°LAUDA

TEMPERATURE CONTROL SOLUTIONS FOR THE SEMICONDUCTOR INDUSTRY

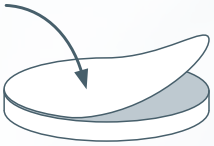
°FAHRENHEIT. °CELSIUS. °LAUDA.

CORE PROCESSES OF SEMICONDUCTOR MANUFACTURING

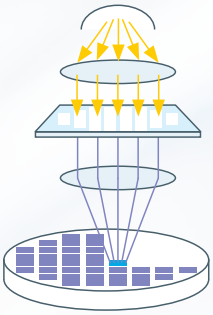
Overview

–150 °C 550 °C

Temperature control solutions for the semiconductor industry – Precision and efficiency for the highest demands
Semiconductors are an essential part of our modern world and will play a decisive role in the future. They are the basis for developing technology such as smartphones, computers, electric vehicles, renewable energies and artificial intelligence. Temperature control plays a decisive role in semiconductor production to meet the highest demands for precision and efficiency. To overcome the challenges faced in microchip manufacturing, LAUDA offers innovative temperature control solutions.

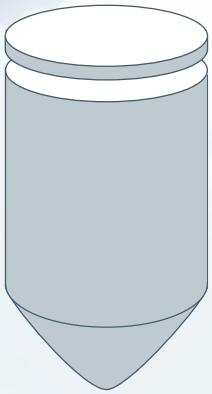


Photoresist coating

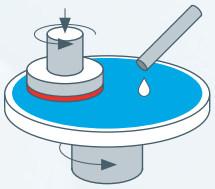


Lithography

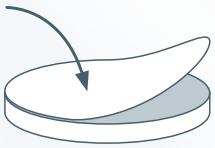
Wafer manufacture



Silicon crystal growing / ingot manufacture

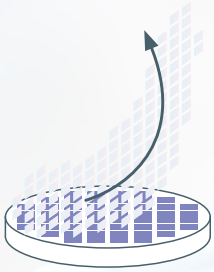


Polishing wafers

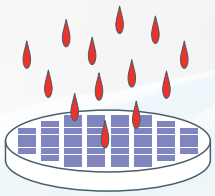


Epitaxy

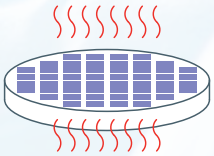
Front-end manufacturing



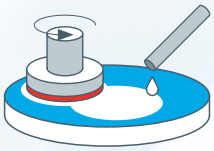
Etching



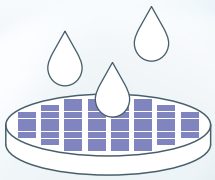
CVD/PVD/
ion implantation



Rapid thermal
processing

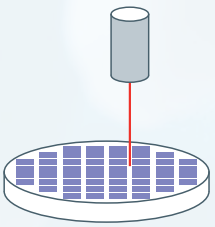


CMP

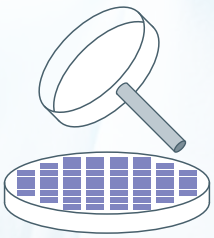


Wafer cleaning

Back-end manufacturing



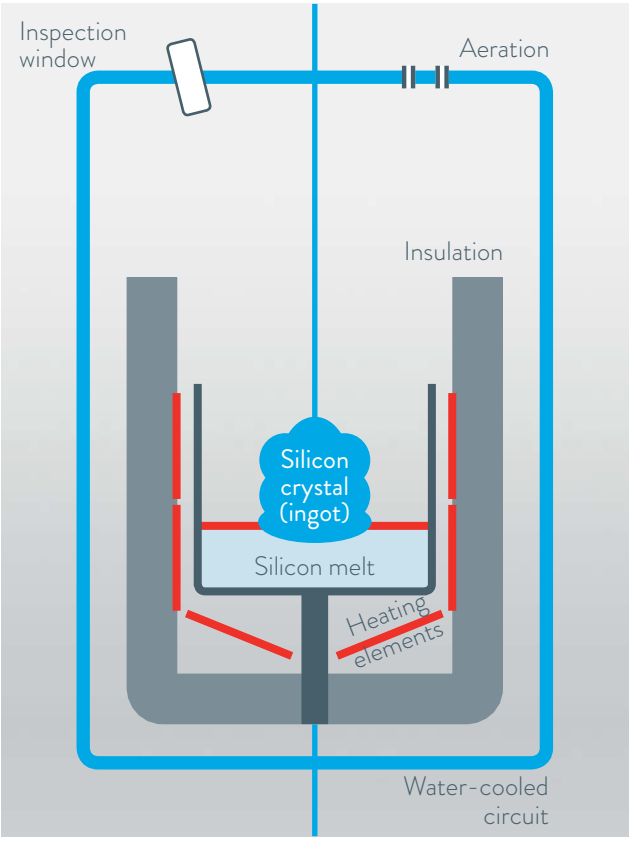
Dicing



Testing

TEMPERATURE CONTROL SOLUTIONS FOR WAFER MANUFACTURING

Wafer: Core of semiconductor manufacturing
Wafers form the foundation of modern electronics. These thin slices of high-purity semiconductor material, such as silicon, are used as a basis for manufacturing microchips. The quality and purity of wafers are crucial for the performance of the components mounted on them.



Czochralski process
The Czochralski process is an established method for manufacturing wafers, whereby silicon is melted in a crucible and a high-purity single crystal is slowly removed as the material solidifies again.
The drawing rod is drawn upwards at a controlled speed of 0.5 - 2 mm per minute, while the molten silicon solidifies at a temperature of 1,410 - 1,420 °C due to undercooling at the interface that forms. By precisely varying the pulling speed and temperature, the growing crystal reaches the desired diameter. Constant temperature control is required throughout the entire pulling process, which can take up to three days. Using water as the temperature control medium to counter-cool reactor heat. With precisely controlled cooling rates, LAUDA supports in minimizing crystal defects in order to maximize ingot quality. The reliability of LAUDA recirculating chillers is of great importance for continuous operation. The TCU components are designed for longevity which means low downtime for the user.

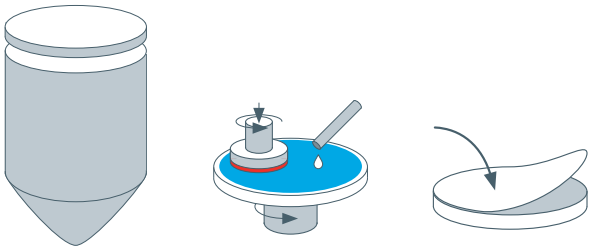
LAUDA application:
Temperature control reactor mantle

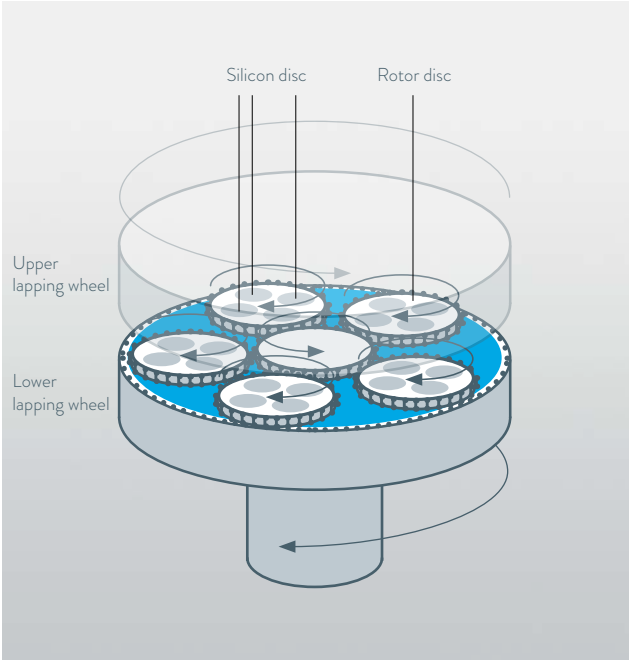
LAUDA product:
Ultracool Circulation chiller

