DENS solutions

Climate∞

In Situ TEM **Gas + Heating + Biasing**

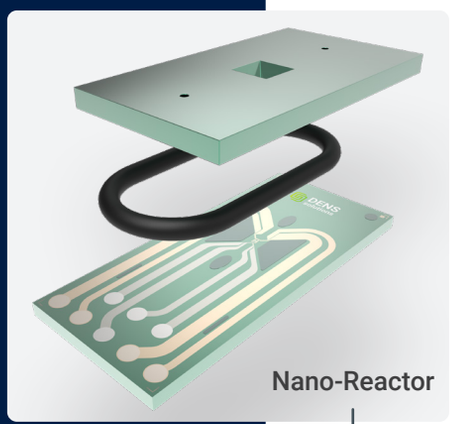
we care
we innovate
we deliver

Introduction

The DENSsolutions Climate Infinity solutions enables the atomic resolution imaging of gas-solid interactions and sample dynamics in research areas such as nanomaterial growth, catalysis, fuel cell and corrosion studies.

Climate Infinity converts 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, materials and techniques.

Climate Infinity is the only environmental solution in the market that allows full dynamic correlation of structural and chemical data. This includes reaction-product analysis due to the integration with the optional dedicated DENSsolutions Gas Analyzer.



The DENSsolutions **Gas Analyzer** enables the analysis of reaction products, transforming Climate into a unique platform able to combine TEM-based data with information about the reaction kinetics.

The DENSsolutions Climate **Vaporizer** elevates your in situ experiments by enabling you to independently add water vapor to any gas mixture. Ultimately, you can work with and even humidify a mixture of up to 3 different gases.

Typical applications

Nanomaterial growth

Catalysis

Fuel cells

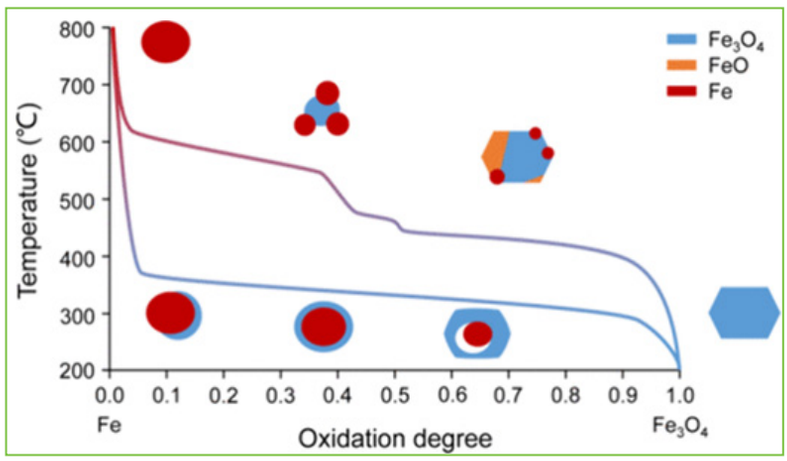
Corrosion

Selected Publications

Atomically Resolved Transition Pathways of Iron Redox

In this study, we explore the atomic-scale transformation of nanosized Fe_3O_4 under ambient-pressure H_2 gas using in-situ environmental transmission electron microscopy. This work elucidates a full dynamical scenario of iron redox under realistic conditions, which is critical for unraveling the intricate mechanisms governing the solid–solid and solid–gas reactions.

