



Model CRX-4K CRYOGEN-FREE 4 K CLOSED CYCLE REFRIGERATOR-BASED CRYOGENIC PROBE STATION

Introduction

The Model CRX-4K is a versatile cryogen-free micro-manipulated probe station used for non-destructive testing of devices on full and partial wafers up to 51 mm (2 in) in diameter. The CRX-4K is a platform for measurement of electrical, electro-optical, parametric, high Z, DC, RF, and microwave properties of materials and test devices. Nanoscale electronics, quantum wires and dots, and semiconductors are typical materials measured in a CRX-4K. A wide selection of probes, cables, sample holders, and options makes it possible to configure the CRX-4K to meet your specific measurement applications.

Based on a Sumitomo 4 K base temperature CCR, the CRX-4K provides efficient temperature operation and control over a temperature range of 4.5 K to 350 K without the operating expense of liquid cryogenics. An optional interchangeable high temperature sample stage provides a temperature range of 20 K to 500 K. Each cryogenic stage is equipped with a sensor and heater to provide fast thermal response and rapid warm up for sample exchange. Actively cooled shielding intercepts blackbody radiation before it reaches the sample, ensuring small thermal gradients.

Careful design consideration was taken to provide a low vibration, user-friendly tool. Integrated vibration isolation and damping prevents mechanical vibration from affecting measurement performance. Sample stage vibration is limited to less than 1 μm (X, Y, and Z axes) through the full-scale temperature range.

The CRX-4K is user configured with up to six ultra-stable micro-manipulated probe arms, each providing precise 3-axis probe position control to land the probe tip accurately on device features. Each probe can also be rotated $\pm 5^\circ$ about its axis (planarized) to ensure multi-tip probes are properly aligned with the sample. DC measurements can be optimized for low-noise, high-impedance (low leakage), or high-thermal contact to the device under test (DUT). RF measurements include configurations up to 67 GHz. Optical sources can be introduced through viewport windows or optional fiber optic probe arm modification. Proprietary probe arms in a variety of sizes and materials minimize thermal mass and optimize electrical contact to the DUT. In addition, probe tips are thermally linked to the sample stage to minimize heat transfer to the DUT.

Features

- Closed cycle refrigerator provides high stability cryogen-free operation from 4.5 K to 350 K
- Optional temperature range from 20 K to 500 K
- Control stability to 10 mK
- Sample exchange cycle time of <3.5 h
- Low vibration design: <1 μm at sample stage (X, Y, and Z axes)
- Measurements from DC to 67 GHz
- Sample holders optimized for low noise, high frequency, or high impedance measurements
- Accommodates up to 51 mm (2 in) diameter wafers
- Configurable with up to six thermally anchored micro-manipulated probe arms
- Probe arms with 3-axis adjustments and $\pm 5^\circ$ planarization
- Cables, shields, and guards minimize electrical noise and thermal radiation losses
- Options and accessories for customization to specific research needs

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Applications

- Electrical and electro-optical measurements over a wide temperature range
- DC, RF and microwave
- Parametric testing
- Shielded/guarded/low noise characterization
- High Z
- Non-destructive, full wafer testing
- Multi-port S-parameter

Materials

- Nanoscale electronics (carbon nanotube transistors, single electron transistors, molecular electronics, nanowires, etc.)
- Quantum wires and dots, quantum tunneling
- Single electron tunneling (Coulomb blockade)
- Basic semiconductor devices including organics, LEDs, and dilute magnetic semiconductors