Typical product properties:
- Temperature stability up to ± 0.5 K
- Cooling capacity up to 240 kW
- Reinforced pump with pump flow rate up to 500 L/min
- Remote access via LAUDA.LIVE


Silicon crystal (ingot) and wafer


Ultracool Circulation chiller

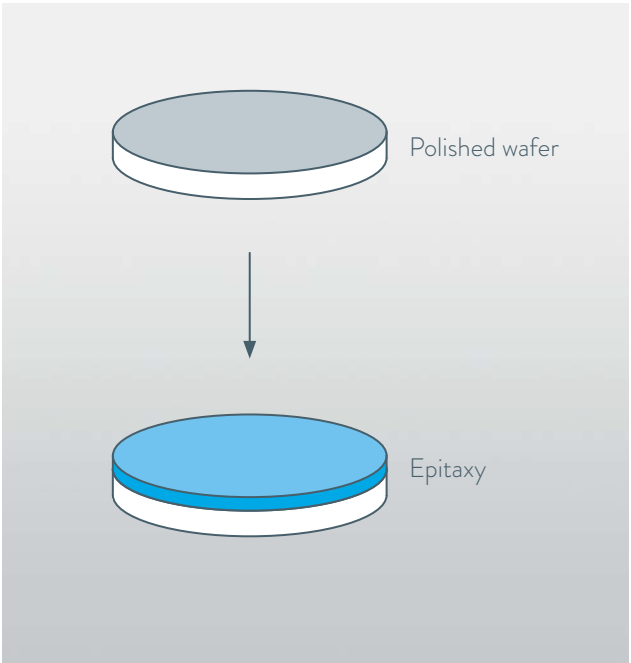




Wafer lapping and polishing processes
A flawless wafer finish is achieved using lapping and polishing processes that remove irregularities and damage that could affect conductivity. Here, precision temperature control technology is also indispensable in preventing thermal stresses and ensuring consistent material properties. Since the polishing process generates heat and temperature fluctuations affect the removal rate, it is important to maintain a constant temperature at the interface between the pad and wafer. This is achieved by actively controlling the temperature of the lapping wheel.

LAUDA application:
Temperature control of lapping/polishing plate, slurry liquid

LAUDA products:
ITHW 350 Heat transfer system,
Ultracool Circulation chiller



Epitaxy
Epitaxy is a deposition process in which new material layers are being added to the underlying substrate. These layers must be perfectly adapted to the base layer. Additionally, precise temperature control during the crystal growth process is vital in minimizing layer defects and maintaining a perfect crystalline structure. LAUDA secondary circuit systems supply the tools with the temperature control required for accurate layer deposition.

LAUDA application:
Temperature control for epitaxy systems
(process gases, reactors, turbo pumps)

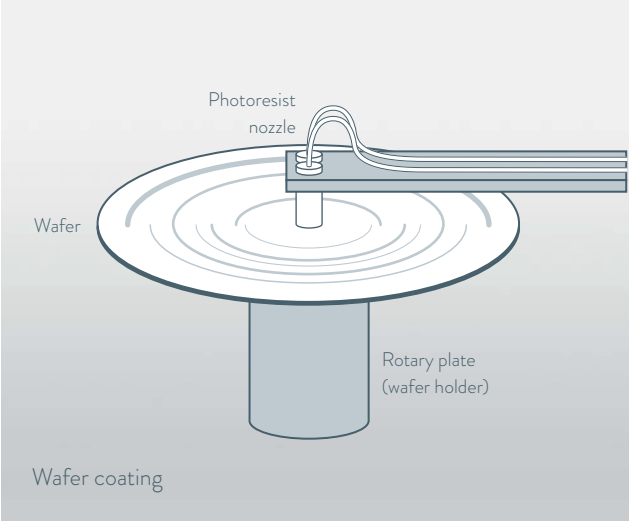
LAUDA product:
TR 400 K Secondary circuit system

Typical product properties:
- Powerful pump for positioning in the subfab
- Emergency cooling function
- 100 kW cooling capacity at 50 °C
- Volume flow up to 106 L/min
- ± 0.5 °C control accuracy
- Interfaces according to customer requirements
- Customized adaptations possible on request

TEMPERATURE CONTROL SOLUTION FOR SPIN COATING AND LITHOGRAPHY SYSTEMS

Lithography – an essential step in the mass production of microchips
In lithography, UV light shines through a stencil and is demagnified to create a microscopic pattern on the wafer through the use of photoresist.

Materials expand when heated and contract when cooled. This also applies to photomasks, exposure lenses and wafers in lithography. Even slight changes in temperature can alter the structure dimensions on a wafer, which can lead to dimensional variations that affect the accuracy and repeatability of the projected patterns.

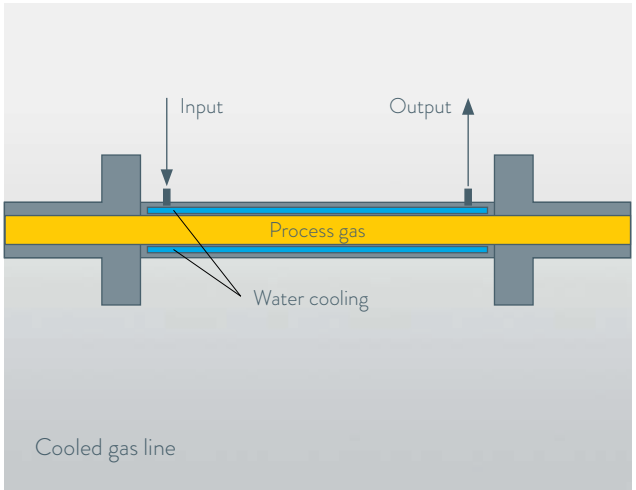


Wafer coating

Temperature control for photoresist spin coating
Lithography uses light-sensitive photoresist whose properties are temperature-dependent. Precise temperature control is crucial for a uniform photoresist temperature and minimizes defects in the transfer process. LAUDA Microcool and Variocool units provide the required temperature stability. Their low-vibration compressors enable placement close to the process without negative influences.

LAUDA application:
Temperature control of photoresist liquid

LAUDA products:
Microcool Circulation chiller, Variocool Process thermostat



Cooled gas line

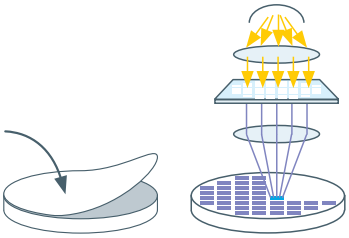
Temperature control of process gases / vacuum
Since most processes take place in a vacuum or gaseous environment, the temperature in these areas must be controlled properly. For example, this can be achieved by adding water-cooled outer jackets to stainless steel pipes or housings.

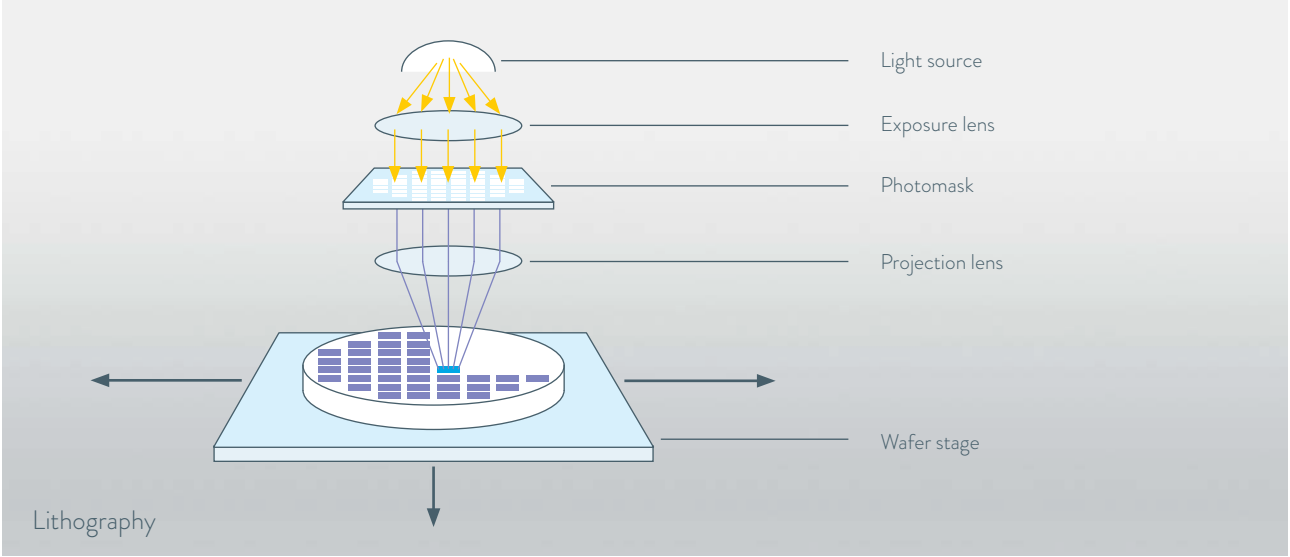
LAUDA application:
Temperature control of process gases and chambers

