DENS solutions

INNOVATIONS THAT MATTER

In Situ GAS & HEATING solution for TEM platforms

climate

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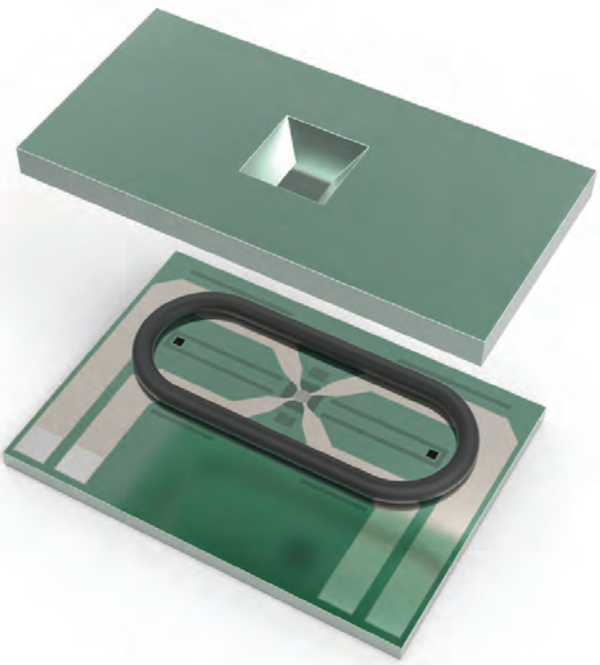
climate

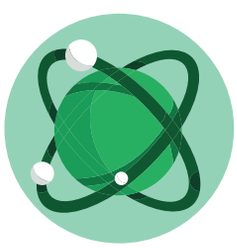


The Climate In Situ TEM Gas & Heating Solution enables dynamic studies of specimen transformations in gas and elevated temperature at sub-Angstrom level. Climate is the only environmental solution in the market that allows full correlation of the structural and chemical data including reaction product analysis due to the integration with dedicated DENSsolutions Gas analyzer. Convert your high vacuum TEM from a static imaging tool into a real-world research laboratory, this will enable you to speed up your development of new catalysts or other energy relevant materials and techniques.

Climate holder

Typical applications

Heterogeneous catalysis

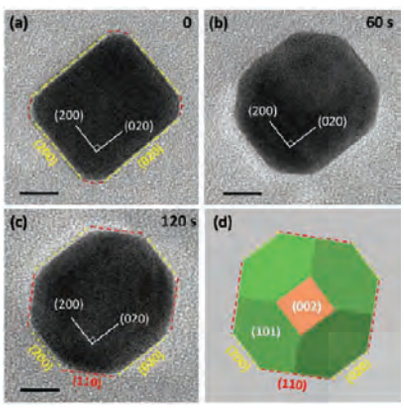


Nanomaterial growth & synthesis

Corrosion of metals & alloys

Green energy materials

Selected publications

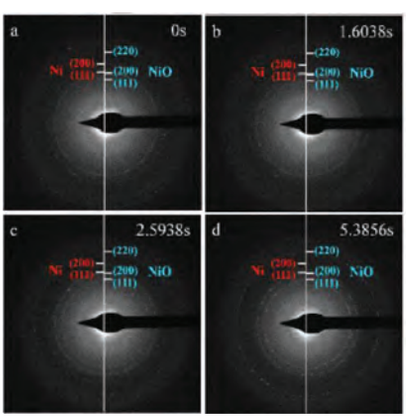


Time resolved in situ TEM images demonstrate the shape evolution of a Pd nanochrystals under 1 bar O_2 at 200 °C and the rebuilt Pd equilibrium structure by calculations. Scale bar: 5 nm.

Shape evolutions of a metal nanocrystal in environmental conditions

The authors 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.

