DENS solutions

INNOVATIONS THAT MATTER

In Situ HEATING & BIASING solution for TEM platforms

lightning

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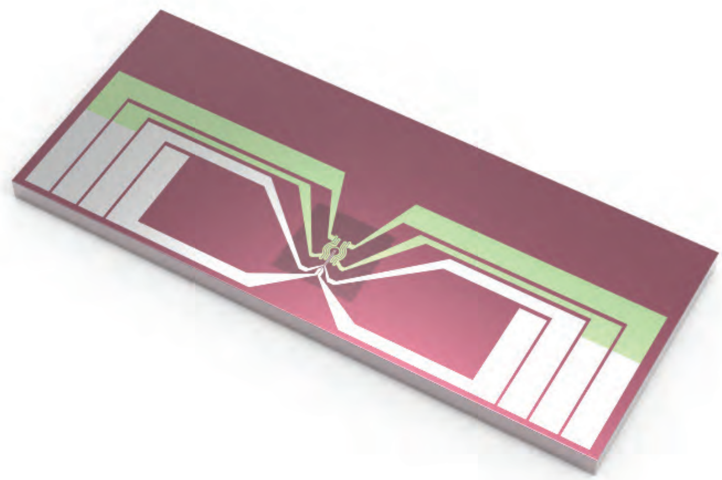
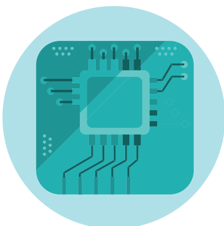


The Lightning In Situ TEM Heating and Biasing Solution allows to observe real-time dynamics of your specimen under a controllable electrical and thermal environment while maintaining the atomic imaging resolution provided by the TEM. State of the art Nano-Chips expands greatly the application space of your TEM, converting it into a real-world laboratory at the nanoscale and providing the unique possibility to link the processing conditions with the structure, properties and performances of your materials and devices.

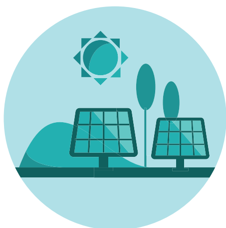
Lightning holder

Typical applications

Solid state batteries



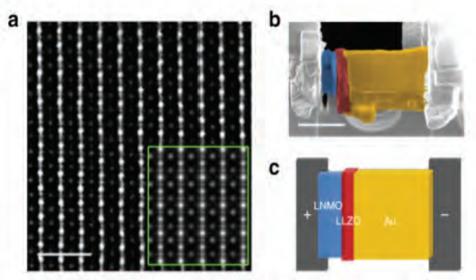
ReRam
& functional oxides



Semiconductor
nanodevices

Selected publications

Li-ion battery research

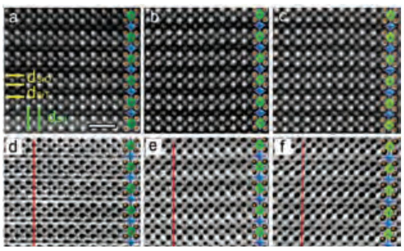


Configuration of the assembled all-solid-state lithium-ion battery and the atomic structure of LNMO a Atomic scale HAADF-STEM of the pristine LNMO cathode along the <112> zone axis. The simulation HAADF-STEM image is shown in a green rectangle which agrees perfectly with the experiment result. b SEM image of the assembled all-solid-state lithium-ion battery, and its corresponding schematic (c).

Most technologically important electrode materials for lithium-ion batteries are essentially lithium ions plus a transition-metal oxide framework. However, their atomic and electronic structure evolution during electrochemical cycling remains poorly understood. Here the authors report the in situ observation of the three-dimensional structural evolution of the transition-metal oxide framework in an all-solid-state battery. The in situ studies $LiNi_{0.5}Mn_{1.5}O_4$ from various zone axes reveal the evolution of both atomic and electronic structures during delithiation, which is found due to the migration of oxygen and transition-metal ions. This study not only shows the importance of atomic scale three-dimensional characterizations for improving our understanding on the dynamic process and fundamental mechanisms of delithiation but also sheds light on optimization of the structural stability, as well as the cycle-ability of all-solid-state battery.

Yue Gong, et.al. "Three-dimensional atomic-scale observation of structural evolution of cathode material in a working all-solid-state battery" Nature Communications 9 (2018): 3341

ReRam & functional oxides

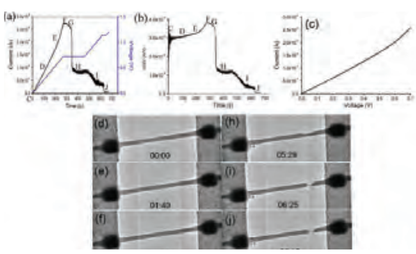


Evolution of lattice and oxygen occupancy in three states.

Oxygen ion transport is the key issue in redox processes. Visualizing the process of oxygen ion migration with atomic resolution is highly desirable for designing novel devices such as oxidation catalysts, oxygen permeation membranes, and solid oxide fuel cells. Here the authors show the process of electrically induced oxygen migration and subsequent reconstructive structural transformation in a $SrCoO_{2.5-\sigma}$ film by scanning transmission electron microscopy.

