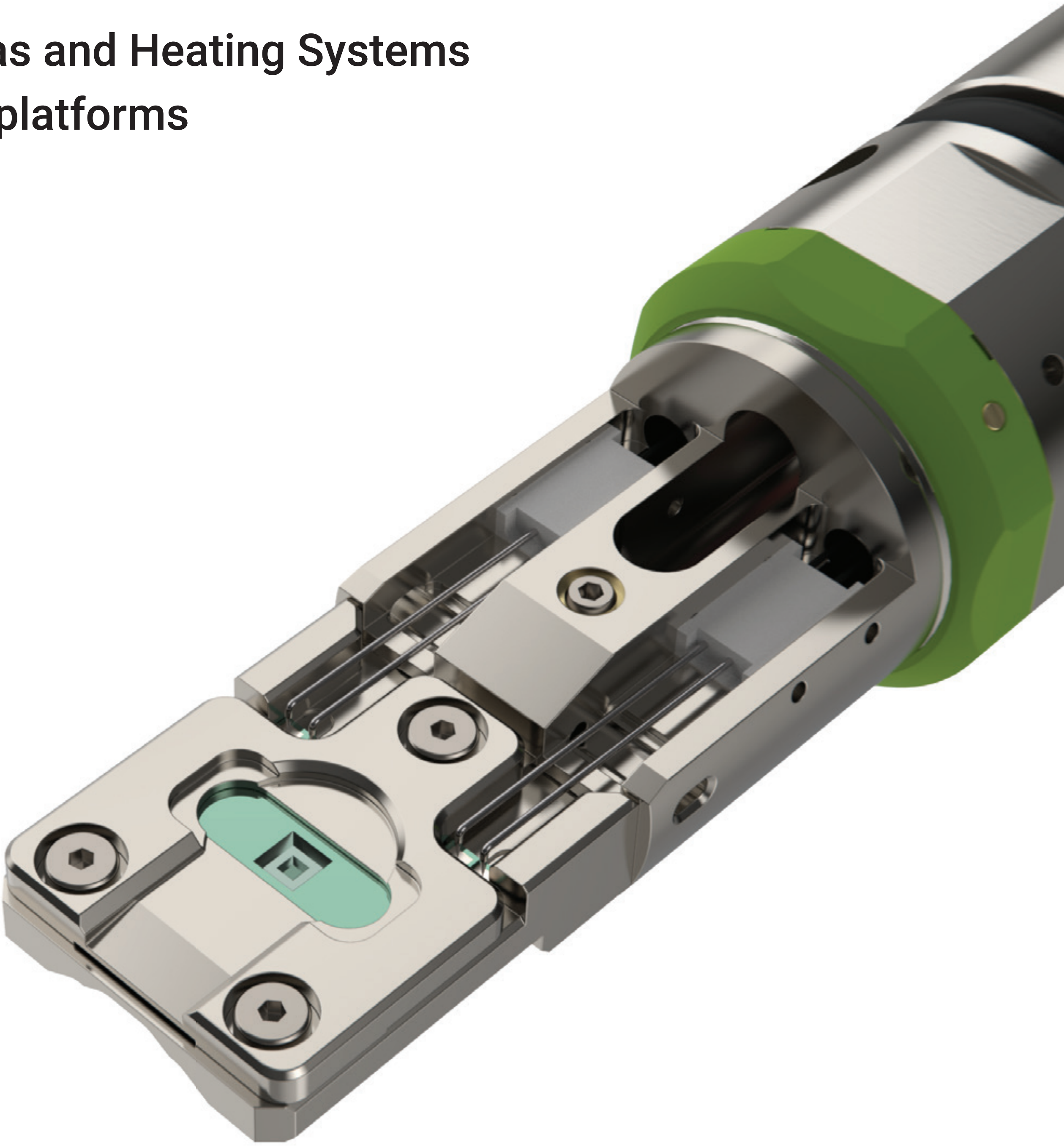
DENS solutions
INNOVATIONS THAT MATTER

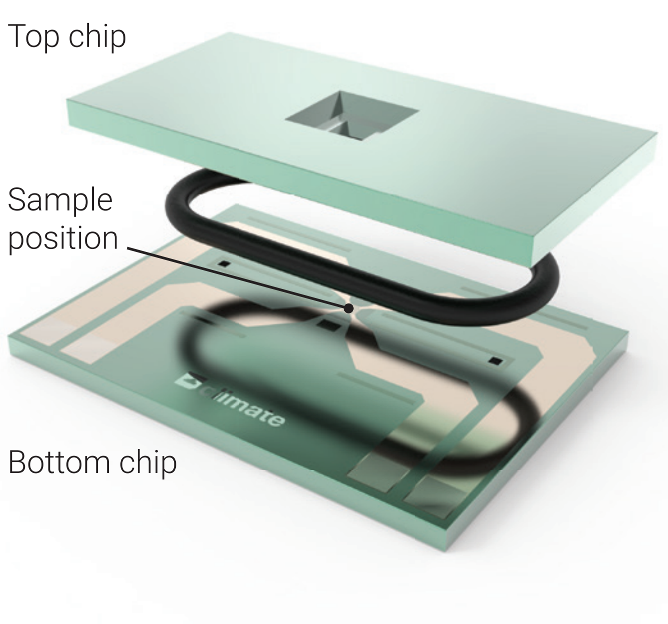
PRODUCT BROCHURE

climate

In Situ Gas and Heating Systems For TEM platforms



Climate Nano-Reactor

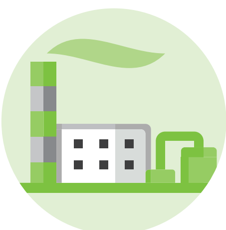


The Climate Gas & Heating Solution enables dynamic studies of cyclic specimen transformations in gaseous environments at elevated temperatures and sub-Angstrom level.

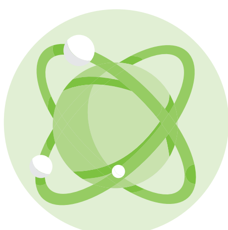
Climate will convert your high vacuum TEM from a static imaging tool into a real-world research laboratory, enabling you to speed up your development of new catalysts or other energy relevant materials and techniques.

