Lightning Arctic
In situ TEM cooling, biasing & heating

Quantum Design EUROPE

Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt

Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com

DENS solutions

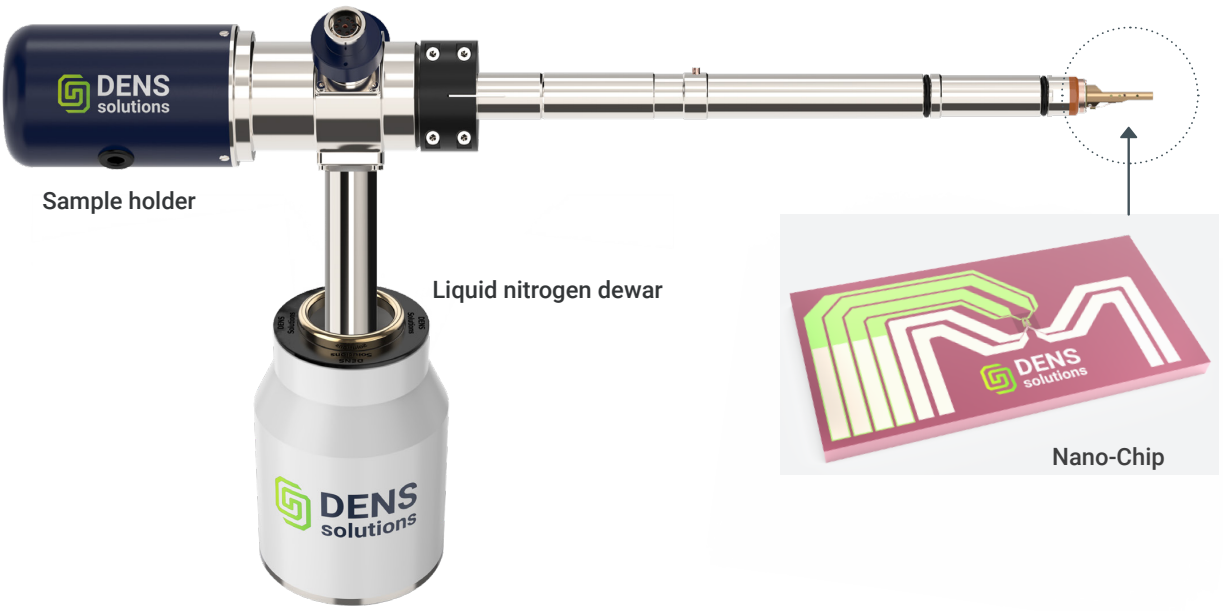
Lightning Arctic
In situ TEM cooling, biasing & heating

Introduction

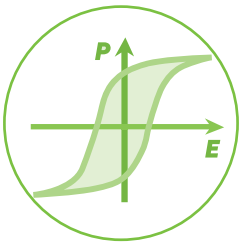
The Lightning Arctic In Situ TEM Cooling, Biasing and Heating Solution is a new addition to the Lightning product family. The Lightning Arctic system allows you to observe the real-time dynamics of your specimen at atomic resolution under a controllable electrical stimuli, either during cooling with liquid nitrogen or during heating.

The Lightning Arctic system has two operation modes, namely: 1) cooling & biasing and 2) heating & biasing. It greatly widens the application space of your TEM, providing the unique possibility to study low-temperature physics and to link processing conditions with the structure, property and performance of your materials and devices.

Our state-of-the-art MEMS Nano-Chip features a 4-point-probe method to accurately control biasing and heating and retrieve meaningful data. Its design sustains the highest reachable electrical fields and temperatures, either individually or simultaneously.

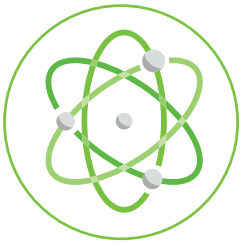


Typical applications



Ferroelectric materials

Magnetic materials



Quantum materials

Quantum Design EUROPE
Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt
Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com
DENS solutions

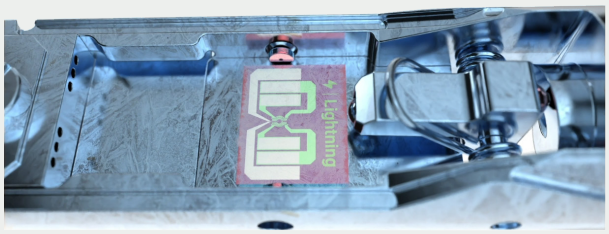
Lightning Arctic
In situ TEM cooling, biasing & heating

Why Lightning Arctic?