Specifications

Temperature*

Sample temperature range	<i>Standard</i>	Base 4.5 K; control range 5 K to 350 K		
	<i>Optional</i>	Base 4.5 K; control range 5 K to 500 K**		
		2 arms	4 arms	6 arms
		4.5 K; 5 K to 500 K**	5.5 K; 6 K to 500 K**	6 K; 6.5 K to 500 K**
Typical cool down time***				
Room temperature to within 10 K of base		1.5 h		
Room temperature to within 1 K of base		2 h		
Warm up time				
From base to room temperature		1 h		
Control stability				
<10 K		50 mK		
11 K to 250 K		10 mK		
251 K to 350 K		20 mK		
351 K to 475 K**		50 mK		
Temperature control (heaters)				
Sample stage		100 W		
CCR second stage		50 W		
CCR first stage		200 W (2 parallel heaters, 100 W each)		
Probe arm		Measurement only		

* Typical temperature performance at 60 Hz, 208 VAC, 25 °C cooling water

** Selectable equipment; high temperature coaxial sample stage limits low end temperature to 20 K

*** 50 Hz operation increases cool down time by 25%

CCR Vibration

Overall (X, Y, and Z axes)	<1 µm peak to peak at sample stage
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Pump Down Time

Before CCR start-up (10 ⁻³ Torr)	20 min
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Vacuum

Volume	8.7 L (530 in ³)
Room temperature	10 ⁻⁴ Torr
At base temperature	10 ⁻⁵ Torr

Probe Arm Thermal Drift

	77 K to 300 K	Base temp to 300 K
X axis	TBD	TBD
Y axis	<5 µm	<5 µm
Z axis	TBD	TBD

Probe Arms

Travel	
X axis	51 mm (2 in)
Y axis	25 mm (1 in)
Z axis	18 mm (0.7 in)
Translation scale	
X axis	20 µm
Y and Z axes	10 µm
Planarization (included with microwave probes)	±5°

Sample Space

Sample area	Up to 51 mm (2 in)
Probing area*	Ø25 mm (1 in)
Sample thickness	Up to 12 mm (thicker samples may reduce probable area)
Working height of sample	889 mm (35 in) from floor
Distance to radiation shield	42 mm (1.65 in) from sample holder to bottom of viewport
Distance from vacuum chamber	72 mm (2.84 in) from sample holder to top of viewport

* Probing possible over entire sample area; all probe tips are guaranteed to land in Ø25 mm (1 in)

CCR Compressor Requirements

Compressor	F50-L	F50-H	
Ambient temperature	5 °C to 28 °C; 28 °C to 35 °C with reduced capacity	5 °C to 28 °C; 28 °C to 35 °C with reduced capacity	
Line voltage	200 VAC ±10%	380/400/415 VAC	460/480 VAC
Frequency	50/60 Hz	50 Hz	60 Hz
Phase	3-phase, delta	3-phase, delta	
Power	8.3 kW max	8.3 kW max	
Cooling water			
Temperature	4 °C to 28 °C		
Flow rate	7 L/min at 28 °C to 4 L/min at 4 °C		
Inlet pressure	0.20 MPa (29 psig) to 0.69 MPa (100 psig)		
Pressure drop	0.05 MPa (7 psig) at 4 L/min to 0.32 MPa (46 psig) at 10 L/min		
Gas line length	6 m (19.7 ft) standard		
Approvals	CE, UL		

Frequency Range

ZN50 DC/RF probe frequency range	
Tungsten with cryogenic coaxial cable	0 to 50 MHz*
Tungsten with semirigid coaxial cable	0 to 1 GHz* [†]
Paliney 7 with cryogenic coaxial cable	0 to 50 MHz*
Paliney 7 with semirigid coaxial cable	0 to 1 GHz* [†]
BeCu with cryogenic coaxial cable	0 to 50 MHz*
BeCu with semirigid coaxial cable	0 to 1 GHz* [†]
GSG microwave probe frequency range	
Low frequency with K connector	0 to 40 GHz*
Mid frequency with 2.4 mm connector	0 to 50 GHz*
High frequency with 1.85 mm connector	0 to 67 GHz*

* Selectable equipment

[†] S21 > -10 dB up to 1 GHz, except for a (-40 dB) spike between 400 MHz and 800 MHz depending on probe model and placement; S11 < -3 dB up to 1 GHz