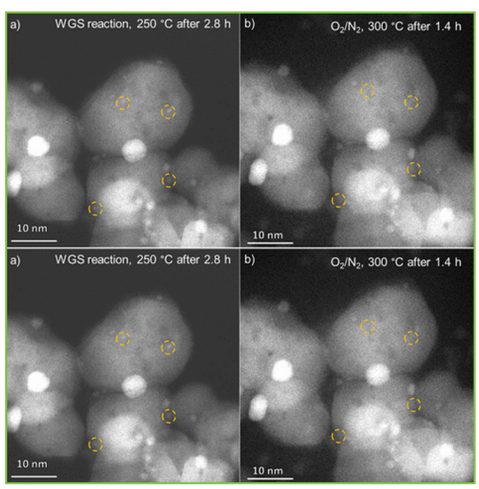
X. Liu, L. Gu, D. Zhou, D. Su et al. J. Am. Chem. Soc. 146, 25 (2024) 17487–17494



Reversible Growth of Gold Nanoparticles in the Low-Temperature Water–Gas Shift Reaction

Using operando X-ray absorption and in situ scanning transmission electron microscopy, users report direct evidence that the deactivation process can be reversed by carrying out a facile oxidative treatment. The use of in situ methods reveals the complex dynamics of supported gold nanoparticles under reaction conditions and demonstrates that gold catalysts can be easily regenerated, expanding their scope for practical

J. H. Carter, D. Zhou, G. J. Hutchings et al. ACS Nano 16 (2022) 15197-15205

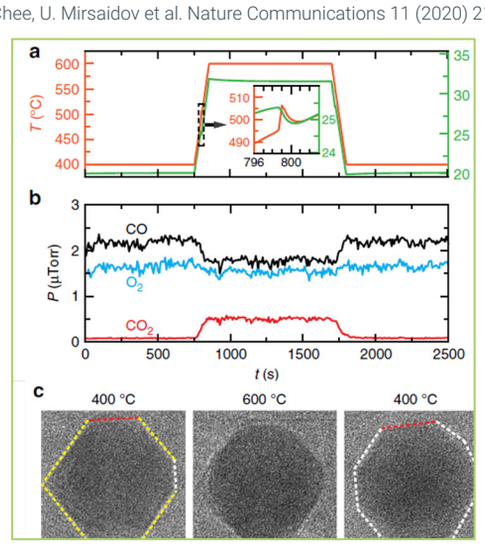


In situ HAADF STEM images of the 2.5 wt % $Au/CeZrO_4$ during the WGS reaction (a and c) and during the oxidative regeneration step (b and d). The orange circles indicate particles that were present during the WGS reaction and then disappeared during the O_2 treatment.

Structural changes in noble metal nanoparticles during CO oxidation and their impact on catalyst activity

Using operando transmission electron microscopy, we show that Pd NPs exhibit reversible structural and activity changes during heating and cooling in mixed gas environments containing O_2 and CO. Below 400 °C, the NPs form flat low index facets and are inactive towards CO oxidation while above 400 °C, the NPs become rounder, and conversion of CO

S.W. Chee, U. Mirsaidov et al. Nature Communications 11 (2020) 2133

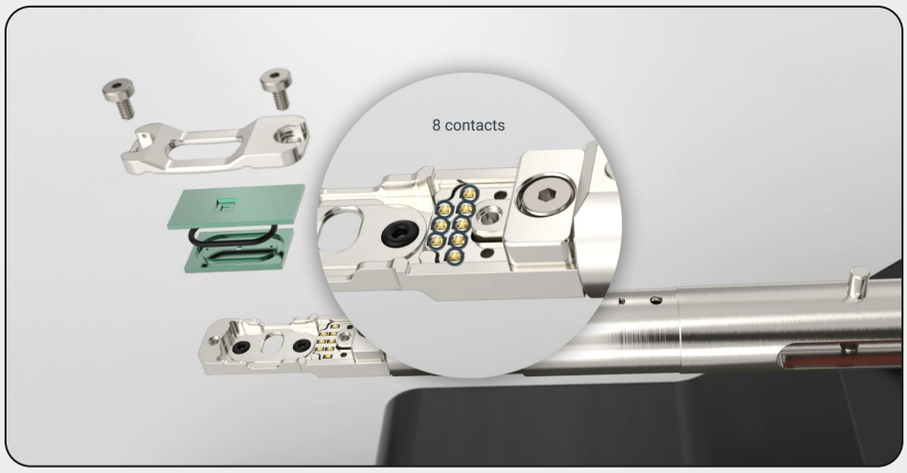


DPd NPs imaged in a gas environment with CO to O_2 ratio of 1.6. a) Measured temperature and heater power profile from the experiment. b) Corresponding measurements of the CO, O_2, and CO_2 content during the experiment. c) Image sequence describing the morphological changes in a Pd NP at different temperatures in the experiment.

