Wafer Level Reliability Systems



Comprehensive, highly scalable solutions for today's reliability test needs and tomorrow's technology

A GREATER MEASURE OF CONFIDENCE



Only Keithley delivers the industry's most comprehensive range of solutions for WLR testing and analysis

Scalable, flexible hardware configurations that adapt to changing reliability test needs economically

The speed, accuracy, and extended voltage range that advanced technology development applications demand

> Get the tools you'll need to bandle tomorrow's WLR test challenges

Compliant with many JEDEC standard test methodologies

Create new test routines quickly to characterize advanced nanoscale structures

Produce lifetime predictions $2-5 \times$ faster than conventional WLR test solutions with SMU-per-pin configurations

Accelerate technology development, process integration, and process monitoring for faster time to market with bigbly parallel on-wafer solutions

Want greater reliability testing confidence from the lab to the fab?

Keithley Instruments has long been an industry leader in both overall parametric test technology and Wafer Level Reliability (WLR) testing. Several generations of Keithley's parametric test solutions have offered WLR test algorithm libraries as options. That gives us decades of experience to draw upon in creating integrated hardware and software solutions for emerging test needs in device characterization, semiconductor parametric test, and electrical parametric process monitoring. Our years of working with WLR users at every technology node have given us an in-depth understanding of the changing needs associated with reliability testing.

Need reliability test solutions that deliver greater speed and simplicity?

Our Integrated WLR Test Systems, based on our Automated Characterization Suite (ACS), let you produce lifetime predictions from two to five times faster than conventional single-device WLR test solutions. By accelerating WLR testing with SMUper-pin parallel device systems during technology development, process integration, and process monitoring, ACS WLR test systems slash time to market for new products. They also have the built-in system scalability and configuration flexibility you need to protect your hardware investment, preventing premature obsolescence as your product mix evolves beyond existing materials and processing technologies. This not only minimizes your capital expenses but minimizes disruptions by allowing you to continue using familiar, already proven systems.

Applications

- Device Reliability
- Hot Carrier Injection (HCI)
- Negative Bias Temperature Instability (NBTI)
- Positive Bias Temperature Instability (PBTI)
- Ultra-Fast BTI

Gate Oxide Integrity

- Time Dependent Dielectric Breakdown (TDDB)
- Voltage Ramp (V_{RAMP})
- Current Ramp (J_{RAMP})
- High voltage GOI

Metal Interconnect

- Isothermal Electromigration (EM)
- Poly Heater
- Constant Current
- Interlayer Dielectric Time Dependent Dielectric Breakdown (ILD TDDB)



What's your old reliability tester missing? *Find out with ACS WLR.*

Processing today's smaller devices demands the ability to acquire ever-larger data sets. Keithley's ACS WLR systems help you gather that huge mass of data quickly and accurately.

A Comprehensive Line of WLR Testing Solutions

ACS WLR integrated test systems offer comprehensive single-device and parallel-device WLR testing capability. Based on our innovative Model 4200-SCS Semiconductor Characterization System and/or our growing family of Series 2600A System SourceMeter[®] instruments, ACS systems provide unmatched testing speed and accuracy. For applications that demand true parallel WLR characterization, ACS system configurations based on the S500 System's SMU-per-pin architecture can support more than 20 Series 2600A SMUs in a single rack. For WLR applications that don't require parallel testing, our Series S530 Low Current and High Voltage Systems offer an economical approach to reliability testing based on fewer SMUs and a switch matrix optimized for the system's instrument configuration.





WLR applications demanding more flexibility than your test system can deliver?



When incorporated into an ACS WLR system, either in combination with Series 2600A SMUs or alone, the Model 4200-SCS Semiconductor Characterization System is a self-contained fully automatic test system optimized for applications that demand the ultimate in testing flexibility. Multi-channel source capabilities up to 1A and 200V and measurement resolution down to 100aA and 1μ V make the Model 4200-SCS suitable for a wide variety of devices and technologies. ACS provides wafer- and cassette-level automation and runs directly on the Model 4200-SCS's internal PC controller.