1) Perform in situ cooling and heating experiments

A cooling rod inside the Lightning Arctic holder can transfer the 'cold' towards the tip of the holder where the MEMS-based Nano-Chip holding the sample is located. Once this cooling rod is connected to a metal cooling braid that is immersed in a liquid nitrogen dewar, the sample can be cooled inside the TEM to liquid nitrogen temperatures. Aside from cooling, the Lightning Arctic holder also enables in situ heating experiments, where the temperature can reach 800 °C and and even 1300 °C depending on the chip used.

-160°C



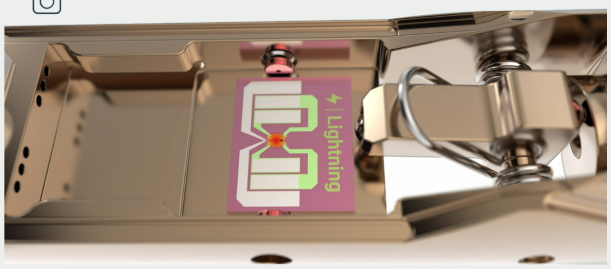
Cooling

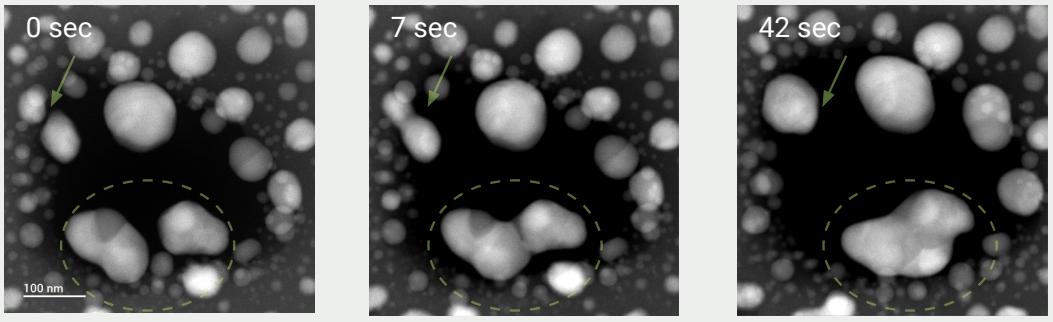
An image of the cooled tip of the Lightning Arctic holder at -160 °C with a Heating and Biasing MEMS Nano-Chip.

Heating

An image of the tip of the Lightning Arctic holder with a Heating and Biasing MEMS Nano-Chip, showing the heating of the sample via the heating spiral.

800 °C





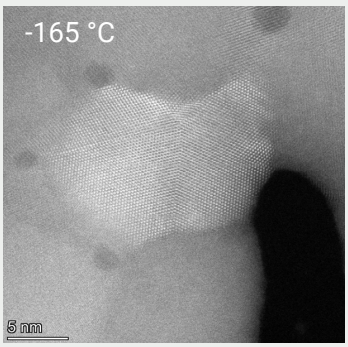
Nanoparticles coalescence and growth during annealing at 800 °C taken with STEM imaging mode (300 kV). The areas marked by the arrow and circles depict these changes.

Quantum Design EUROPE
Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt
Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com
DENS solutions

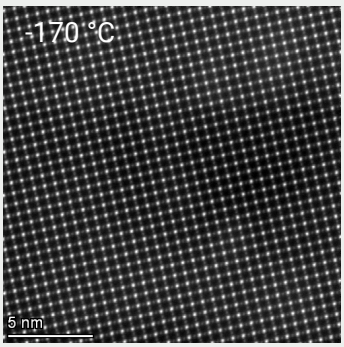
Why Lightning Arctic?

2) Experience atomic imaging stability

The Lightning Arctic holder was uniquely designed to host a number of additional temperature controllers that work to stabilize the sample drift during cooling. One controller ensures the temperature equilibrium with the TEM while the other stabilizes the cold influx towards the sample. The usage of the external dewar that helps to minimize the liquid nitrogen bubbling ensures that atomic imaging with low sample drift can be achieved.