Zhang, Qinghua, et al. "Atomic-resolution imaging of electrically induced oxygen vacancy migration and phase transformation in $SrCoO_{2.5-\sigma}$." Nature Communications 8.1 (2017): 104.

Semiconductor nanodevices

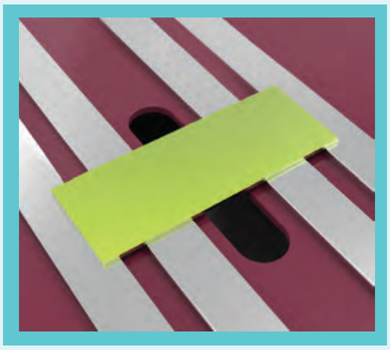


(a) – (c) I–V curves vs time of InAs NW during the whole process. (d) – (k) The corresponding TEM images at certain points depicted in (a) and (b).

The electrical properties of segments of tapered InAs nanowires (NWs) were investigated by in situ transmission electron microscopy with simultaneous I–V measurements using good ohmic contacts, thus excluding experimental artefacts as Joule heating caused by high-resistivity contacts. At low voltage the resistivity of InAs NWs with a diameter larger than 120 nm is constant ($\sim 10^{-2}\ \Omega \cdot cm$). When the current is strongly increased a breakdown of the NW occurs close to the cathode side, whereby the main changes are an electromigration of In and a sublimation of As. The critical current density for breakdown was close to $10^6\ Acm^{-2}$ in most cases. A Joule heating and electromigration mechanism for the breakdown process is proposed.

Zhang, Chao, et al. "In situ electrical characterization of tapered InAs nanowires in a transmission electron microscope with ohmic contacts." Nanotechnology 26.15 (2015): 155703.

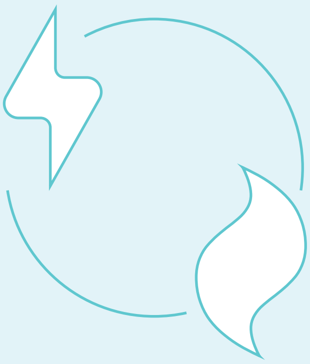
Why Lightning?



1 Simplified sample preparation

1. Best quality FIB lamellae
Final thinning directly on the chip without affecting the heating and biasing performance

2. High success rate
Specially designed FIB stub, Nano-Chip & detailed workflow to simplify the procedure

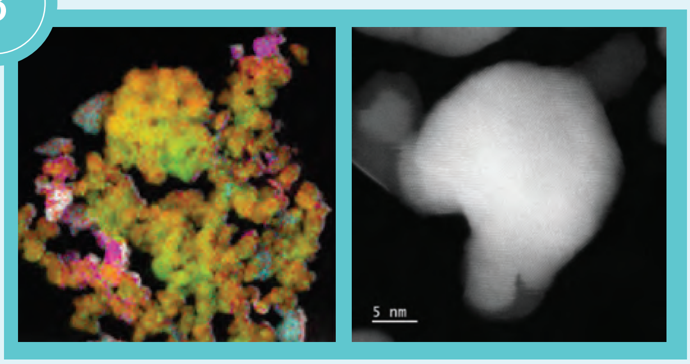


2 Reliable stimuli control

1. Heating & Biasing accuracy
4-point probe heating & biasing provides the most accurate temperature, voltage and current control

2. Wide in situ stimuli range
MEMS-based Nano-Chips are designed to sustain the highest temperatures and electric fields, individually or simultaneously

3. Reliable temperature
Temperature verified directly in TEM using EELS and SAED techniques



3 High impact results

1. New insights
The design of the Nano-Chips enables the user to perform thermal studies while simultaneously measuring I-V measurements with true pA current sensitivity

2. High Stability
Less than 200 nm displacement and short settling time even for $\Delta T = 1000$ °C, as well as atomic resolution routinely achievable even at extreme electric fields

3. Unaffected S/TEM performance
Minor Z-displacement (bulging) preserves the ultimate resolution without tedious stage movements

Software for accurate Heating and Biasing control

Impulse Software

Advanced control and data analysis

Full integration

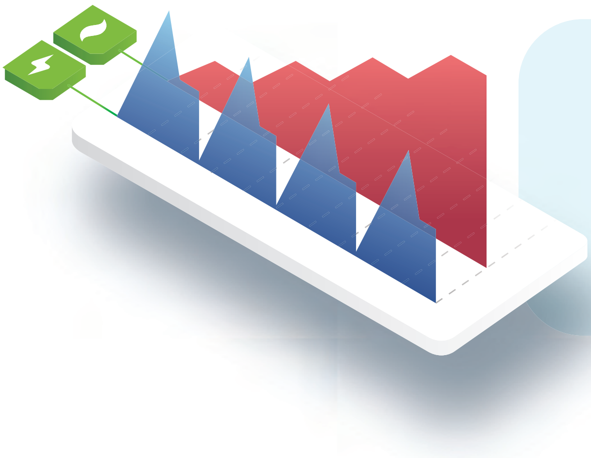
- Sleek interface to execute and monitor the experiment
- Complete control over your sample environment
- Access to calorimetry measurements