Model 4200-SCS instrumentation includes precision DC mediumand high-power SMUs with optional preamps for ultra low-level current measurements. The latest system options support ultra-fast I-V and capacitance-voltage testing, critical capabilities for today's WLR characterization challenges. That allows combining advanced characterization techniques, such as single-pulse charge trapping, ultra-fast I-V sweeps, and charge pumping, with traditional DC techniques – all in one system, with all instrumentation controlled through the same ACS WLR software environment.

MODEL 4200-SCS CAPABILITIES				
DC Current-Voltage (I-V)	SMU measurement range	Voltage	1µV/200V	
		Current	0.1fA/1A	
	SMU measurement resolution	Voltage	1μV	
		Current	0.1fA	
	SMU measurement accuracy	Voltage	100μV	
		Current	10fA	
Capacitance-Voltage (C-V) (with optional Model 4210-CVU)	Frequency range	10kHz to 10MHz		
	Measurement parameters	Cp-G, Cp-D, Cs-Rs, Cs-D, R-jX, Z-theta		
	Measurement terminal configuration	Four-terminal pair		
	Available sweep parameters	DC bias voltage, frequency		
	Sweep type	Linear, custom		
	Sweep direction	Up sweep, down sweep		
Ultra-Fast Current- Voltage (UF I-V) (with optional Model 4225-PMU)	Voltage outputs	60ns to DC in 10ns steps (programmable)		
	I and V measurement acquisition rates	Up to 200 megasamples/second (MS/s)		
	Voltage source ranges	±10V or ± 40V		
	Current measurement ranges	800mA, 200mA, 10mA, 100μA (Optional Model 4225-RPM Remote Amplifier/ Switch adds 10mA, 1mA, 100μA, 10μA, 1μA, 100nA ranges)		
	Number of channels	Each Model 4225-PMU module provides two channels of I-V sourcing/ measurement; chassis supports up to four modules for eight synchronized channels		

Need ultra-fast I-V to characterize BTI?

Bias temperature instability is a highly dynamic phenomenon that requires ultra-fast and sensitive measurements for accurate characterization. The Model 4200-BTI-A Ultra-Fast BTI Package, the newest addition to the growing list of options for the Model 4200-SCS, combines high measurement speed and sensitivity with exceptional ease of use. The package, which is engineered to provide optimal ultra-fast results without the use of RF structures and interconnects, includes all the hardware and software needed to make the most sophisticated NBTI and PBTI measurements on leading-edge silicon CMOS technology:

- Model 4225-PMU Ultra-Fast I-V Module
- Two Model 4225-RPM Remote Amplifier/Switches
- ACS Software
- Ultra-Fast BTI Test Project Module
- All necessary cabling



The **Model 4225-PMU Ultra-Fast I-V Module** plugs directly into a slot in the Model 4200-SCS chassis, integrating ultra-fast voltage waveform generation and signal observation capabilities into the system's already powerful test environment.

Multiple modules can be installed to create a BTI test system with more ultra-fast source and measure channels.



Each Model 4225-PMU module can be equipped with up to two optional **Model 4225-RPM Remote Amplifier/Switches** to extend the module's low current measurement capabilities. The Model 4225-RPM reduces cable capacitance effects and supports switching automatically between the Model 4225-PMU, the Model 4210-CVU, and any DC SMU modules installed in the chassis, so you can choose the most appropriate instrument for a particular measurement task without re-cabling.



Define stress timing and stress conditions easily using familiar parameters like timing—log, linear, custom list; measurements per decade; AC or DC stress; optional recovery test sequence; and test sample rate (speed).



The **Ultra-Fast BTI test software module** supports spot, step sweep, smooth sweep, and sample measurement types. Each type's timing is defined by the test sample rate and the individual measurement settings. The software module also provides control over the voltage conditions between each element in the test sequence, for maximum flexibility and ease of use, even when defining complex test sequences.