Optical

Optical viewports—located on top lids	Ø54 mm (2.13 in) outer window and Ø50 mm (2 in) inner window
Outer, clear fused quartz	99% IR transmittance
Inner	IR absorbing with narrow band visible light transmittance

Optical resolution—microscope	
7:1 zoom	4 µm
16:1 zoom	4 µm*

* Selectable equipment

Sample Holder (Chuck)

Maximum sample size—overall	Up to Ø51 mm (2 in)*
SH-1.25-G, grounded chuck	Up to Ø32 mm (1.25 in) and 350 K
SH-1.25-I, isolated chuck	Up to Ø32 mm (1.25 in) and 350 K*
SH-1.25-C, coaxial chuck	Up to Ø32 mm (1.25 in) and 350 K*
SH-1.25-T, triaxial chuck	Up to Ø32 mm (1.25 in) and 350 K*
SH-2.00-G, grounded chuck	Up to Ø51 mm (2 in) and 350 K*
SH-2.00-C, coaxial chuck	Up to Ø51 mm (2 in) and 350 K*
SH-2.00-T, triaxial chuck	Up to Ø51 mm (2 in) and 350 K*

* Selectable equipment

Standard Equipment

Closed cycle refrigerator — SHI RDK-408D2	4.5 K (base); 5 K to 475 K (control)
Sample stage temperature sensor	Lake Shore Model CX-1050-CU-HT-1.4M calibrated Cernox™ RTD
CCR second stage temperature sensor	Lake Shore Model DT-670C-CU silicon diode
CCR first stage temperature sensor	Lake Shore Model DT-670C-CU silicon diode
Sample stage heater	100 W
CCR second stage heater	50 W
CCR first stage heater	200 W (2 parallel heaters, 100 W each)
Cooled radiation shield and cooled IR-absorbing window above the sample	
Diameter	127 mm (5 in)
Radiation shield temperature sensor	Lake Shore Model DT-670C-CU silicon diode
Material	Nickel-plated aluminum
Radiation shield heater	100 W
Removable top lid with viewport	Ø51 mm (2 in) window; Ø50 mm (1.97 in) viewing area
Sample access	127 mm (5 in)
Typical temperature	30 K to 35 K throughout the full-scale temperature range
Temperature control	One Lake Shore Model 336 temperature controller, one Lake Shore Model 211 temperature monitor and one Model 142 200 W (two channels, 100 W each) power supply (independent regulation of sample stage, CCR second stage, CCR first stage, and probe arm temperature monitoring)
Electroless nickel-plated aluminum vacuum chamber	
Diameter	203 mm (8 in)
Seals	O-ring (370 Buna-N)
Removable top lid with clear fused quartz viewport	Ø64 mm (2.5 in) window
Viewable area	Ø54 mm (2.13 in)
Probe ports	Up to 6 surround the sample thermal radiation shield
Pump port	KF-40 with valve (pump sold separately)
Gauge port	KF-25 (gauge not included)
Gas port	0.25 in NPT with valve (inert gas only)
Over pressure safety	3.4 kPa (0.5 psi) pressure relief valve
Machined nickel-plated aluminum base plate (table)	635 mm × 508 mm (25 in × 20 in)
Support stand	Low vibration, welded steel stand with integrated passive vibration isolation and dampening—minimizes system vibration displacement
Temperature sensor installed and wired to a 6-pin feedthrough (included on one probe arm)	
Grounded sample holder	SH-1.25-G, accommodates up to a Ø32 mm (1.25 in) sample with a Ø25 mm (1 in) probe area to land all probes
Optics	
Zoom 70 microscope	7:1 zoom with 4 µm resolution
Color CCD camera	S-video or composite output format
Swing arm	Optics can be manipulated to view any part of the sample or wafer, and can be retracted and swung away to allow access to the top of the vacuum chamber for sample exchange
Video monitor	High resolution, 17-inch
Sample illumination	Coaxial via fiber optic or ring light from an adjustable light source and power supply (must specify sample illumination at time of order) NOTE: Coaxial illumination is recommended for highly reflective materials
Instrument console	
Basic tools and spares kit for standard operation	