Climate is the only environmental solution in the market that allows full dynamic correlation of the structural and chemical data including reaction product analysis due to the integration with the optional dedicated DENSsolutions gas analyzer.

Typical applications



Heterogeneous catalysis

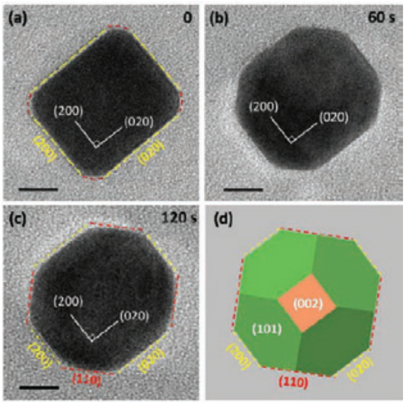


Nanomaterial growth & synthesis

Corrosion of metals & alloys

Green energy materials

Selected publications



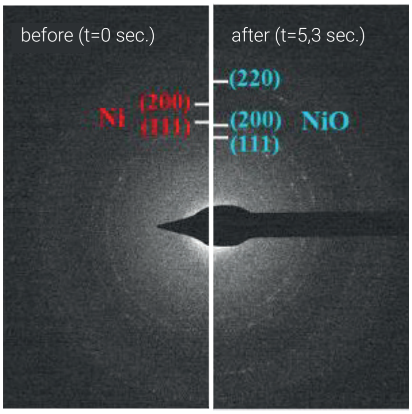
Time resolved in situ TEM images demonstrate the shape evolution of a Pd nanochrystals under 1 bar O_2 at 200 °C and the rebuilt Pd equilibrium structure by calculations. Scale bar: 5 nm.

