DATASHEET

Themis ETEM

Environmental Transmission Electron Microscope for dynamic *in situ* exploration at the nanometer and atomic scale

The characterization of new, improved functional nanomaterials for energy and environmental technologies requires both a detailed understanding of their structure-performance relationships and atomic-scale insight into their geometric and electronic structures and chemical composition.

The Thermo Scientific™ Themis™ ETEM atomic-resolution Scanning/Transmission Electron Microscope (S/TEM) is an all-in-one solution for time-resolved *in situ* studies of dynamic behavior of nanomaterials during exposure to reactive gas environments and elevated temperatures. Built on the world-class Themis TEM platform, which delivers the ultimate performance in mechanical, electronic and thermal stability, Themis ETEM is a flexible solution for imaging of static specimens, observations of nanomaterials' dynamic response to the applied stimulus (gas and temperature), observations of growth (kinetics) as well as function, reliability and breakdown studies of nanodevices. Themis ETEM can be combined with optional image C_s corrector, Thermo Scientific™ X-FEG module and monochromator technology to further extend it to meet the high standards in atomic-resolution STEM imaging and spectroscopy expected from Themis TEM technology.

The Themis ETEM features an innovative differentially pumped objective lens, uniquely designed for the ETEM platform. This lens design enables all the same features you would expect from a standard Themis S/TEM, such as window-free imaging and compatibility with Themis TEM heating holders for easy sample insertion, while also allowing ample chamber space for full double-tilt capability to support 3-D tomography. Gas inlets allow you to safely add inert and reactive gases to the chamber. Gas pressures in ETEM experiments can be accurately preset from 10^{-3} Pa up to 2,000 Pa (for N_2). The new software-controlled user interface offers a range of settings to accommodate handling by both novices (automatic mode) as well as advanced operators (manual control).

Key benefits

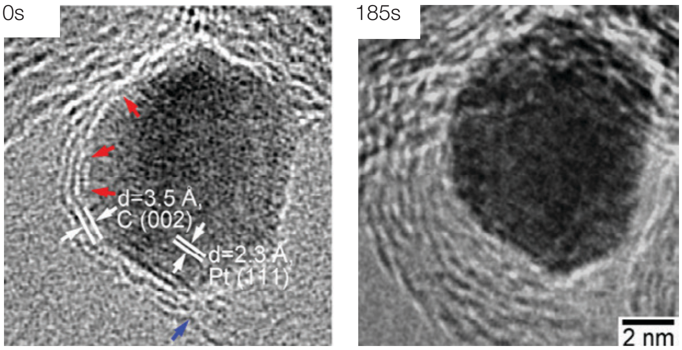
- **Observe** functional nanomaterials' time-resolved (dynamic) response to gas and temperature stimuli *in situ*.
- **Study** gas-solid interactions at the nanometer and atomic scale, including shape and morphology, and interactions at surfaces and interfaces.
- **Gain insight** at the atomic-scale into the geometric and electronic structure and chemical composition of functional nanomaterials.
- **Redesigned** ETEM user interface and full software control of all operational parameters.
- **Rapid interchange** between ETEM and high-vacuum mode.
- **Large polepiece gap** allows full tilt capability of the specimen holder for optimal orientation and electron tomography.
- **Compact and bakeable** gas inlet system.
- **Linear gas flow regimen** to minimize cross-contamination.
- **Built-in protection** assures a safe working environment and safe use of flammable gases.

The Themis ETEM is equipped with a mass spectrometer to determine gas composition in either the gas inlet system or in the specimen area. A built-in plasma cleaner allows for cleaning of the specimen area after using a gas. For safe and reliable use, the Themis ETEM features built-in hardware and software protections.