Automate your experiments

- Designed for ease of use
- Drag and drop profile builder with a wide choice of parameters
- Graphical visualization of the profile during creation and execution

Flexible graph interface

- Large canvas area for graphs
- Monitor in real-time only the parameters you are interested in
- Add new graphs, drag and drop to re-arrange them



Real-time data analysis

- Plot real-time I-V and R-T curves to fully understand the structure-property relationship of your material

lightning

System specifications

JEOL	Lightning HB	Lightning HB+
Heating & Biasing control	Four point probe resistive feedback	
Temperature range	RT - 1300 °C	RT - 1300 °C
Membrane Breakdown Voltage	> 200 V at RT	> 200 V at RT > 150 V at 900 °C
Attainable E-fields	≥ 400 kV/cm at RT	≥ 400 kV / cm at RT ≥ 300 kV/cm at 900 °C
Detectable Current range	1 pA to 100 mA	1 pA to 100 mA
AC measurement	Up to 100 Hz	Up to 100 Hz
Polepiece compatibility	All	All
Alpha tilt range	URP, FHP ± 15 deg HRP, WGP ± 20 deg	URP, FHP ± 8 deg HRP, WGP ± 20 deg
Beta tilt range	± 15 deg	± 15 deg
Attainable resolution	< 60 pA*	< 60 pA*
Drift Rate	< 0.5 nm/min*	< 0.5 nm/min*
Temperature accuracy	≥ 95%	≥ 95%
Temperature Homogeneity	≥ 99.5%	≥ 99.5%
EDS maximum temperature	1000 °C*	1000 °C*
Number of contacts	4	8

Thermo Fisher Scientific	Lightning HB	Lightning HB+
Heating & Biasing control	Four point probe resistive feedback	
Temperature range	RT - 1300 °C	RT - 1300 °C
Membrane Breakdown Voltage	> 200 V at RT	> 200 V at RT > 150 V at 900 °C
Attainable E-fields	≥ 400 kV/cm at RT	≥ 400 kV / cm at RT ≥ 300 kV/cm at 900 °C
Detectable Current range	1 pA to 100 mA	1 pA to 100 mA
AC measurement	Up to 100 Hz	Up to 100 Hz
Polepiece compatibility	Bio-TWIN, C-TWIN, TWIN, S-TWIN, X-TWIN	Bio-TWIN, C-TWIN, TWIN, S-TWIN, X-TWIN
Alpha tilt range	± 25 deg	± 22 deg
Beta tilt range	± 25 deg	± 25 deg
Attainable resolution	< 60 pA*	< 60 pA*
Drift Rate	< 0.5 nm/min*	< 0.5 nm/min*
Temperature accuracy	≥ 95%	≥ 95%
Temperature Homogeneity	≥ 99.5%	≥ 99.5%
EDS maximum temperature	1000 °C*	1000 °C*
Number of contacts	4	6

*Listed specifications are dependent on microscope configuration

Complete 'plug & play' package

1. Lightning heating & biasing TEM specimen holder
2. Nano-Chips starter pack
3. Heating Control Unit
4. Interconnect box
5. Laptop with Impulse software
6. Supporting tools
7. Optional: Keithley 2450 Source Measuring Unit

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

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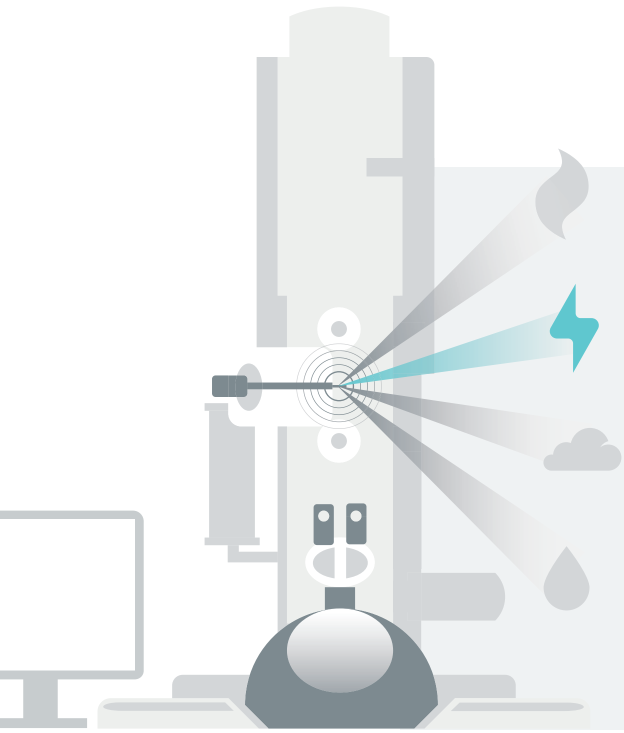

wildfire Heating
lightning Heating + Biasing
climate Gas + Heating
stream Liquid + Biasing or Heating