Required User Configurable Equipment — Micro-manipulated Stages, Probes, Probe Tips, and Cables

MICRO-MANIPULATED STAGES

Part Number	Description
MMS-09	Micro-manipulated stage with thermal radiation shields, stainless steel welded bellows, and feedthrough ports—includes probe arm and base; probes, probe tips, and cables sold separately

ZN50 DC/RF PROBES

- Ideal for: DC biasing, low/high frequency measurements, low noise shielded, and low-leakage guarded measurement
- ZN50 probe base incorporates a pair of copper braids that anchor to the sample stage to dynamically cool/heat the probe to the sample temperature
- SMA connector mounted directly to a replaceable alumina ceramic blade with a 50 Ω stripline routed to the probe contact

We understand that today's researcher requires flexibility. Our wide selection of probes, cables, sample holders, and options make it possible to configure a probe station to meet your specific measurement applications.

Part number (probe body)	Description
ZN50-26U	50 Ω stripline probe body mount (each probe body mount requires a ceramic blade—selectable below)

Part number (ceramic blade)	Tip material	Maximum frequency (GHz)	Maximum probe temperature*	Maximum sample temperature**	Tip radius (μm)
ZN50R-03-W	Tungsten	1 <i>(maximum frequency 50 MHz with ZN50C-G or ZN50C-T cable; maximum frequency 1 GHz with MWC-09-00K cable)</i>	350 K	500 K	3
ZN50R-10-W					10
ZN50R-25-W					25
ZN50R-03-P7	Paliney 7				3
ZN50R-10-P7					10
ZN50R-25-P7					25
ZN50R-03-BECU	BeCu				3
ZN50R-10-BECU					10
ZN50R-25-BECU					25
ZN50R-100-BECU		100			
ZN50R-200-BECU		200			

* As measured by the probe arm temperature sensor

** Selectable equipment

ZN50 DC/RF CABLES

Part number	Cable type	Connector type	Feedthrough type	Measurement configuration	Maximum frequency	Maximum cable temperature*	Maximum sample temperature**
ZN50C-G	Ultra-miniature cryogenic coaxial	SMA	BNC	Shielded	50 MHz	350 K	500 K
ZN50C-T	Ultra-miniature cryogenic coaxial	SMA	3-lug triaxial	Low leakage	50 MHz		
MWC-09-00K	Semirigid microwave coaxial	K (SMA compatible)	Loss-less compression seal	High frequency	1 GHz [†]		

* As measured by the probe arm temperature sensor

** Selectable equipment

[†] S21 > -10 dB up to 1 GHz, except for a (-40 dB) spike between 400 MHz and 800 MHz depending on probe model and placement; S11 < -3 dB up to 1 GHz

GSG MICROWAVE PROBES

- Coplanar waveguide probe with ground-signal-ground (GSG) contact geometry
- User-specified pitch (spacing)
- Optimized low thermal conductivity coaxial leading to low thermal conductivity tips
- Include a copper braid assembly to cool the probe to near sample temperature
- Separate planarization module with $\pm 5^\circ$ rotation mechanism is provided

Part number	Connector type	Maximum frequency (GHz)	Maximum probe temperature*	Maximum sample temperature**	Pitch (μm)
GSG-050-40A-26U-E	K	40	350 K	500 K	50
GSG-100-40A-26U-E					100
GSG-150-40A-26U-E					150
GSG-200-40A-26U-E					200
GSG-250-40A-26U-E					250
GSG-050-50A-26U-E	2.4 mm	50	350 K	500 K	50
GSG-100-50A-26U-E					100
GSG-150-50A-26U-E					150
GSG-200-50A-26U-E					200
GSG-250-50A-26U-E					250
GSG-050-67A-26U-E	1.85 mm	67	350 K	500 K	50
GSG-100-67A-26U-E					100
GSG-150-67A-26U-E					150
GSG-200-67A-26U-E					200
GSG-250-67A-26U-E					250