LAUDA products:
Ultracool Circulation chiller, Variocool Process thermostat


Variocool
Process thermostat
Microcool
Circulation chiller
Ultracool
Circulation chiller

Typical product properties:
- Very high temperature stability
- Simple interior device structure for servicing
- Low-vibration compressors
- High compactness





Temperature control for UV light
The generation of a laser beam is produced by a huge amount of energy, which must be regulated in the form of waste heat. Reliable recirculating coolers such as the LAUDA Ultracool units prevent the laser module from overheating.

LAUDA application:
Cooling of laser generator

LAUDA products:
Variocool Process thermostat, Ultracool Circulation chiller

Temperature control of wafer stages and measuring systems
The accuracy of wafer stages and measurement systems can be affected by operation and subsequent heat generation. Precision temperature control is required to avoid thermal expansion and ensure that positioning accuracy is maintained in the nanometer range.

LAUDA application:
Cooling of wafer stage

LAUDA product:
Ultracool Circulation chiller

Temperature control for exposure lenses and photomasks
Due to the high radiation power and high absorption of the lens, the system must be cooled substantially in order to maintain a constant temperature. Compact LAUDA devices counteract the deformation of optics and mirrors, which is essential for precise exposure.

LAUDA application:
Cooling of lenses / mirrors

LAUDA product:
Variocool Process thermostat

Temperature control for vacuum pumps
The turbo molecular pumps used in many applications consist of rotating blades that operate at extremely high speeds in order to create a high vacuum. These pumps generate heat through friction, which may cause damage or loss of performance without proper cooling. Cooling the vacuum pumps helps keep the operating temperature within the specified limits, which is essential for maintaining the required vacuum as well as the efficiency and reliability.

LAUDA application:
Cooling of vacuum pump

LAUDA product:
Ultracool Circulation chiller

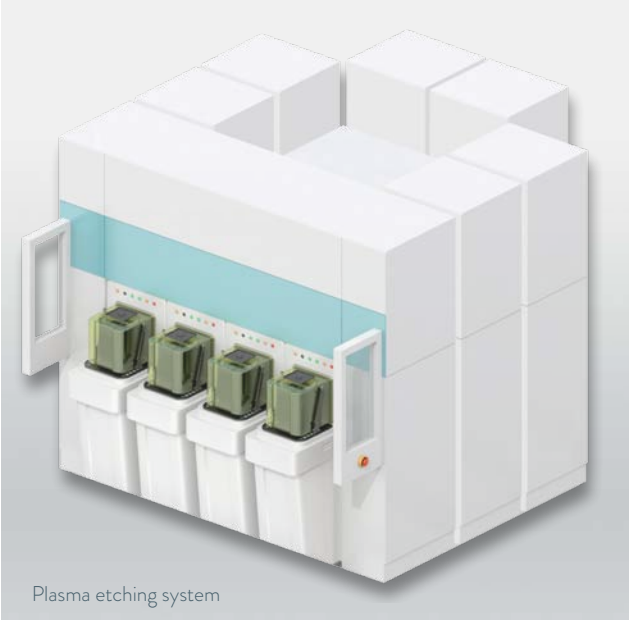
TEMPERATURE CONTROL SOLUTIONS FOR PLASMA ETCHING SYSTEMS

Plasma etching is a process of fundamental importance for the production of the complex circuits required to manufacture the most modern electronic devices
In semiconductor production, plasma etching is a primary component for material removal in the manufacturing sequence. Plasma etch, also known as dry etch, is a process in which wafers are exposed to plasma in a vacuum etching chamber. The wafers are bombarded with the ions in the plasma to remove material. The temperature of the plasma influences the speed and efficiency of the etching process. In semiconductor production, it is important to control the temperature of the plasma with high precision, because the wafers are processed in the micrometer and nanometer range. Even slight changes in temperature can result in significant changes to the size and shape of the etched structures. LAUDA offers the specially designed Semistat for this sensitive process.

Temperature solutions for etching systems
Based on the tried-and-tested principles of heat transfer used for Peltier elements, LAUDA Semistat process thermostats allow reproducible temperature control for plasma etching applications. The dynamic temperature control of the electrostatic chuck (ESC) makes the Semistat a universal TCU for a variety of process types. Energy-efficient and space-saving with stable temperature control, they are the perfect POU chiller.

LAUDA application:
Temperature control of wafer chuck

LAUDA product:
Semistat Peltier thermostat



Plasma etching system

LAUDA Semistat S 1200, S 2400 and S 4400

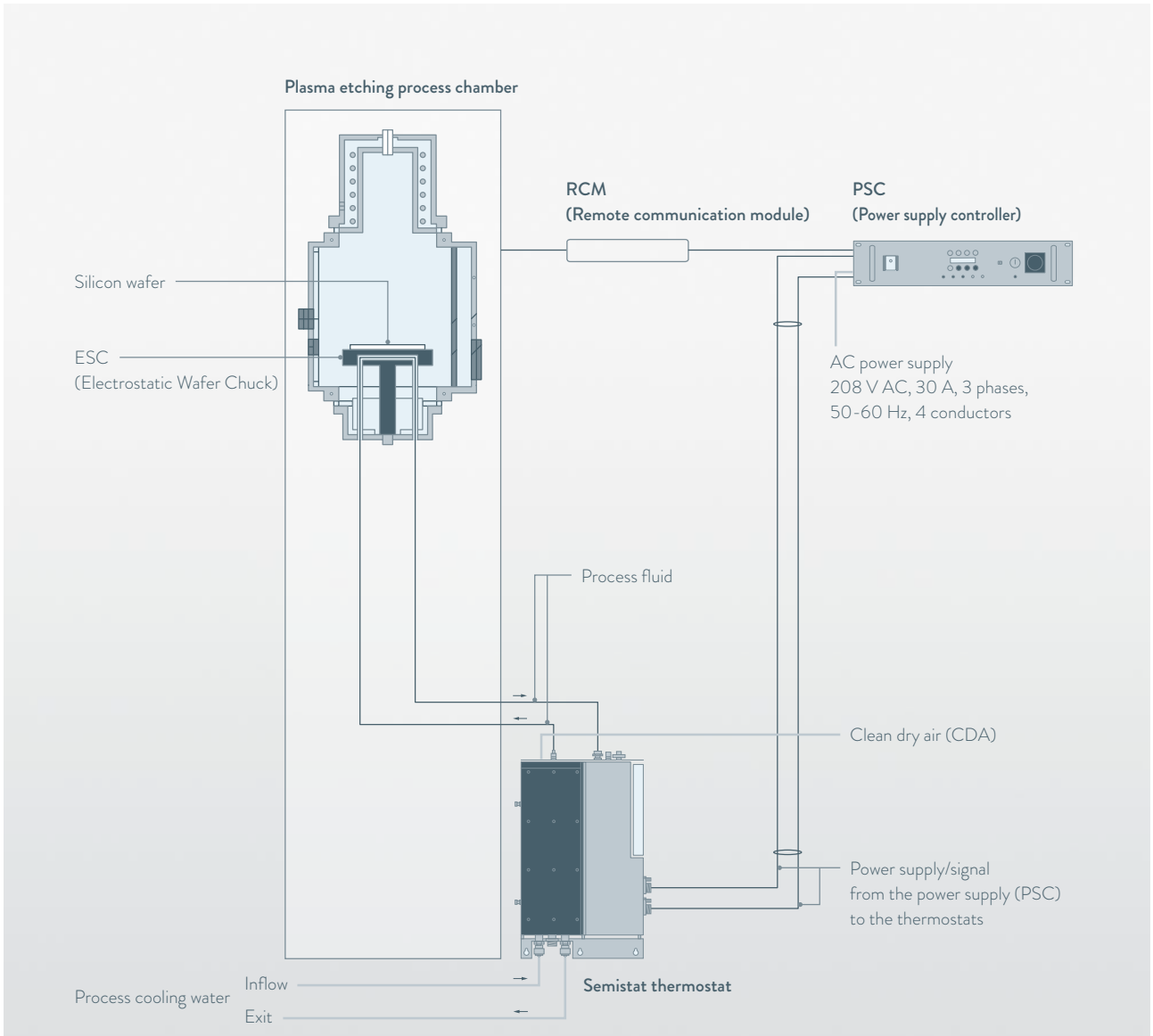
LAUDA Power supply controller (PSC)