Why Climate∞?

1 Apply heating *and* biasing stimuli

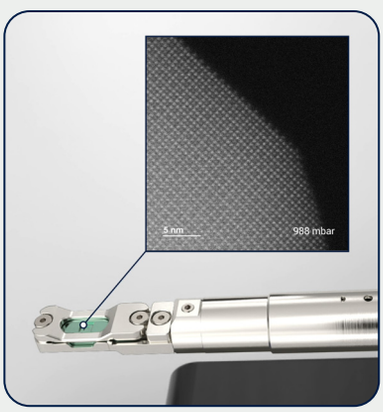
The new Climate Infinity holder features eight electrical contacts that enable simultaneous application of electrical and thermal stimuli in a gas environment. The contacts can be used for various electrically driven MEMS-based sensors and actuators, making the Infinity platform essentially a research playground.



2 Easily switch between STEM and TEM mode

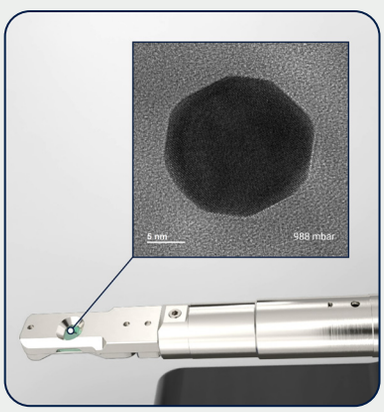
By flipping the tip 180 degrees, you can directly change the sample position to be either on the top or bottom without a need to disassemble the tip. This grants you the freedom to flawlessly switch between STEM or TEM mode, respectively, depending on your experimental needs, while maintaining the best resolution performance. Importantly, you can switch between both imaging modes within a matter of seconds.

Courtesy of Prof. Dong Su – IOP, CAS



STEM mode
(sample on top)

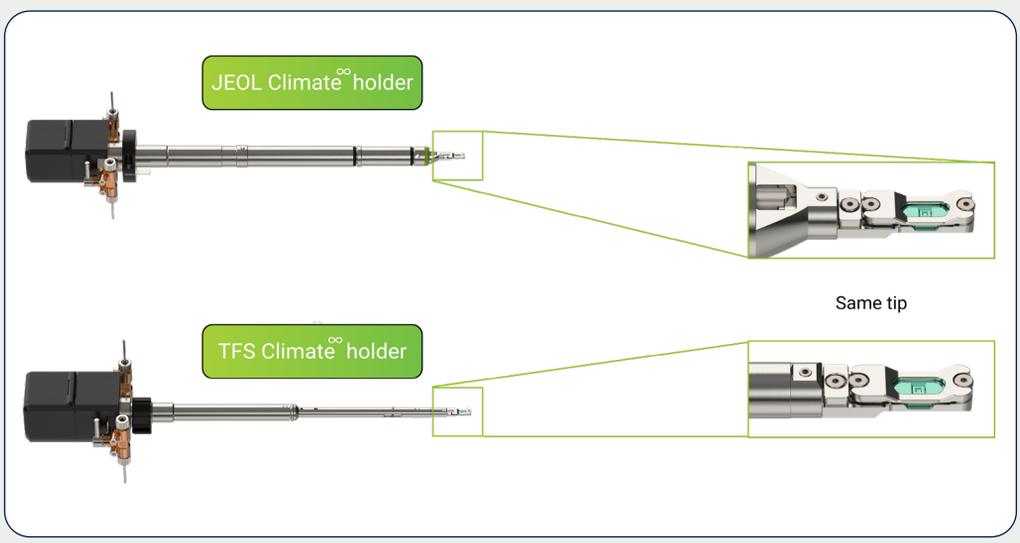
Flip the tip



TEM mode
(sample on the bottom)