ETEM applications

Alkene-producing catalysts: deactivation by carbonaceous layer growth

In situ: Haldor Topsøe A/S, Titan ETEM (300 kV)

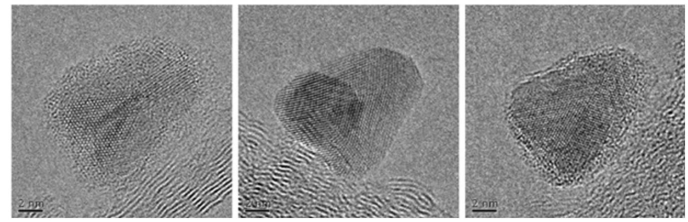


Surface-step as growth centers for graphene on a Pt / MgO alkane dehydrogenation catalyst – dynamic *in-situ* ETEM study (1.3 mbar C_4H_8, 475°C) with atomic-scale resolution. Z. Peng, et al., J. Catal. 286 (2012) 22; *Courtesy of A. Bell (UC Berkeley), C. Kisielowski (LBNL) & S. Helveg (HTAS).*

Reduction and oxidation reactions over nanoparticle catalysts

In situ: DTU Cen, Titan ETEM (300 kV)

Oxidized surface of metal particle | Reduced in H_2 atmosphere | Re-oxidized surface of metal particle



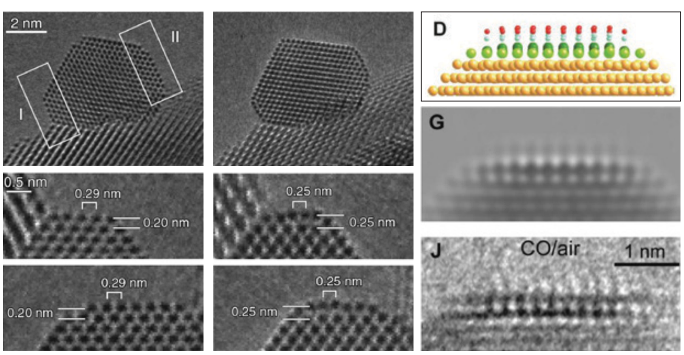
No gas, room temperature | H_2 atmosphere, elevated temp | No gas, room temperature

Atomic-resolution images of an oxidized metal nanoparticle undergoing reduction in hydrogen gas followed by subsequent re-oxidation. *Courtesy of T. Hansen & J. Wagner, DTU Cen, and J. Nielsen. DTU Cinf.*

Low-temperature CO oxidation catalysts—example: Au/CeO_2

In situ: Osaka University, Titan ETEM (80 and 300 kV)

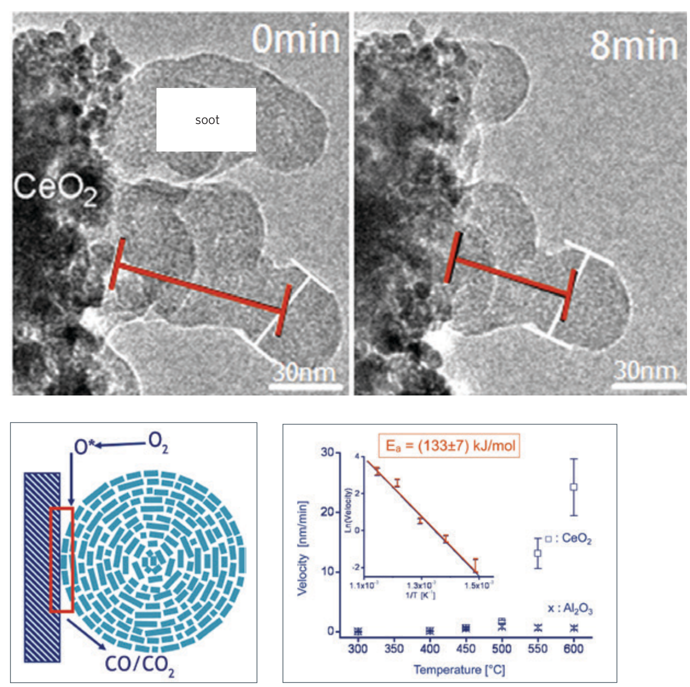
Vacuum | CO/air | CO/air



Dynamic ETEM study (1 vol% CO in air gas mixture at 0.45 mbar at room temperature) of carbon monoxide oxidation on Au/CeO_2. Visualization of surface reconstruction and CO gas molecules interaction with surface of Au nanocatalysts at reaction conditions. H. Yoshida, et al., Science 335 (2012) 317; *Courtesy of S. Takeda (Osaka University).*

Diesel automotive exhaust clean-up catalyst role of CeO_2 surface in soot oxidation

In situ: Haldor Topsøe A/S, Philips CM300 ETEM (300 kV)