LAUDA Semistat

Pioneering Peltier thermostats: Fast and precise temperature control for demanding processes

Thermoelectric process thermostats from −20 to 90 °C for the semiconductor industry:

- Cooling output from 1.2 to 4.4 kW
- Heating output from 3 to 12 kW



System configuration for plasma etching system with constant temperature equipment

Technical data

	S 1200	S 2400	S 4400
Temperature stability	± 0.1 K	± 0.1 K	± 0.1 K
Cooling output (at 20 °C)	1.2 kW	2.45 kW	4.4 kW
Max. discharge pressure	2.8 bar	2.8 bar	2.8 bar
Max. flow rate	22 L/min	24 L/min	27 L/min
Max. filling volume	1 L	1.25 L	2.8 L
Dimensions (mm)	116 × 232 × 500	116 × 300 × 560	194 × 300 × 560

Other advantages of thermoelectric constant temperature equipment

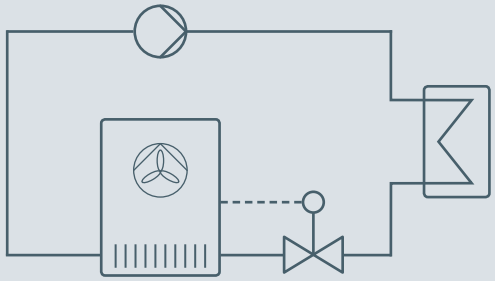
- No refrigerant
- Small in size saves valuable clean room surface
- Lower coolant consumption
- Less maintenance required
- Significant reduction in use of high-priced heat transfer liquids

TEMPERATURE CONTROL SOLUTIONS FOR PLASMA ETCHING SYSTEMS

High energy efficiency with constant temperature equipment optimized for the application
Extremely energy-efficient operation is possible, especially when controlling temperature in plasma etch applications and using thermoelectric-based constant temperature equipment.

Thermoelectric advantages over compressor-based thermostats are explained in the following.

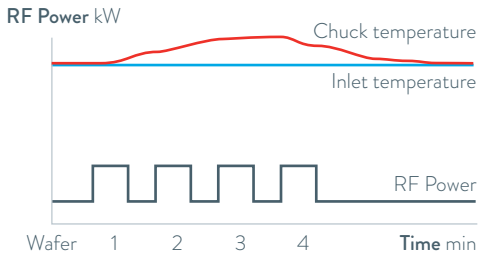
Compressor-based



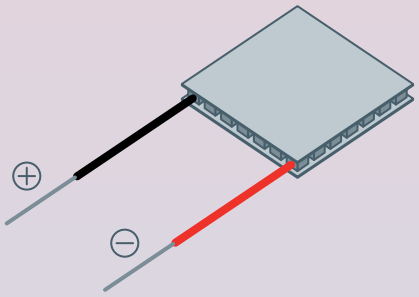
High filling volume in liquid tank
- 20 - 30 L

Long tubing connection between application and constant temperature equipment
- up to 20 m

Static temperature control
- High fluid volume
- Far away from the application
- Slow heating/cooling
  –> temperature drift and wafer to wafer uniformity issues



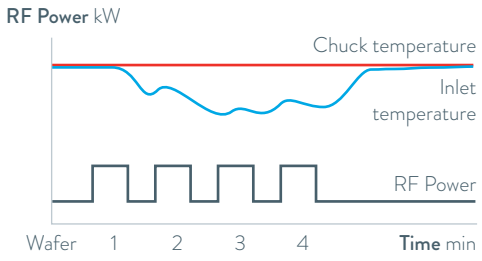
Thermoelectric (LAUDA Semistat)

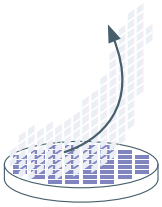


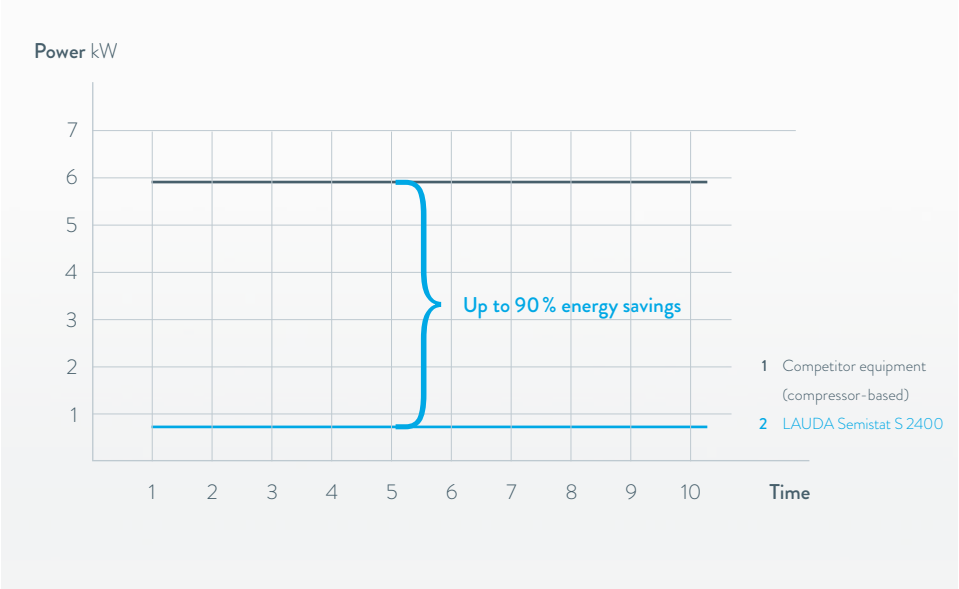
Low filling volume in liquid tank
- < 3 L

Short tubing connection between application and constant temperature equipment
- 2 - 4 m

Dynamic temperature control
- Low fluid volume
- RTD readings taken at the TCU inlet for better ESC temperature stability
- Close to the application
- Rapid heating/cooling
  –> Uniform chuck temperature