Shape evolutions of a metal nanocrystal in environmental conditions

The climate S3+ customers demonstrate an atomic scale TEM observation of shape evolutions of Pd nanocrystals under oxygen and hydrogen environment at atmospheric pressure. Combined with multi-scale structure reconstruction model calculations, the reshaping mechanism is fully understood.

These results give a direct insight into the behavioural response of nanoparticles to a 'real' reactive pressure environment, which is likely to improve the understanding of solid-gas reaction during catalytic applications.

Zhang, Xun, et al. "In situ TEM studies of the shape evolution of Pd nanocrystals under oxygen and hydrogen environments at atmospheric pressure." Chemical Communications 53.99 (2017): 13213-13216.



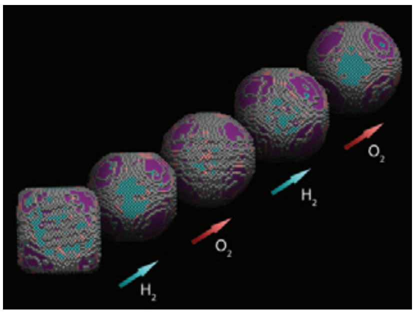
In Situ selected area electron diffraction (SAED) images. In Situ conditions: T = 600 °C, 200 mbar O2, 800 mbar N2, Flow = 0,6 ml/min. .

The reaction kinetics of nanoparticles

Acquiring the kinetics of gas–nanoparticle fast reactions under ambient pressure is a challenge owing to the lack of appropriate in-situ techniques. Now an approach has been developed that integrates time-resolved In Situ electron diffraction and a climate S3+ atmospheric gas cell system in TEM, allowing quantitative structural information to be obtained under ambient pressure with millisecond time resolution.

The ultrafast oxidation kinetics of Ni nanoparticles in oxygen was vividly obtained. This study gives new insights into Ni oxidation and paves the way to study the fast reaction kinetics of nanoparticles using ultrafast In Situ techniques.

Yu, Jian, et al. "Fast gas-solid reaction kinetics of nanoparticles unveiled by millisecond in-situ electron diffraction at ambient pressure." Angewandte Chemie (2018).



3D atomic structure reconstruction of Pt nanoparticles under the flow of selected gases.

In Situ conditions: T = 300°C, P = 1 Bar, Gas = O2 (pure) or H2 (5% diluted).

Three-Dimensional Quantification of the Facet Evolution of Pt Nanoparticles in a Variable Gaseous Environment

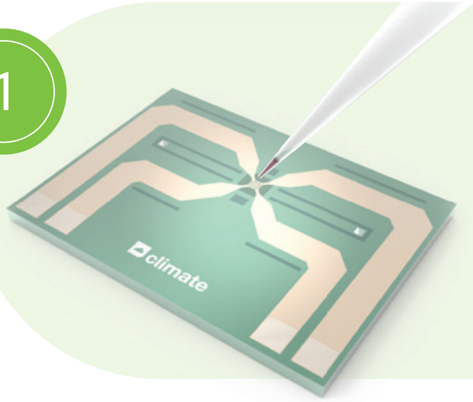
The Climate G+ customers were able to quantify refaceting of Pt nanoparticles with atomic resolution during various oxidation–reduction cycles. In a H_2 environment, a more faceted surface morphology of the particles was observed with {100} and {111} planes being dominant. On the other hand, in O_2 the percentage of {100} and {111} facets decreased and a significant increase of higher order facets was found, resulting in a more rounded morphology.

This methodology opens up new opportunities toward in situ characterization of catalytic nanoparticles because for the first time it enables one to directly measure 3D morphology variations at the atomic scale in a specific gaseous reaction environment created by Climate G+.

Thomas Altantzis, et al. EMAT, University of Antwerp, Belgium. Nano lett. (2019).

Why Climate?