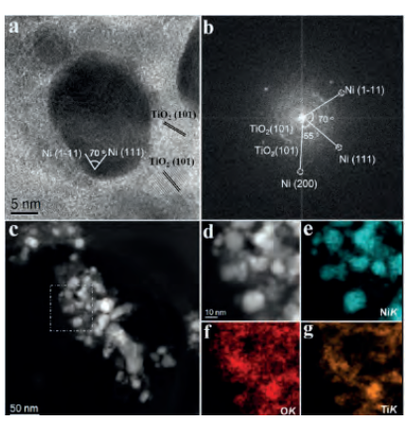


In-situ selected area electron diffraction (SAED) images.

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 an 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).



HRTEM images extracted from video sequences recorded under a mixture of CH4:H_2O at pressures equal to 10-2 mbar and 1.2 mbar respectively in a-b) and c-f). Initial Ir + Ir_2O_3 composite nanoparticle at 290°C (a- b) is gradually further oxidized (c-d) before and almost complete homogenization as Ir_2O_3 at 460°C (e) and its final complete reduction into metallic Ir at 485°C (f).

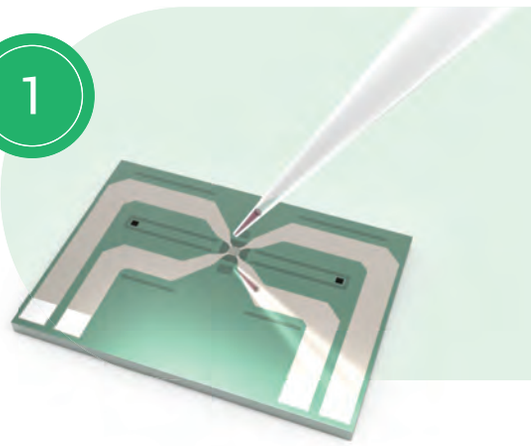
Structural & morphological evolution of catalyst

The mechanism of interfacial synergistic catalysis for supported metal catalysts has long been explored and investigated in several important heterogeneous catalytic processes. The modulation of metal–support interactions imposes a substantial influence on activity and selectivity of the catalytic reaction, due to the geometric/electronic structure of interfacial sites. Although great efforts have been made to validate the key role of interfacial sites in water-gas shift (WGS) over metal catalysts supported on reducible oxides, direct evidence at the atomic level is lacking and the mechanism of interfacial synergistic catalysis is still ambiguous. This work provides a fundamental understanding of interfacial synergistic catalysis toward the WGS reaction, which is constructive for the rational design and fabrication of high activity heterogeneous catalysts.

Xu, Ming, et al. "Insights into Interfacial Synergistic Catalysis over Ni@ TiO_{2-x} Catalyst toward Water-Gas Shift Reaction." Journal of the American Chemical Society (2018).

Why Climate?

1



Experimental preparation made easy

1. Easy sample preparation
Experienced Application Engineers will provide you with tips and tricks to avoid carbon contaminations from the beam for drop casted particles and a detailed workflow for FIB lamella preparation

2. Predefine the experimental conditions
Calorimetry and Mass spectrometry data produced by Climate system before TEM studies allows you to more easily define the optimum conditions for your experiment

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 relative concentrations with dilutions of 0.1 %

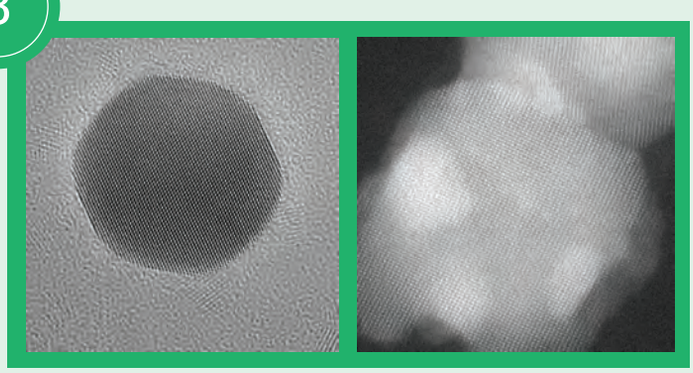
2. Fast switching
Defined gas channel and minimal gas volume inside the Nano-Reactor enable to change the gas environment within seconds