3 Securely transfer your sample from one microscope to another

The universal tip of the Infinity holder works as a cartridge that can be moved from one holder body to another, without disassembling the universal Nano-Reactor. This feature enables complementary cross-platform studies of the same sample in SEM, beamline setups or using TEM's from JEOL or Thermo Fisher Scientific (TFS). These setups can either be located in the same lab, user facility or even in different universities/institutes, allowing for correlating experimental results in different platforms.



4 Perform gas and liquid studies with the same holder

The new environmental Infinity holder is your all-in-one solution for both gas and liquid experiments. Simply choose the appropriate function for the chips and connect the necessary gas or liquid supply system. Our extensive range of chip types includes gas-heating (GH), liquid-heating (LH), gas-heating-biasing (GHB), and liquid-heating-biasing (LHB), offering unparalleled versatility for your experimental needs. New MEMS chip designs can further expand the application space of the Infinity system.

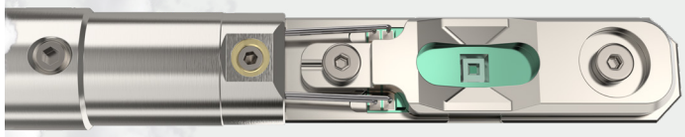
System specifications

Specification	Thermo Fisher Scientific	JEOL
Polepiece compatibility	Twin, S-twin, X-twin	UHR, FHP, HRP, WGP
EDS compatibility	Side entry, Super-X, Ultra-X*	Side entry
EELS compatibility	Yes	Yes
Number of electrical contacts	8	8
System operation modes	Gas + Heating | Gas + Biasing | Gas + Heating + Biasing	
Number of heating electrodes	4	
Number of biasing electrodes	4	
Chips compatibility	Universal chips for TFS and JEOL holders	
Gas inlet/outlet	Directly on the chip	
Modular holder design	Yes, removable tip	
Tip compatibility	Universal tip for TFS and JEOL** holder	
Flipping the tip	Yes (180 degrees)	
Sample position	Top or bottom window (STEM or TEM optimized)	
Gas mixing method	Continuous (flow-based) and volumetric (pressure-based)	
Gas input lines	3	
Gas operation mode	Static, flow	
Independent gas composition, flow, and pressure control**	Yes	
Continuous gas mixing of any composition**	Yes	
Mixing explosive & flammable mixtures**	Yes	
Nano-Calorimetry	Yes	
Mass Spectrometer	Yes, optional	
Vapor compatibility	Yes, add-on (water + alcohols)	
Perform liquid experiments	Yes (via an upgrade)	

** Contact DENSsolutions for more information*

*** Applicable to JEOL TEMs with HRP and WGP pole pieces*

**** Applicable to continuous (flow-based) gas mixing method (e.g. GSS)*



Climate

Microscopy TODAY 2021 Innovation Award

Complete ‘plug & play’ package

1. Climate Infinity TEM holder
2. Nano-Reactor starter pack
3. Heating control unit*
4. Laptop with pre-installed software

5a. Gas Supply System for Climate GVB

5b. Gas Supply System for Climate G+

6. Vaporizer (optional)
7. Gas Analyzer (optional)

** Integrated inside the GSS for Climate GVB and G+ (5a. and 5b.)*

Including:
Supporting tools

Service and Support

Product warranty	24 months with optional extension
Regulatory compliance	CE, RoHS, FCC
Radiation safety	According to TEM manufacturers compliance regulations

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www.DENSsolutions.com/distributors

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Lightning
Heating + Biasing

Lightning Arctic
Cooling + Biasing + Heating

Climate∞
Gas + Heating + Biasing

Stream∞
Liquid + Heating + Biasing

Version 5.2.1