1



Experimental preparation made easy

1. Full support with sample preparation
Experienced Application Engineers will provide you with tips and tricks on how to prepare your sample and a detailed workflow for FIB lamella preparation

2. Predefine the experimental conditions
Calorimetry and Mass spectrometry data can be produced ex situ by the Climate system if required. This allows you to define the optimum experiment conditions before going to the TEM

2

State of art environmental control

1. Dynamic mixing
Using a specially designed and patented mixing valve instead of a premixing tank allows you to change the gas composition on the fly and to vary rates with an accuracy of 0.1 %

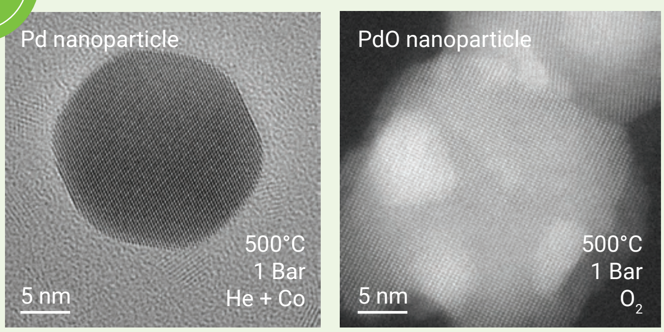
2. Fast switching
The defined gas channel and minimal gas volume inside the Nano-Reactor enable you to change the gas environment within seconds

3. Independent control
Gas composition, pressure and flow rate can be controlled independently using the widest experimental range

4. Clean experiments
The modular design concept enables easy on-site exchange and cleaning of all critical components without gluing or welding

5. Temperature accuracy and stability in gas environment
4-point probe heating provides the most accurate temperature with 0.01°C stability, even during gas flow. This allows accurate calorimetry data to be acquired during the experiment

3



High impact results

1. Data cross-correlation
Crystal structure, morphology, chemistry, thermodynamics and kinetics in one experiment

2. Product analysis
The optimized gas analyzer and defined gas channel of the Nano-Reactor guarantees an accurate analysis of the environment at any time with a sensitivity of 5 ppm

3. High Stability
Atomic resolution in TEM and STEM is routinely achievable in static and flow modes

4. Optimized analytical capabilities
The optimized design enables EELS and large solid angle EDS collection

Software for accurate environmental control

Climate Software

Advanced control and data analysis

Guided system preparation

• A step by step procedure for the preparation of the system with multiple safety features included in the software, ensures a peace of mind

Stimulus control

• The 'Direct control mode' allows each user to set all relevant parameters for the experiment such as pressure, gas composition and the flow rate in the Nano-Reactor

• The 'Flowsheet' mode allows the advanced user to set every component of the gas supply system independently

Automate your experiments

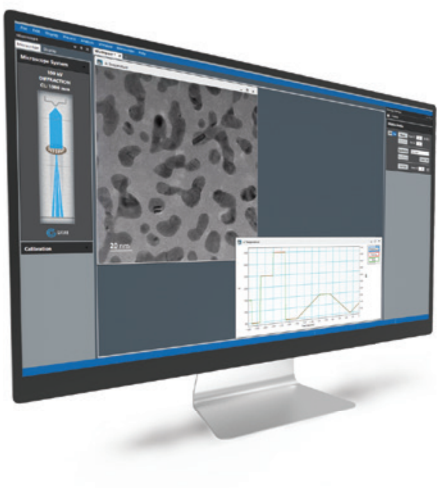
• Design your experimental workflow and obtain reproducible results with an embedded profile builder

Safe operation

• The gas flow in the Nano-Reactor is monitored and includes an automatic safety check to stop the flow if required