When equipped with the Model 4200-BTI-A Ultra-Fast BTI Package, the Model 4200-SCS parameter analyzer offers the industry's most advanced NBTI/PBTI test capabilities:

- Best-in-class test speed allows faster, more complete device characterization
 - Begin measuring BTI degradation as soon as 30ns after stress is removed
- Measure transistor VT in less than 1μ s using ID–VG sweep method
- Model 4225-RPM Remote Amplifier/Switch
 - Switches automatically between low-level precision DC I-V (via standard SMUs) and ultra-fast I-V measurements with no need for re-cabling
 - Improves single-pulse source and measurement performance by minimizing cable parasitic effects and increasing low current sensitivity
- Best high-speed, low-current measurement sensitivity available in a single-box integrated solution
 - Supports sub-microsecond pulse characterization of drain current at reduced drain voltage, minimizing drain-to-source fields that could otherwise skew test results
 - Ensures the source/measure instrumentation won't be the limiting factor when making low-level measurements
 - Detects degradation trends sooner during the test, reduces the time needed to perform process reliability monitoring
- Simple, predictable interconnect scheme prevents measurement problems due to incorrect DUT connections
- Optional Multi-Measurement Performance Cables (MMPC) optimize measurement performance of configurations that combine DC I-V, C-V, and ultra-fast I-V capabilities
- ACS software supports building complex test sequences including up to 20 measurement sequences and full prober integration
 - DC I-V and ultra-fast I-V measurements can be easily integrated into a stress-measure sequence
 - Degradation and recovery behaviors can be characterized using either AC or DC stress
 - Spot measurements can be combined with precision SMU sweeps in pre-testing and post-testing
 - Single pulse charge trapping (SPCT) measurements can be incorporated into longer stress-measure sequences
 - Support for handling the large data sets required in device reliability modeling and process monitoring applications
- Support for hot chucks and fully and semi automatic probers, including wafer maps, wafer, and cassette-level sample plans

Consult our online data sheet for further details on the Model 4200-BTI-A Ultra-Fast BTI Package: http://www.keithley.com/data?asset=52856.

ACS software provides wafer- and cassette-level automation capabilities compatible with semi and fully automatic probe stations.

Need to get from "data" to "decision" sooner?

All ACS WLR systems leverage the test power of Keithley's ACS software with the addition of a powerful Reliability Test Module (RTM), which provides an intuitive, interactive, no-coding-required environment for setting up stress/measure sequences. The RTM supports traditional JEDEC standard reliability tests and is flexible enough to accelerate the development of the new test methodologies necessary to characterize emerging technologies. RTM projects for TDDB, J_{RMP}, V_{RAMP}, HCI, Isothermal Electromigration, and NBTI are included. An integrated formulator populated with standard parametric extraction calculations allows easy point-and-click analysis. A variety of modeling, line fitting, and standard math functions allows custom data manipulation without programming.

Flexible test sequencing capabilities support pre- and post-testing, as well as intra-stress testing and stress monitoring. During testing, you can log raw reliability data into the database and/or plot it in real time. This "sneak peek" at a test's outcome lets you know whether time-consuming tests

are on track to deliver meaningful results. The reliability test option complies with many JEDEC standard test methodologies, but it also offers the flexibility to create new test routines quickly to characterize advanced nanoscale structures.

Software tools designed to simplify extracting data from the database are included to make it easy to transfer test results to any custom analysis tools you have developed.