*As measured by the probe arm temperature sensor

**Selectable equipment

GSG MICROWAVE CABLES

- Loss-less compression seal
- Semirigid with Teflon® dielectric

Part number	Cable type	Feedthrough type	Maximum cable temperature*	Maximum sample temperature**	Connector type	Maximum frequency
MWC-09-00K	Semirigid microwave coaxial	Loss-less compression seal	350 K	500 K	K (SMA compatible)	40 GHz
MWC-09-240					2.4 mm	50 GHz
MWC-09-185					1.85 mm	67 GHz

*As measured by the probe arm temperature sensor

**Selectable equipment

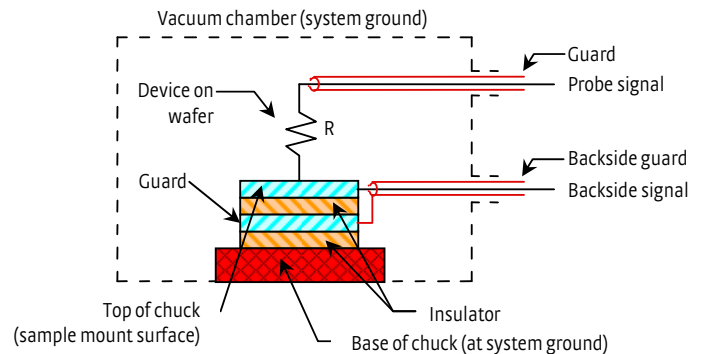
Sample Holders (Chucks)

Typical sample holder configuration characterized by:

- Leakage resistance between
 - Top surface and guard
 - Guard and ground
- Capacitance between
 - Top surface and guard
 - Guard and ground

Types of sample holders

- Grounded sample holder—sample mount surface at system ground
- Isolated sample holder—backside contact not needed; sample mount surface is electrically non-conductive and isolated from ground
- Coaxial sample holder—backside contact can be made; sample mount surface is isolated from ground
- Triaxial sample holder—guarded backside contact can be made; sample mount surface has guarded isolation from ground



Part number	Measurement configuration	Separate feedthrough required	Maximum sample (diameter)	Maximum voltage	Maximum temperature	Change in temperature at 4.2 K
SH-1.25-G	Grounded	No	Ø32 mm (1.25 in)	NA	350 K	0.1 K
SH-1.25-I	Isolated					1.5 K
SH-1.25-C	Coaxial	Yes*		70 V		2 K
SH-1.25-T	Triaxial	Yes**	Ø51 mm (2 in)	NA	350 K†	0.5 K
SH-2.00-G	Grounded	No				70 V
SH-2.00-C	Coaxial	Yes*		2 K		
SH-2.00-T	Triaxial	Yes**				2 K

* Coaxial sample holders require one FT-BNC or FT-TRIAX feedthrough as listed below

** Triaxial sample holders require one FT-TRIAX feedthrough as listed below

† Selectable equipment

Part Number	Description
FT-BNC	Coaxial feedthrough and coaxial cable, installed and wired
FT-TRIAX	Triaxial feedthrough and coaxial cable, installed and wired