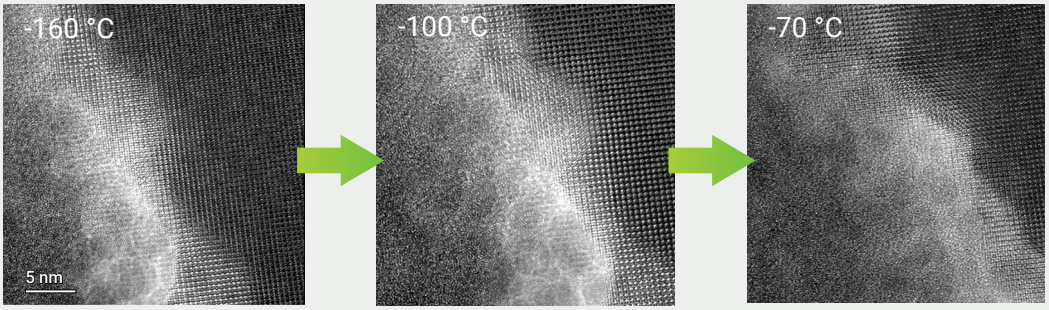
Au/Pd nanoparticles during cooling in STEM imaging mode (300 kV).



Fe-containing boracite FIB lamella aligned towards a zone axis (alpha tilt = -2 degrees; beta tilt = 7 degrees) at -170 °C taken in STEM imaging mode (300 kV) - Courtesy of Dr. Shelly Conroy, ICL.

3) Continous temperature control

Our state-of-the-art Heating and Biasing Nano-Chips enable the local manipulation of the temperature of the sample while not disturbing the cooling process of the holder. This means that you can achieve the fast setting of any user-defined temperature and the minimization of the image and focus shift when changing the temperature setpoint, all while ensuring atomic-scale imaging quality.



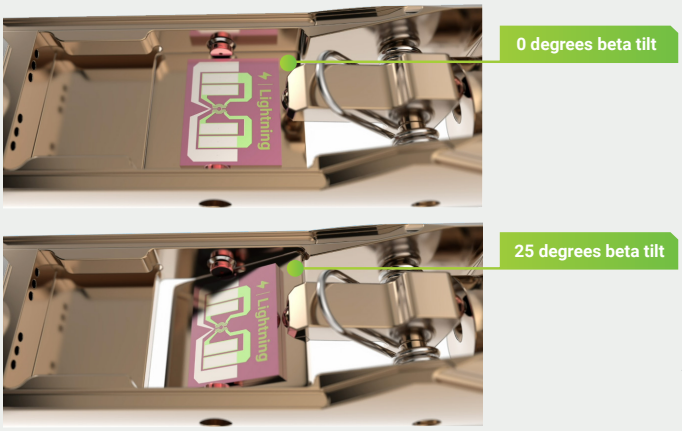
TEM images showing the boundary between the sample and the Pt protection layer at different temperatures during cooling (300 kV, exposure time = 1 sec).

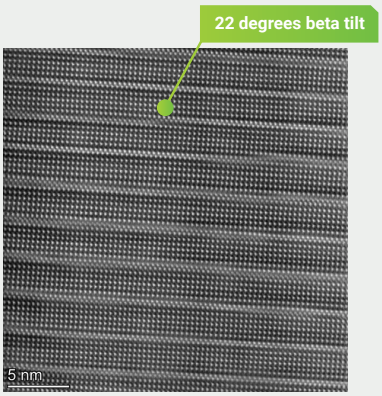
Quantum Design EUROPE
Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt
Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com

Lightning Arctic
In situ TEM cooling, biasing & heating

4) Achieve your required sample orientation

The double tilt Lightning Arctic holder allows tilting the sample in both alpha and beta directions of 10-25 degrees to find the required zone axis of the sample.

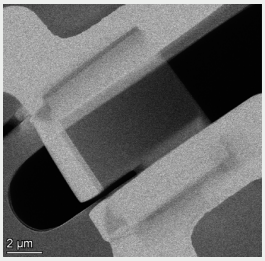




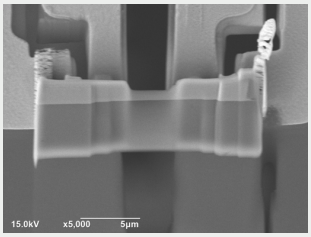
Aurivillius phase FIB lamella aligned towards a zone axis (alpha tilt = 6 degrees; beta tilt = 22 degrees) at -170 °C taken in STEM imaging mode (300 kV; scan time = 23 sec) - Courtesy of Dr. Shelly Conroy, ICL.