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

4. Clean experiments
The modular design concept enables easy on-site exchange 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

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 GSS independently

Automate your experiments

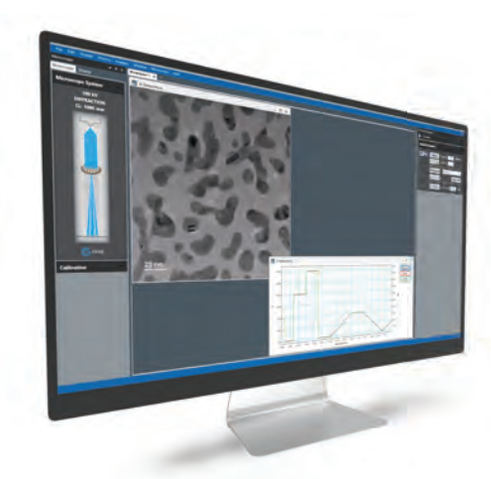
• Design your experimental workflow and obtain reproducible results with an embedded profile builder

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	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	All	All
Alpha tilt range	URP,FHP limited HRP, WGP ±20 deg	URP, FHP limited HRP, WGP ±20 deg	URP, FHP limited HRP, WGP ±20 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
Mass Spectrometer	V	V	V

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	BioTWIN, S-TWIN, , TWIN: ±35 deg X-TWIN, C-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
Mass Spectrometer	V	V	V

*Listed specifications are dependent on microscope configuration

Complete ‘plug & play’ package

1. Climate Gas & Heating TEM specimen holder
2. Nano-Chips starter pack
3. Heating Control Unit
4. Laptop with Climate and Digiheater software

5a. GSS light (Climate G); 5b. GSS (Climate G+)

6. Optional: Gas Analyzer
7. Supporting tools

Service and Support:

Product Warranty	24 months* with a possibility of extension
Product Liability Insurance	Every system includes product liability insurance to cover unlikely damages to the TEM or operators
Regulatory compliance	CE, RoHS, FCC
Mechanical compatibility	Approved by TEM manufacturers
Radiation safety	According to TEM manufacturers compliance regulations
Service	Dedicated Field Service Engineer

*Depending on configuration

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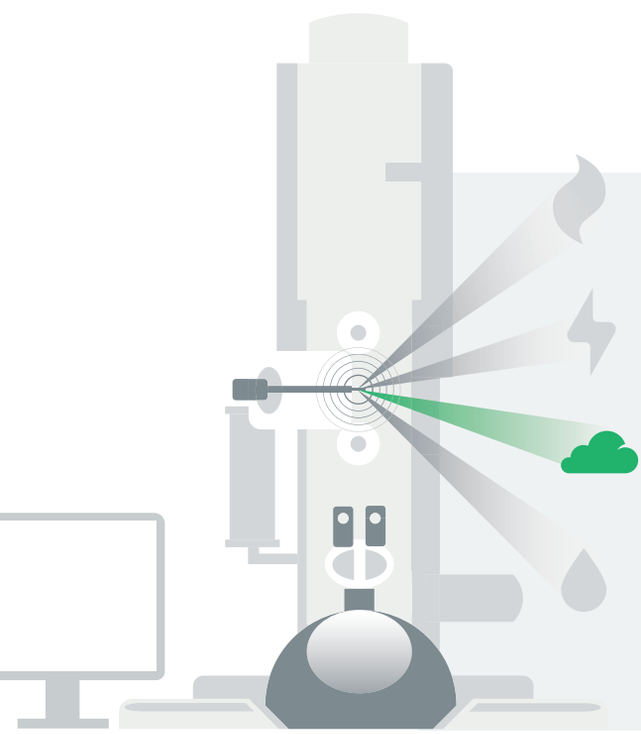

wildfire Heating
lightning Heating + Biasing
climate Gas + Heating
stream Liquid + Biasing or Heating

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