Dynamic ETEM study (2.0 mbar O_2, 475°C) of soot oxidization near the soot-CeO_2 interface. Soot particles observed to move with constant velocity towards CeO_2. S.B. Simonsen, et al., J. Catal. 255 (2008) 1; *Courtesy of S. Simonsen & S. Helveg (HTAS).*

	STANDARD MODE		ETEM MODE (<0.5 MBAR NITROGEN)	
	NO CORRECTOR	C_S IMAGE CORRECTED	NO CORRECTOR	C_S IMAGE CORRECTED
TEM information limit (nm)	0.10	0.10 (0.09 mono on)	0.12	0.12
TEM point resolution (nm)	0.20	0.10	0.20	0.12
Probe current @ 1 nm (nA*)	0.6	0.6	0.6	0.6
System energy resolution*	0.7 eV	0.7 eV	0.8 eV	0.8 eV
STEM resolution (nm)	0.136	0.136	0.16	0.16

Note: All specifications are at 300 kV. For a list of specifications at other acceleration voltages, please contact your Thermo Fisher Scientific sales representative.

* With SFEG. The ETEM is also optionally available with X-FEG and gun monochromator. Depending on the energy filter option the energy resolution could be 0.20 eV (0.2 5 eV in ETEM mode).

Technical highlights

- Ultra-stable Schottky field emitter gun
- New three-lens condenser system with quantitative indication of convergence angle and size of illuminated area
- Flexible high tension from 80 to 300 kV
- X-FEG high-brightness gun (optional)
- Gun monochromator (optional)
- Image C_s correction (optional)
- Proven sub-Ångström performance
- Modular column design
- Patented accurate mechanical stacking system
- Thermo Scientific™ ConstantPower™ Lens Design
- Low-hysteresis design to minimize crosstalk between optical components
- Symmetric S-TWIN objective lens with wide, 5.4 mm pole piece gap and objective aperture in the back focal plane of the objective lens for TEM dark field applications
- Automatic apertures
- Rotation-free imaging
- Computerized 5-axis specimen stage
- Tilt range +/- 35 degrees for analytical double tilt holder and with tomography holder +/- 70 degrees
- Field-free imaging in Lorentz mode
- Holography mode
- Thermo Scientific™ TrueImage™ ATLAS Focus Series Software for quantitative HR-TEM applications
- Thermo Scientific™ Xplore3D™ Software for automated tomography STEM experiments and Xpress3D for ultra-fast 3D reconstructions

Detector options

- On-axis triple BF/DF detector (DF1/DF2/BF)
- HAADF detector
- Gatan US1000XP camera
- Thermo Scientific™ Eagle™ Series Cameras
- Gatan energy filter series
- EDS detector 0.13 srad solid angle (for detailed EDS performance, please contact sales and service organization)

ETEM technology

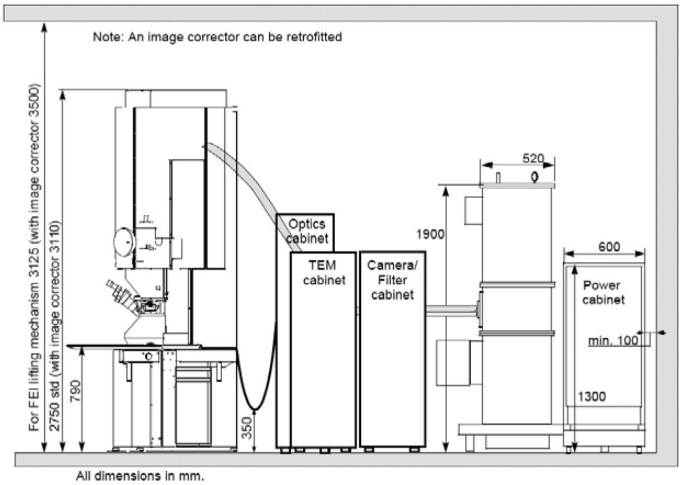
- Maximum protection for FEG emitter with differential pumping apertures (window-free imaging)
- Differentially pumped S-TWIN pole piece, space for full double tilt capability
- Regular Themis TEM operation in non-ETEM mode (see table)
- HAADF STEM scattering angle up to 70 mrad
- Compatible with regular Themis TEM holders for simple sample insertion
- Fast switching between ETEM and high-vacuum modes <4 minutes
- Accurate, computer-controlled gas pressure in ETEM experiments, from 10^{-3} Pa up to 2,000 Pa (20 mbar, 15 torr; N_2) and efficient pumping of gases (incl. H_2)
- 3 different gases via 3 gas inlets with preset partial pressure
- Reactant gas analysis via mass spectrometer (RGA)
- Effective cleaning of the column with built-in plasma cleaner
- Built-in safety features (for hardware protection and safe working environment)