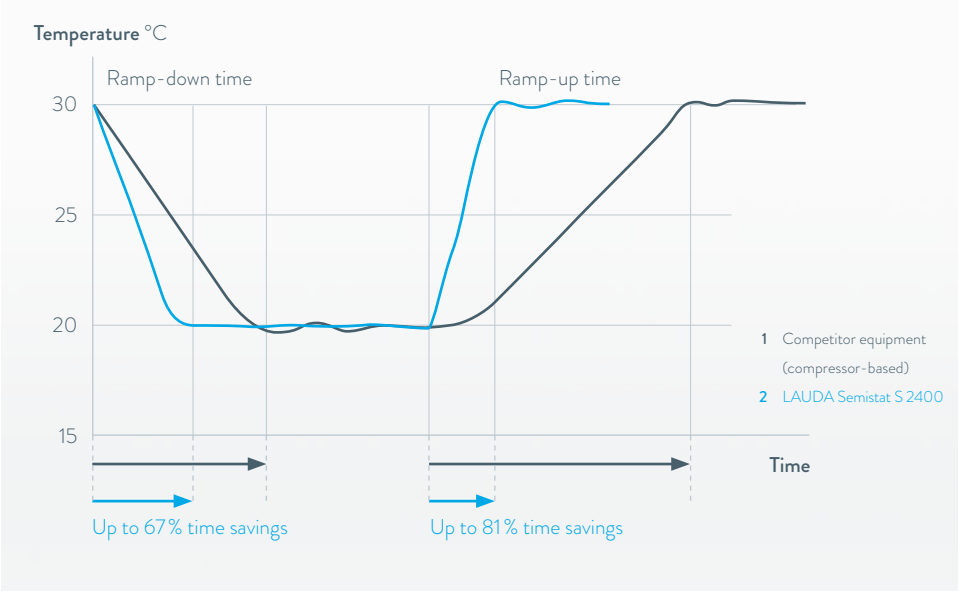






Data based on comparative measurements of a LAUDA Semistat S 2400 thermostat and a competitor's circulation chiller in a real customer application. The respective costs were determined and the savings were calculated based on the measured electricity consumption.

The above aspects increase the efficiency of thermoelectric constant temperature equipment used in plasma etching applications and significantly reduce energy consumption.



Data based on comparative measurements of a LAUDA Semistat S 2400 thermostat and a competitor's circulation chiller in a real customer application. The settling times were determined and the time savings were calculated based on the measured heating and cooling rates.

The settling times for cooling and heating (ramp-down and ramp-up times) are also significantly less for thermoelectric equipment than for compressor-powered equipment.

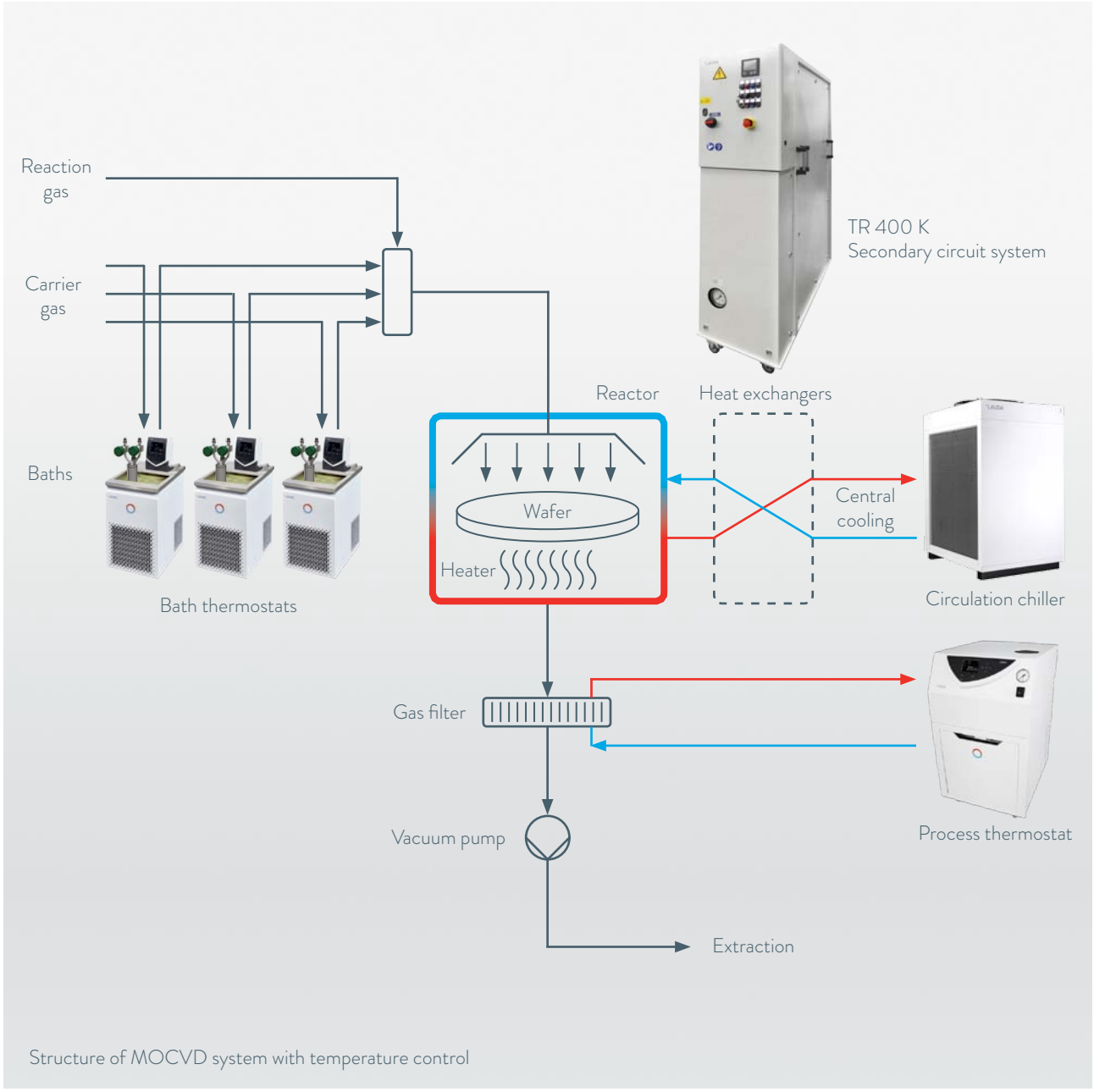
For detailed comparative measurements, please contact our LAUDA sales department directly.

TEMPERATURE CONTROL SOLUTIONS FOR MOCVD SYSTEMS (METAL-ORGANIC CHEMICAL VAPOR DEPOSITION)

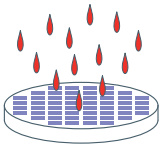
Temperature control solutions for MOCVD systems
Metal-organic chemical vapor deposition (MOCVD) is a key technology in the manufacture of LEDs, lasers, transistors and solar cells. In this process, extremely thin, single-crystalline layers are applied to a wafer. The coating process occurs in a reactor chamber at temperatures above 1,000 °C, which requires effective heat dissipation.

The temperature of the turbo molecular pumps for vacuum generation and the bubblers containing the gaseous precursors must also be maintained constant.

LAUDA offers an extensive range of products for the various temperature control tasks of an MOCVD system.



Structure of MOCVD system with temperature control



Bath thermostats
- Temperature range –100 to 200 °C
- High temperature stability
- Extremely compact

LAUDA application:
Bubbler temperature control

LAUDA products:
ECO, PRO Bath thermostat

Secondary circuit units with heat exchanger module
- Emergency cooling function
- Powerful pump for positioning in the subfab
- 100 kW cooling capacity at 50 °C
- Volume flow up to 106 L/min

LAUDA application:
MOCVD system temperature control/reactor temperature control

LAUDA product:
TR 400 K Secondary circuit system

Circulation chillers
- Temperature range –10 to 35 °C
- Max. cooling output 330 kW
- High energy efficiency

LAUDA application:
MOCVD system temperature control/central cooling

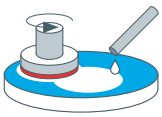
LAUDA product:
Ultracool Circulation chiller