Equipment Options

Part number	Description
PS-FOA	Fiber optic probe arm modification. Transmit or receive light or IR/UV radiation. Fiber optic terminated with SMA connector or compression feedthrough. (Fiber optic wire not included. Fiber optic and probe cannot be used simultaneously.)
PS-HTA	High temperature sample stage for temperature operation from 20 K to 500 K. Integrated into the stage are a 51 mm (2 in) diameter coaxial sample holder, thermal standoff, calibrated PT-100 temperature sensor, heater, wiring, and cabling. The high temperature sample stage is interchangeable; standard sample holders can be used when the high temperature sample stage is removed. NOTE: reduces Z-axis travel to 12 mm; requires manual switching of 100 W radiation shield heater and sensor for closed loop control. Optional Model 336 temperature controller available for dedicated control loop.
PS-Z16	16:1 zoom microscope upgrade; provides 4 µm resolution NOTE: consult Lake Shore for field upgrade
PS-V81DPC	Compact turbo pumping system—includes Varian V-81 turbo pump with oil free dry scroll backing pump, vacuum gauge for high vacuum, controller, and adaptors (specify 120 V/60 Hz or 220 V/50 Hz)
PS-PLVI-40	Pump-line vibration isolator—includes NW 40 fittings, 1 m stainless steel bellows, clamps, and rings (placed between pump cart and system); requires one bag of cement. NOTE: for use with PS-V81DP

Equipment Options, continued

PA-SEN	Probe arm modification with temperature sensor installed and wired to a 6-pin feedthrough
PS-PAB-09	Probe arm and base
CS-5	Calibration substrate for GSG probes—pad size: 50 μm^2 ; calibration type: SOLT (short-open-load-through), LRL (line-reflective-line), LRM (line-reflective-match); pitch range: 75 to 250 μm
CS-15	Calibration substrate for GSG probes—pad size: 25 μm^2 ; calibration type: SOLT (short-open-load-through), LRL (line-reflective-line), LRM (line-reflective-match); pitch range: 40 to 150 μm
RC-EM10-208230-60-CE	Recirculating chiller; P-3, 208 to 230 V / 60 Hz / 3-ph / 20 A, 10000 W, 10 gpm, 32 psi; TF-10000
RC-EM10-400-50-CE	Recirculating chiller; P-2, 380 to 400 V / 50 Hz / 3-ph / 16 A, 8500 W, 3.3 gpm, 60 psi; TF-10000

Lake Shore Cryotronics is a leading supplier of cryogenic, superconducting magnet-based, electromagnet-based, high vacuum, and load-lock probe stations. We offer a full line of standard probe stations to meet your research requirements.

Our standard line of probe stations includes:

Model TTPX

- Up to six micro-manipulated probe stages
- Temperature range capabilities from 3.2 K to 675 K
- Up to 51 mm (2 in) diameter wafer capabilities
- Optical access through sample stage

Model CPX

- Up to six micro-manipulated probe stages
- Temperature range capabilities from 1.5 K to 675 K
- Up to 51 mm (2 in) diameter wafer capabilities
- $\pm 5^\circ$ sample stage rotation
- Load-lock and high vacuum options

Model FWPX

- Up to six micro-manipulated probe stages
- Temperature range capabilities from 3.5 K to 475 K
- $\pm 5^\circ$ sample stage rotation
- Up to 102 mm (4 in) diameter wafer capabilities

Model CPX-HF

- 1 T horizontal field split pair superconducting magnet
- Up to four micro-manipulated probe stages
- Temperature range capabilities from 2 K to 400 K with field on or off
- $\pm 5^\circ$ sample stage rotation
- Up to 25 mm (1 in) diameter wafer capabilities
- High vacuum option

Model CPX-VF

- 2.5 T vertical field solenoid superconducting magnet
- Up to six micro-manipulated probe stages
- Temperature range capabilities from 2 K to 400 K with field on or off
- $\pm 5^\circ$ sample stage rotation
- Up to 51 mm (2 in) diameter wafer capabilities
- High vacuum option

Model EMPX-HF

- 0.55 T horizontal (in-plane field) electromagnet
- Up to four micro-manipulated probe stages
- Temperature range capabilities from 3.2 K to 400 K
- Up to 25 mm (1 in) diameter wafer capabilities
- 360° sample stage rotation option

Model CRX-4K

- Low vibration, cryogen-free closed cycle refrigerator
- Up to six micro-manipulated probe stages
- Temperature range capabilities from 4.5 K to 475 K
- Up to 51 mm (2 in) diameter wafer capabilities