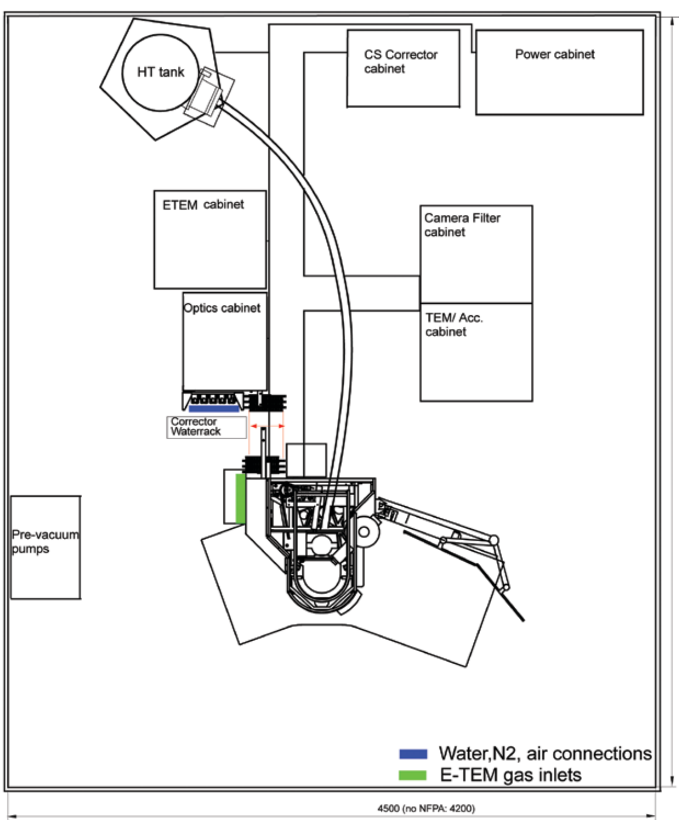
Holders options (requires gas compatibility in ETEM gas experiments)

- Single tilt holder
- Analytical double tilt holder
- Tomography holder
- Single/double tilt cryo-holder (LN_2)
- Single/double tilt heating holder
- Straining holder
- STM/AFM holder

thermoscientific

Floorplan





Schematic drawing of Themis ETEM room layout. In addition to standard TEM room requirements (room survey, etc.), please consider space, installation, and safety requirements for gas supply, gas storage, gas inlet/mixing units and gas exhausts. Please contact your Thermo Fisher Scientific representative.

Installation requirements

- Environment temperature 18° C to 23° C temperature stability 0.2° C/h heat dissipation into air nominal 4300 W
- Door height: 2,275 mm (depends on version)
- Door width: 1,320 mm
- Ceiling height: 3,500 mm (max. configuration)
- Required floor space for microscope 4,500 x 5,500 mm
- Max weight microscope coumn: 1,800 kg max
- Max point loading: 105 N/cm^2
- Power voltage: 3 phase including neutral and earth 398 V (+6 %, -10 %)
- Frequency 50 or 60 Hz (+/- 3 %)
- Power consumption with all microscope options max. 14,330 W
- Electrical connection single phase for water cooler 230 V, 4 kVA
- Cooling water required depending on ordered water cooling unit
- Double earth connection required
- Compressed air supply, pressure min. 6 bar max. 7 bar
- Nitrogen N_2, pressure min. 1 bar max. 3 bar
- SF_6 gas—proper ventilation required
- Gas exhaust system
- Liquid nitrogen LN_2
- LAN connection for remote diagnostics telephone line

Please contact your sales and service organization for more detailed information and for a complete pre-installation requirement document.

Certain gases may not be approved for use with the ETEM or their use may be restricted. Please contact Thermo Fisher Scientific for additional information on approved gases and our gas approval process.

Find out more at **thermofisher.com/EM-sales**

ThermoFisher SCIENTIFIC