• Flammability limit check

• Automatic data logging during the experiment



Camera integration

True experimental integration

Easy & Fast experiments

• One SW to control in situ parameters & imaging

No mistakes or misinterpretation

• Synchronized in situ data with images at any frame rate

Save your time with your analysis

• Analyze images as a function of in situ parameters

System specifications

JEOL

JEOL	Climate Air	Climate G	Climate G+
Heating control	Four point probe resistive feedback		
Temperature range	RT to 1000 °C	RT to 1000 °C	RT to 1000 °C
Temperature Stability	0.01 °C	0.01 °C	0.01 °C
Pressure range	Ambient	0 - 1000 mbar	0 - 1000 mbar
Polepiece compatibility	All		
Alpha tilt range	UHR = ± 9 deg , FHP = ± 8 deg, HRP = ±15 deg, WGP = ±21 deg		
Modular design	Replaceable tubing and holder tip		
Resolution	≤100 pm*	≤100 pm*	≤100 pm*
Drift rate at in situ conditions	< 0.5 nm/min	< 0.5 nm/min	< 0.5 nm/min
Gas Mixing	N/A	Discrete	Continuous
Gas switching	N/A	< 60 s	< 1 s
Gas flow rate	Static	0 – 3 mln/min	0 – 3 mln/min
Micro-Calorimetry	V	V	V
EDS & EELS compatible	V	V	V

Thermo Fisher Scientific

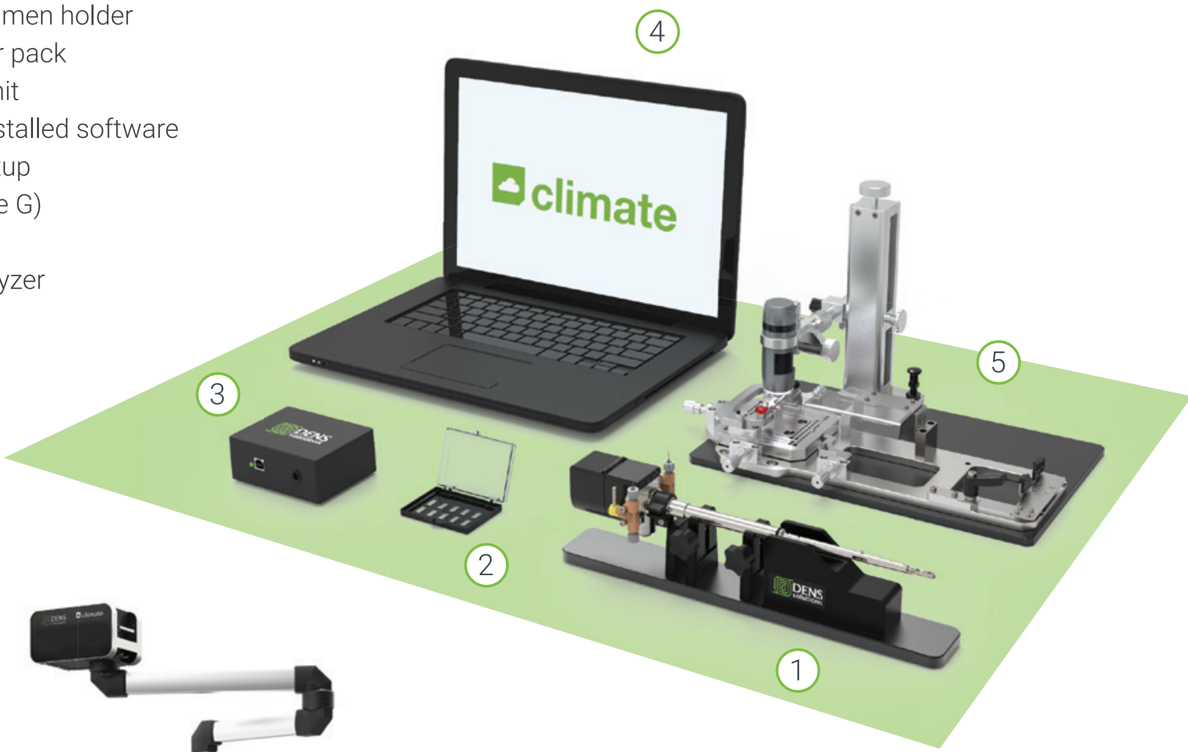
Thermo Fisher Scientific	Climate Air	Climate G	Climate G+
Heating control	Four point probe resistive feedback		
Temperature range	RT to 1000 °C	RT to 1000 °C	RT to 1000 °C
Temperature Stability	0.01 °C	0.01 °C	0.01 °C
Pressure range	Ambient	0 - 1000 mbar	0 - 1000 mbar
Polepiece compatibility	BioTWIN, S-TWIN, , TWIN, X-TWIN, C-TWIN		
Alpha tilt range	Bio-TWIN, C-TWIN, TWIN = ± 35 deg, X-TWIN, S-TWIN = ± 25 deg		
Modular design	Replaceable tubing and holder tip		
Resolution	≤100 pm*	≤100 pm*	≤100 pm*
Drift rate at in situ conditions	< 0.5 nm/min	< 0.5 nm/min	< 0.5 nm/min
Gas Mixing	N/A	Discrete	Continuous
Gas switching	N/A	< 60 s	< 1 s
Gas flow rate	Static	0 – 3 mln/min	0 – 3 mln/min
Micro-Calorimetry	V	V	V
EDS & EELS compatible	V	V	V