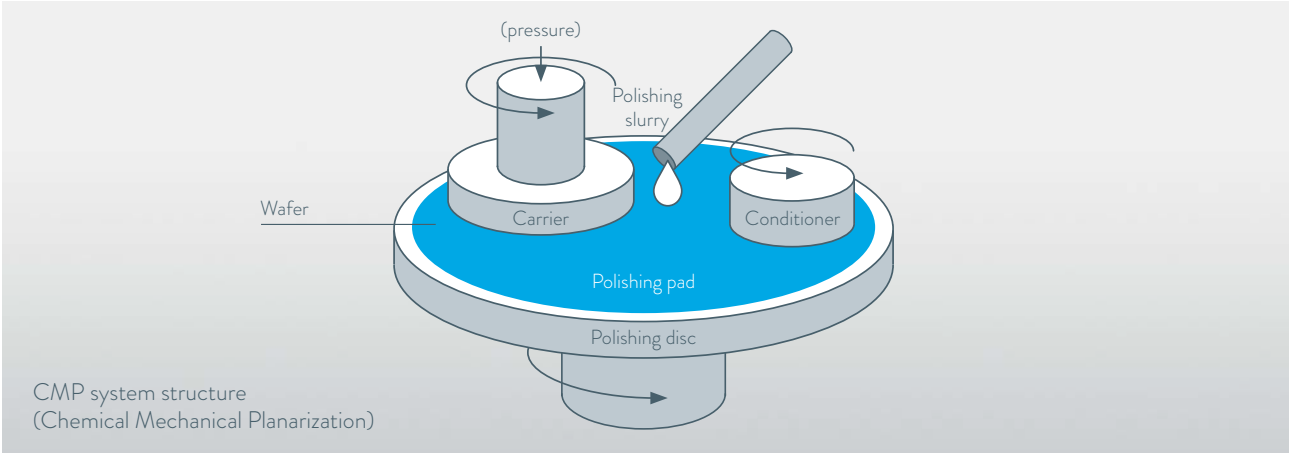
Process thermostats
- Temperature range –25 to 80 °C
- Max. cooling output 10 kW
- Max. heating output 7.5 kW
- Extremely compact and reliable, outstanding temperature stability

LAUDA application:
Gas filter cooling

LAUDA product:
Variocool Process thermostat

TEMPERATURE CONTROL SOLUTIONS FOR CMP (CHEMICAL MECHANICAL PLANARIZATION)





CMP system structure
(Chemical Mechanical Planarization)

CMP – a process for surface smoothing by combining chemical and mechanical processes

In the different production steps of a microchip, the surface of the wafer must be smoothed to perfection.
Chip manufacturers use a process called chemical mechanical planarization (CMP) to achieve this. CMP removes and planarizes excess material on the front of the wafer by exerting forces of pressure precisely to the back of the wafer and pressing the front against a rotating pad made of special material that also contains a combination of chemicals and abrasives. In order to guarantee the precision of this process, the temperature of the polishing fluid must be precisely controlled and the resulting heat must be dissipated from the sanding pad, which is where LAUDA constant temperature equipment comes into play.
Precision temperature control is essential in maintaining the quality and reliability of the CMP process.

CMP (Chemical Mechanical Planarization)

The right temperature ensures that cleaning chemicals work effectively and integrity of the wafer is not compromised.

System and process stability

At the start of the CMP process, the polishing components must be heated to the correct process temperature. The temperature of the components must then be maintained constant during the process to ensure process reliability and prevent any stress on the wafers. The high heating capacity of LAUDA's ITHW systems allow users to quickly reach their desired process temperatures, while the high cooling capacity allows for ample heat dissipation during the polishing process.

LAUDA application:

Temperature control of polishing disc

LAUDA products:

Ultracool, ITHW 350 Heat transfer systems

Typical product properties:

- 20 - 95 °C Working temperature
- 100 kW Cooling capacity via heat exchanger
- 12 kW Heating capacity via electric heater
- ±1 K Control accuracy
- Heat transfer medium water
- Cooling medium tap water 20 °C
- Customized adaptations possible on request

Ultracool
Circulation chiller

Temperature control of polishing slurry

The slurry must be maintained at the required temperature to ensure the reaction rate and efficiency of the slurry material.

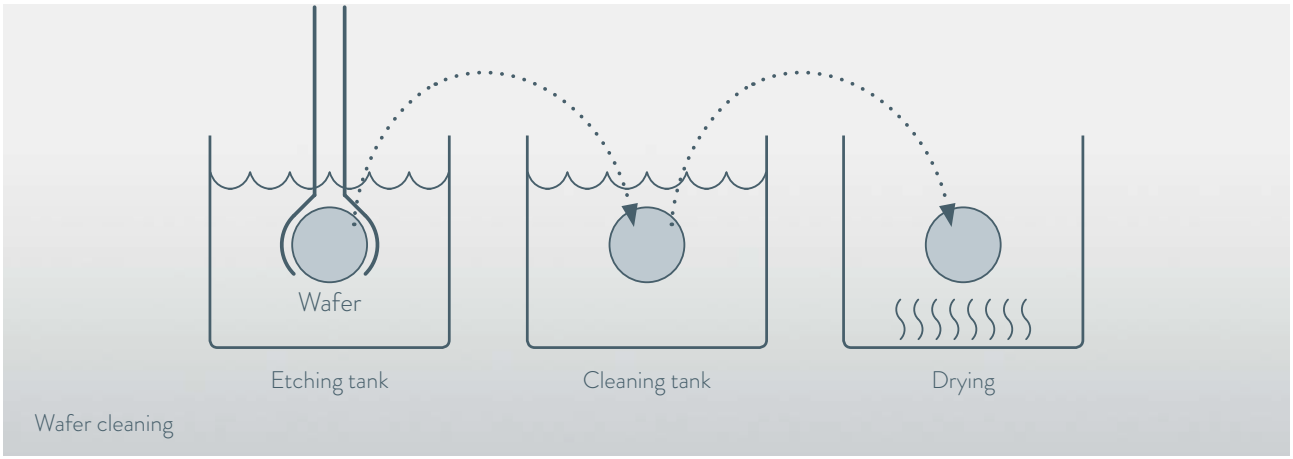
LAUDA application:

Temperature control of polishing slurry

LAUDA product:

Ultracool Circulation chiller

TEMPERATURE CONTROL SOLUTIONS FOR WAFER CLEANING



Wafer cleaning

Wafer cleaning – removal of chemical and particulate contaminants without altering or damaging the wafer surface or substrate
The cleaning of wafers is essential in ensuring a high yield rate in semiconductor production, since more than a third of all manufacturing steps are dedicated to cleaning alone.
Up to 200 cleaning steps may be required for state-of-the-art memory chips, such as a 20 nm Node DRAM.

Temperature control technology is essential in ensuring that a constant temperature is maintained during cleaning to optimize the efficiency and effectiveness of the cleaning process.
Our advanced temperature control technology minimizes the risk of contamination and improves the reliability of semiconductor products by ensuring a stable process temperature that maintains the integrity of the wafers and ensures the best preparation for subsequent production steps.

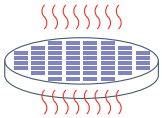
Temperature control of wash basins
Process temperature control for preventing wafer stress and maintaining the washing fluid at a perfect temperature.

LAUDA application:
Temperature control of washing fluid

LAUDA product:
Variocool Process thermostat


Variocool
Process thermostat

TEMPERATURE CONTROL SOLUTIONS FOR RTP (RAPID THERMAL PROCESSING)



Temperature control technology in RTP systems
In the world of semiconductor manufacturing, Rapid Thermal Processing (RTP) systems play a vital role in the production of high-quality electronic components. RTP is a process in which wafers are exposed to extremely rapid, controlled temperature changes in order to induce specific chemical and physical changes in the material. The temperature control technology must be extremely precise to correctly adapt the properties of the semiconductor material. The efficiency and quality of these processes depend largely on the performance of the temperature control technology.

In order to meet the complex requirements of temperature profiles, RTP systems use sophisticated temperature control technology that also incorporates heating and cooling systems.

