materials, deposited in PICOSUN™ tools. Wafer size 150/200 mm (6/8").*

Material	Non-uniformity [1σ], %
Al <sub>2</sub> O <sub>3</sub>	0.50
AlN	0.62
In <sub>2</sub> O <sub>3</sub>	0.87
SiO <sub>2</sub> (low-T)	1.10
SiN (low-T)	1.58
TiN	2.16
ZnO	2.64
TiAlN	2.87

*Above: Highly conformal and uniform PEALD TiN films on high aspect ratio trenches, deposited with the PICOPLASMA™ source system.*

*On the left: PICOPLASMA™ technology enables successful large area deposition of materials with extremely challenging process chemistries, such as gold.*

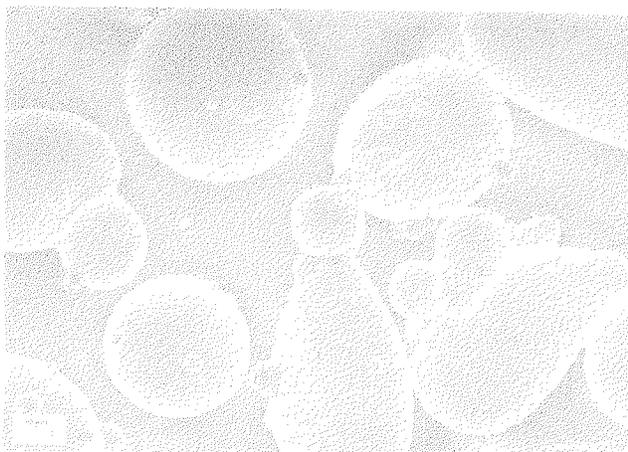
## Additional Options

### PICOFLOW™ diffusion enhancer

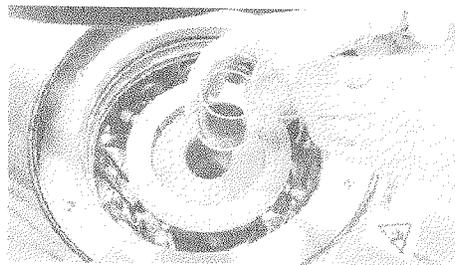
The PICOFLOW™ diffusion enhancer enables and improves the coating of deep trenches and other high aspect ratio samples, as well as porous, through-porous, powderous, or otherwise complex nanostructures. The PICOFLOW™ feature is available for all PICOSUN™ ALD tools.

### POCA™ and PICOVIBE™ powder coating systems

Picosun offers powder coating solutions for both industry and R&D. Our POCA™ 200 flow-through cartridge is a compact, versatile, and cost-efficient solution for top quality powder materials research, development, and small-scale pilot production. For example catalysts, medical substances, battery materials, and light-emitting phosphors are developed with Picosun's powder processing tools. The POCA™ 200 cartridge can be directly integrated into all PICOSUN™ R-series tools. Picosun's novel, innovative PICOVIBE™ feature improves the powder coating process even further by enhancing the distribution of the precursor vapors inside the powder batch, resulting in uniform film formation on every particle.



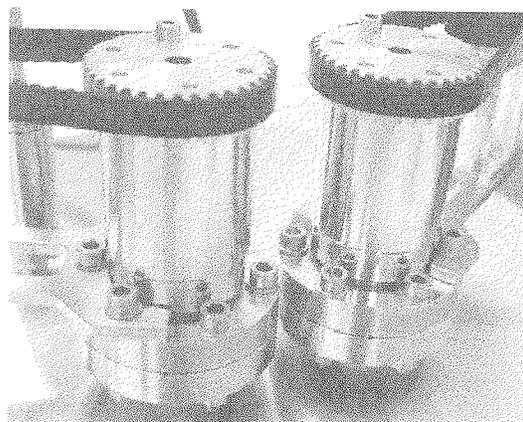
*Micrometer-scale ZnO particles coated with highly uniform ALD Al<sub>2</sub>O<sub>3</sub> layer in a PICOSUN™ ALD tool. Figure © VTT Technical Research Centre of Finland.*



*Aalto University's School of Chemical Technology develops battery materials for car manufacturers using Picosun's powder coating ALD technology. Photo © Mikko Raskinen / Aalto University Communications.*

### Roll-to-roll feature for continuous ALD

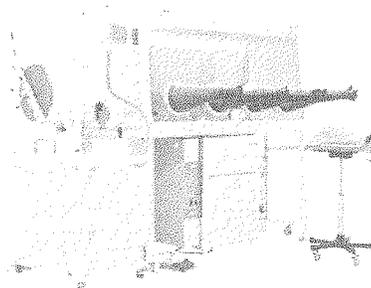
Continuous ALD is a potential manufacturing method for printed electronics and OLEDs, thin film batteries, smart textiles, organic sensors, and flexible displays. The PICOSUN™ R&D scale roll-to-roll ALD feature accommodates substrates up to 70 mm of width and it can be directly integrated into the reaction chamber of all air-opening PICOSUN™ R-200 ALD tool models.



*Picosun's compact, cost-efficient, and retro-fittable roll-to-roll ALD feature is ideal for continuous ALD R&D.*

### Glove box compatibility

All PICOSUN™ ALD tools can be integrated with various types of glove boxes to eliminate handling of sensitive substrates or precursors in air. Tools with separate load locks or the standard pneumatic lift elevator can both be connected with a leak tight seal to the glove box wall or bottom plate.



### UHV compatibility

All PICOSUN™ ALD systems can be made ultra-high vacuum (UHV) compatible either by integration with a pumpdown chamber or by modifying the tool itself, enabling pumpdown down to UHV region.