5) Perform in situ biasing experiments while cooling/heating

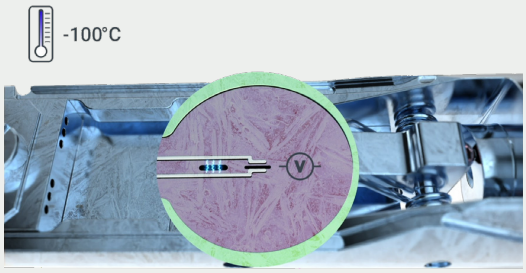
The Heating and Biasing Nano-Chips compatible with the Lightning Arctic holder contain biasing electrodes that can be used to apply and measure electrical signals either during cooling or during heating. Of course, the preparation of FIB lamellas on the Nano-Chips for electrical experiments is very crucial. There are already proven methods and tools developed for the Lightning system (like the DENSsolutions FIB stub) that can be used to prepare top-quality, short-circuit-free FIB lamellas on the Heating and Biasing chips for the Lightning Arctic system.



Ferroelectric FIB lamella prepared on the TFS Heating and Biasing Nano-Chip.



MIM (resistive switching) lamella prepared on the JEOL Heating and Biasing Nano-Chip.



An image of the tip of the Lightning Arctic holder with a Heating and Biasing MEMS Nano-Chip, illustrating the chip's biasing capability while cooling.

Quantum Design EUROPE
Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt
Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com
DENS solutions

Lightning Arctic
In situ TEM cooling, biasing & heating

System specifications

	Lightning Arctic	
	Thermo Fisher Scientific	JEOL
Pole piece compatibility	Twin, S-twin, X-twin	UHR, SAP, FHP, HRP, WGP
EDS compatibility	Side entry, Super-X	Side entry
EELS compatibility	Yes	Yes
Number of electrical contacts	6	9
Sample carrier compatibility	MEMS-based Nano-Chips, 3 mm TEM	
MEMS Nano-Chips compatibility	Heating, Heating & Biasing	Heating & Biasing
Alpha tilt range*	S-twin ≥ ± 25 deg X-twin ≥ ± 17 deg	UHR, FHP, SAP ≥ ± 10 deg HRP ≥ ± 15 deg
Beta tilt range*	S-twin ≥ ± 25 deg X-twin ≥ ± 25 deg	UHR, FHP, SAP ≥ ± 10 deg HRP ≥ ± 15 deg
System operation modes	Cooling and/or Biasing, Heating and/or Biasing	
Operational temperature range**	≤ -160 °C – 800 °C	
Temperature range on heating**	RT – 800 °C	
Temperature range on cooling	≤ -160 °C – 100 °C	
Temperature control mode	Closed 4-point probe feedback loop	
Continuous temperature control	Yes	
Cooling agent	Liquid nitrogen	
Liquid nitrogen dewar	External	
Cooling & stabilization time	≤ 60 min	
Operational time	≤ 4 hr	
Attainable resolution (TEM/STEM)***	≤ 1 Å	
Drift rate	≤ 2 nm/min	
Temperature cycling in cooling	Yes	
Detectable current range	1 pA to 100 mA	
Membrane breakdown voltage (≤ -160 °C – 800 °C)	≥ 100 V	

** Listed specifications are dependent on the exact pole piece gap, microscope configuration and EDS detector*

*** The maximum heating temperature can be extended when using a dedicated heating Nano-Chip*

**** Listed specifications are dependent on microscope specifications & performance*

Quantum Design EUROPE
Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt
Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com
DENS solutions

Lightning Arctic
In situ TEM cooling, biasing & heating

Complete ‘plug & play’ package

1. Lightning Arctic TEM specimen holder with the holder stand
2. Heating and Biasing Nano-Chips starter pack
3. Heating and Cooling control unit
4. LN_2 dewar with metallic braid (not shown)
5. Laptop with Impulse software
6. FIB stub 3.0
7. Keithley 2450 source measuring unit (optional)

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

Quantum Design EUROPE
Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt
Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com
DENS solutions

Lightning Arctic
In situ TEM cooling, biasing & heating

Wildfire
Heating

Lightning
Heating + Biasing

Lightning Arctic
Cooling + Biasing + Heating

Climate
Gas + Heating

Stream
Liquid + Biasing or Heating

Version 1.0

Quantum Design EUROPE
Quantum Design GmbH
Im Tiefen See 58
D-64293 Darmstadt
Please contact: Dr. Dominic Vogt
+49 6151 8806-557, vogt@qd-europe.com
Find your local contact at: www.qd-europe.com
DENS solutions