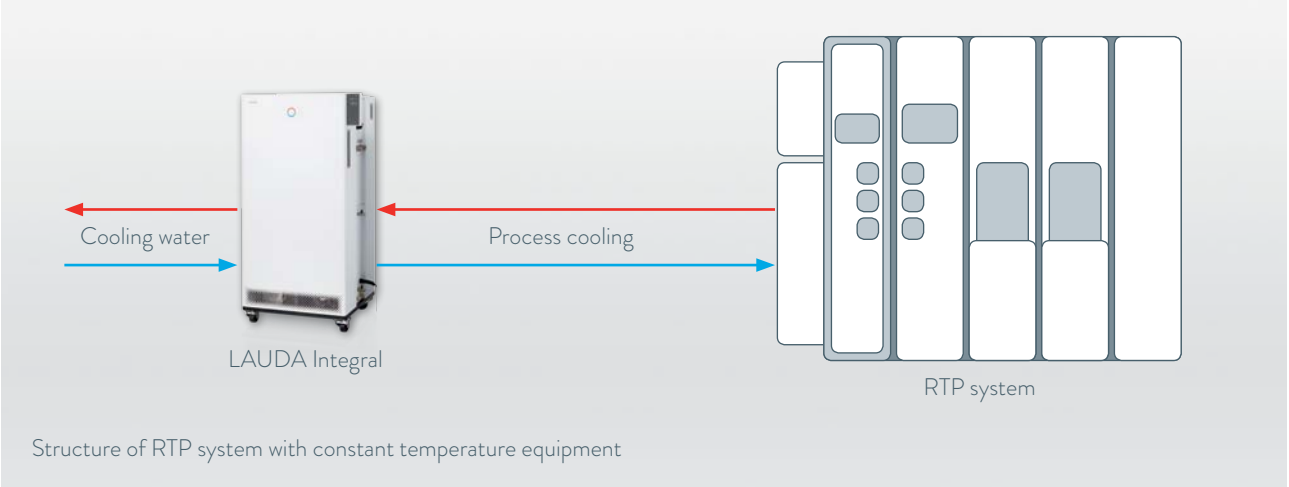
LAUDA application:
Cooling of RTP chambers

LAUDA product:
Integral Process thermostat

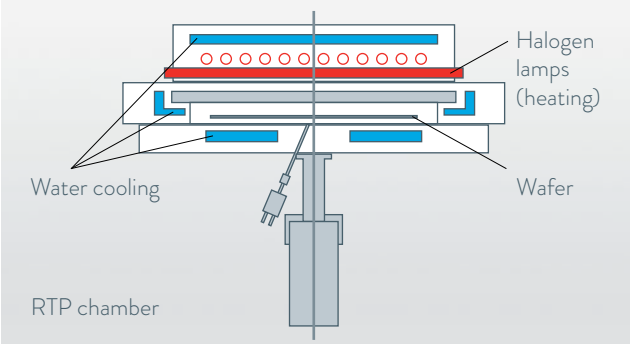
High-performance heating elements
Heating elements in RTP systems must be capable of reaching and maintaining high temperatures of up to 1,200 °C in just a few seconds.

Cooling systems
Just as important as the heating process is the controlled cooling of the wafers after they have been heated up to 1,200 °C for a short time. For this purpose, dynamic temperature control units such as the LAUDA Integral series enable rapid heat dissipation without jeopardizing the quality of the wafer.

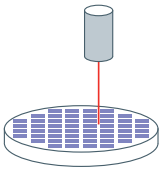
Typical product properties:
- High cooling capacity for rapid heat dissipation
- High pump pressure (positioning in the subfab)
- Simple interior device structure for servicing
- Fleet management (LAUDA.LIVE)

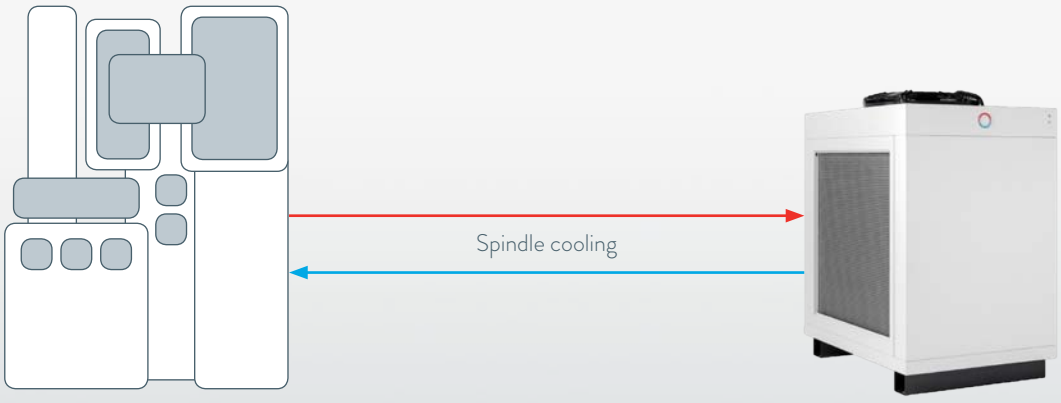


Structure of RTP system with constant temperature equipment



TEMPERATURE CONTROL SOLUTIONS FOR WAFER DICING





Structure of dicing system with temperature control

Wafer dicing
Various elements must be cooled during the wafer dicing process to prevent thermal damage and ensure the high quality of the chips. Some elements that may require cooling include:

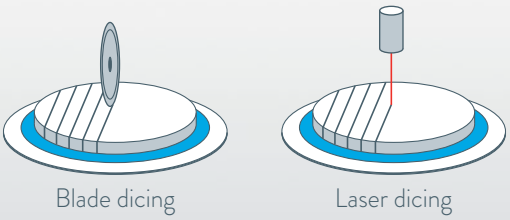
Wafer surface: Cooling prevents heat damage and defects during the cutting process.

Blade dicing: Cooling reduces frictional heat and extends the life of the saw blade.

System components: Maintains machine performance by cooling heated parts such as motors and spindles.

Coolant jet: Dissipates heat and flushes particles away. Particularly important for blade dicing.

Laser dicing systems: Laser components require cooling to maintain efficiency and precision.
Modern dicing systems have sophisticated temperature controllers for an efficient, high-quality dicing process.



Wafer dicing methods

The specific cooling requirements may vary depending on the dicing process used and must be adapted to maintain the integrity and purity of the wafer. Modern dicing systems incorporate complex temperature controllers to meet these requirements.

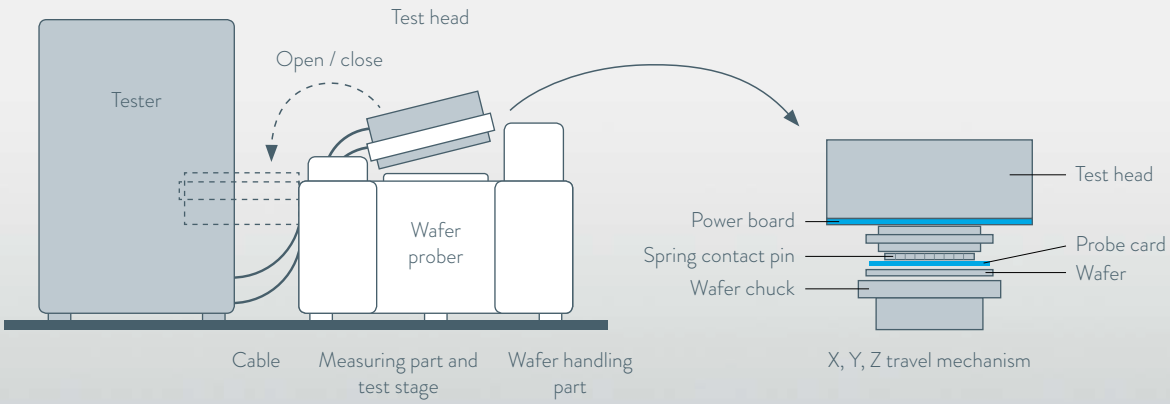
LAUDA application:
Cooling of cutting spindles, laser generators

LAUDA products:
Variocool Process thermostat, Ultracool Circulation chiller

Variocool
Process thermostat

Ultracool
Circulation chiller

TEMPERATURE CONTROL SOLUTIONS FOR CHIP TESTING SYSTEMS



Wafer testing systems

Chip testing
Chip testing systems use constant temperature equipment to thermally condition the chips during the testing process. This means that the chips are heated to specific temperatures to observe their operating behavior under different thermal conditions. The specific scenarios where constant temperature equipment is required include:

Temperature cycle tests: During these tests, chips are repeatedly heated and cooled to determine how they behave under conditions of thermal expansion and contraction.