*Listed specifications are dependent on microscope configuration

Complete 'plug & play' package

1. Climate TEM specimen holder
2. Nano-Chips starter pack
3. Heating Control Unit
4. Laptop with pre-installed software
5. Chip alignment setup
6a. GSS light (Climate G)
6b. GSS (Climate G+)
7. Optional: Gas Analyzer

Including:
Supporting tools



Service and Support

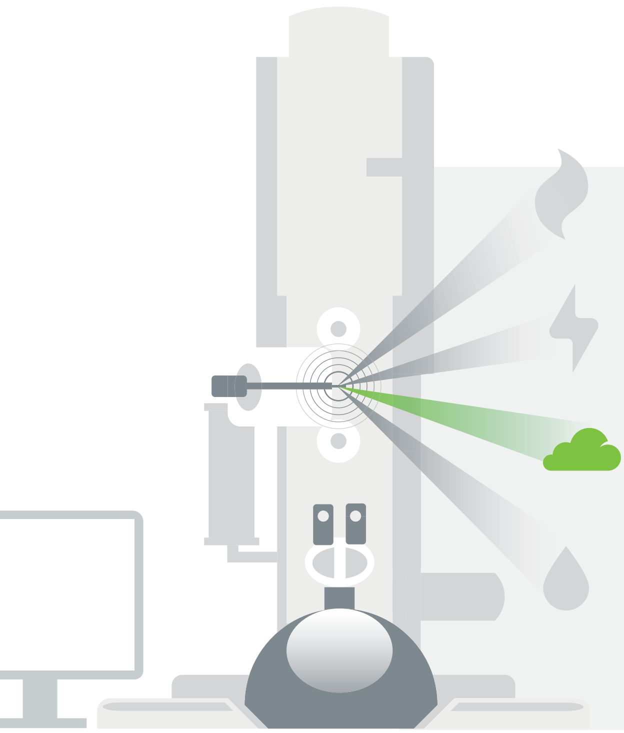
Product Warranty	24 months with optional extension
Regulatory compliance	CE, RoHS, FCC
Mechanical compatibility	Approved by TEM manufacturers
Radiation safety	According to TEM manufacturers compliance regulations
Service	Dedicated Field Service Engineer

INNOVATIONS THAT MATTER

DENSsolutions

Informaticalaan 12
2628ZD Delft
The Netherlands
Phone: +31 (0) 153 030 214
Email: info@DENSsolutions.com
www.DENSsolutions.com

To find your local distributor, please visit:
www.DENSsolutions.com/distributors



wildfire Heating
lightning Heating + Biasing
climate Gas + Heating
stream Liquid + Biasing or Heating