Burn-in tests: These are stress tests where chips are tested at higher temperatures for longer periods.

Cold and heat tests: Chips are exposed to extreme temperatures that exceed normal operating temperatures in order to determine their operating limits.

Quality assurance and control: During the production phase, manufacturers must ensure that each chip meets the relevant requirements. Constant temperature equipment is used to ensure the constant and controlled temperature environment required for accurate, reproducible test results.

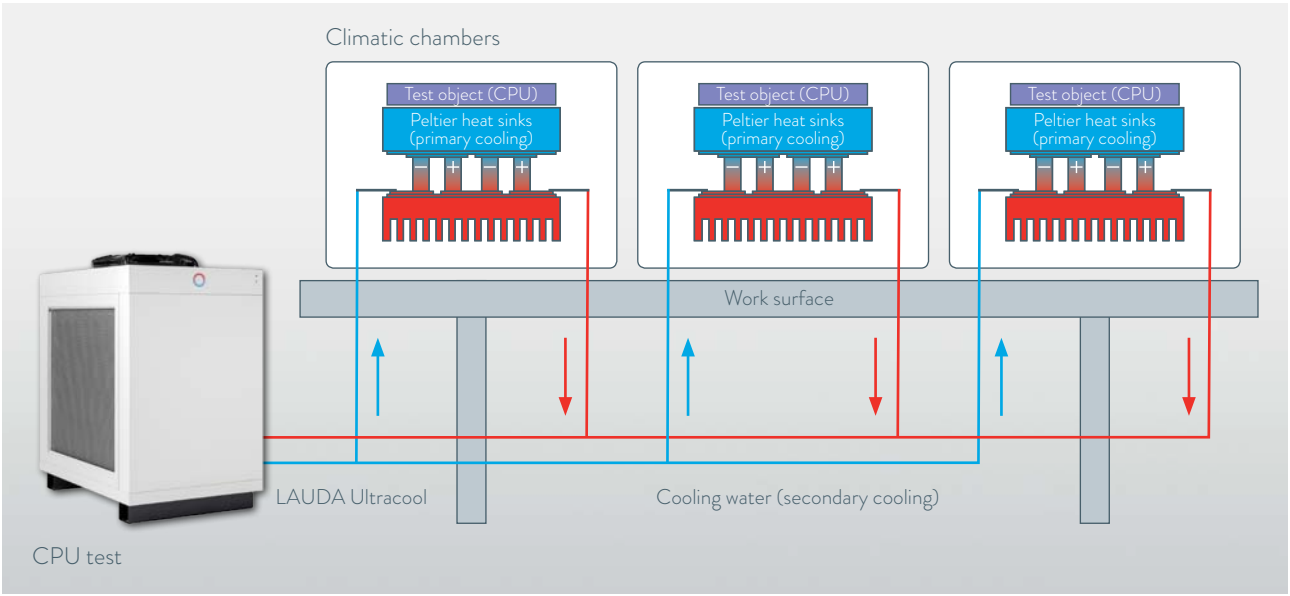
Temperature control is essential in ensuring that chips operate reliably in a variety of environments, especially in applications where temperature fluctuations are common, such as automotive, aerospace and consumer electronics. Modern temperature control systems must be extremely precise and capable of reacting quickly to changes in order to ensure that test cycles remain efficient and effective.

LAUDA application:
Wafer chuck tempering in the wafer prober

LAUDA product:
Integral Process thermostat

Typical product properties:
- High cooling capacity at low temperatures down to −60 °C
- Robust compressors (devices often switched on and off)
- Simple interior device structure for servicing
- Robust cabling (units exposed to vibrations when moving)
- Possible data export via network (LAUDA.LIVE)

Integral
Process thermostat



CPU temperature tests –
Cooling systems for high quality assurance standards

The semiconductor industry sets the highest standards of precision and reliability, especially when it comes to CPU quality assurance. Once manufactured, these powerful chips must undergo a series of demanding tests to ensure that they function correctly under different conditions. One crucial aspect of this process is the temperature tests conducted in specially designed climatic chambers. These chambers use innovative cooling technologies to create constant precision test conditions. The CPUs are mounted directly onto Peltier heat sinks, which serve as primary cooling units. This technology guarantees extremely precise temperature control, which is essential for the production of meaningful test results. In order to counter-cool these primary cooling units, air-cooled circulation chillers are used as secondary cooling units for multiple climate chambers. These systems provide the necessary cooling water and ensure that the test conditions remain stable over long periods of time. The high reliability and durability of the LAUDA circulation chillers are crucial in ensuring that the test procedures run smoothly.

LAUDA application:
Provision of secondary cooling

LAUDA product:
Ultracool Circulation chiller

THE RIGHT LAUDA TEMPERATURE CONTROL SOLUTION FOR EVERY APPLICATION

LAUDA ECO low temperature thermostats

Low-temperature thermostats for economical temperature control in the lab

- Extremely high temperature stability
- Cooling output from 0.18 to 0.7 kW
- Heating output from 1 to 2.6 kW

−50 °C 200 °C

LAUDA Microcool circulation chillers

Circulation chillers for reliable constant operation for process cooling

- Extremely high temperature stability
- Cooling output from 0.25 to 1.2 kW

−10 °C 40 °C

LAUDA Variocool process thermostats

Precise process thermostats for dissipating process heat in production plants

- Extremely high temperature stability
- Cooling output from 1.12 to 10 kW
- Heating output from 1 to 7.5 kW

−25 °C 80 °C

LAUDA Integral XT process thermostats

Powerful Integral process thermostats for dynamic applications with high heating and cooling capacities

- Extremely high temperature stability
- Cooling output from 1.5 to 25 kW
- Heating output from 3.5 to 24 kW

−90 °C 320 °C

LAUDA Ultracool circulation chillers

Energy-efficient circulation chillers with unique connectivity

- Suitable for outdoor installation
- Cooling output from 3.1 to 121.4 kW

−10 °C 35 °C

- Cooling output from 182.1 to 336.9 kW

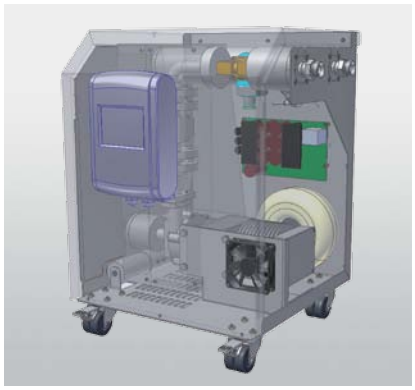
−5 °C 25 °C

LAUDA Semistat Process thermostats

Thermoelectric Peltier thermostats for plasma etching applications

- Compact
- Rapid temperature changes
- Cooling output from 1.2 to 4.4 kW
- Heating output from 3 to 12 kW

−20 °C 90 °C



Customized temperature control solutions

Customer-specific consultation and development of custom solutions and concepts

LAUDA's comprehensive product portfolio and almost 70 years of development expertise guarantee targeted consulting and equipment selection for our customers all over the world. From the product idea to series production, LAUDA can rely on series products, adaption modifications, and customer-specific developments, and offer these.

−90 °C 200 °C

LAUDA plant engineering

Secondary circuit systems and heat transfer layers for the semiconductor industry

LAUDA offers customized systems for the demanding requirements of the semiconductor industry (MOCVD equipment cooling - secondary circuit systems, wafer polishing and CMP process cooling - heat transfer systems). All LAUDA systems are characterized by their reliability and energy efficiency and are individual solutions that are precisely tailored to your process requirements.

−150 °C 550 °C

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