- Reliability Test Module (RTM) complies with JEDEC standard test methodologies
- Create new test routines quickly and easily with RTM and characterize advanced nanoscale structures or emulate existing WLR test methods
- Flexible test setup editor and sequencing capabilities support pre- and post-testing, as well as intra-stress testing and stress monitoring
- Built-in database engine provides a simple-to-use file structure for selecting, merging, exporting, archiving, and retrieving results
- Integrated formulator allows simple point-and-click analysis
- Test results can be logged into the database and/or plotted in real time
- Built-in software support for popular probers and hot chucks
- Both wafer- and cassette-level automation



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Prefer the high speed parallel test capabilities of an SMU-per-pin configuration or the

ACS WLR test systems based on the S500 system architecture offer comprehensive single-device and parallel-device WLR testing capability. Based on our expanding line of Series 2600A System SourceMeter[®] instruments, their SMU-per-pin architecture can increase system throughput by a factor of $2-5\times$. This modular system architecture also lets you expand your system economically as new test needs emerge, just by adding SMUs. Standard configurations can support more than 40 SMUs in a single rack for true parallel WLR characterization applications. We can also customize S500-based ACS WLR systems by adding a Model 4200-SCS system for reliability test tasks that demand extended low current resolution.

Multiple Series 2600A SourceMeter units are networked together via their on-board processors and the TSP-Link[®] virtual backplane. This architecture provides high precision source/measure timing to capture fast time-resolved breakdown events. Because the ACS WLR system dynamically reallocates resource connections, the array of SMUs in the system is automatically instructed either to work together as a single tightly coordinated group or as several small groups working in concert to characterize several devices.

For parallel testing, test scripts are pre-loaded into each "master" Series 2600A instrument and stored in its memory. Once triggered, the ACS WLR system controller issues a function call to each group's master, which executes the script in coordination with the other units in that group. The controller then scans the bus to receive the test results from the master instruments.

The ACS WLR S500 architecture supports both high voltage (200V) and high current (1.5A) sourcing and measurement to every test structure pad. Whether you are testing thick oxide or advanced gate stacks, you can characterize lifetime acceleration with a single touchdown— and because every SMU can be programmed independently, you can perform splits on a single structure.

Even ACS WLR systems without a Model 4200-SCS installed can support three different NBTI characterization techniques:

- **DC On-the-Fly:** Makes measurements at the stress condition then extracts the device's degradation at the operating condition.
- Pulse On-the-Fly: Uses a series of very short pulses to capture the complete I-V curve before and during stress and extracts VTH directly.
- Fast DC NBTI: Measures a single point (ID) directly at the operating condition as fast as possible.



flexibility a switch matrix provides?

Our Series S530 Parametric Test Systems are optimized for production parametric test but are readily adaptable to WLR testing with the addition of the Reliability Test Module to the ACS environment. All Series S530 systems are equipped with Keithley's proven high power SMUs, which provide up to 20W source or sink capability on both the 200V and 20V ranges.

The core of each S530-based ACS WLR test system is a set of high fidelity signal pathways that direct signals between instruments and test pins. The performance of these pathways directly influences the performance of the test system as a whole by setting upper current and voltage ranges, and limiting low-level measurements due to current offsets. The S530 has eight high fidelity pathways that can be used to route instruments to pins dynamically. For example, up to eight SMUs can be routed to any pin (or number of pins) at one time. The S530 Low Current System delivers uniform performance across all eight pathways; the S530 High Voltage System provides two high voltage/low leakage pathways, four general-purpose pathways, and two C-V pathways.

\$530 system configuration options

- Customizable for low current and high voltage applications
- Up to 8 SMUs
- Up to 60 pins
- Full Kelvin measurement (remote voltage sense) option for enhanced measurement accuracy on up to 24 pins
- C-V meter (up to 2MHz) for measurements on any pin
- Model 9139A Probe Card Adapter

Series 2600A System SourceMeter **Instrument (SMU) Options:**

- Model 2602A Dual-channel System SourceMeter Instrument (3A DC,10A Pulse)
- Model 2612A Dual-channel System SourceMeter Instrument (200V, 10A Pulse)
- Model 2636A Dual-channel System SourceMeter Instrument (1fA, 10A Pulse)





Need to maximize the return on your WLR test system investment?

System Development Services. Let us help you maximize your WLR test productivity by integrating additional instrumentation into your ACS system.

Software Services. Short of in-house programmers? We can develop custom test projects and drivers for your application or review and can optimize other software you've already developed.

Installation Services. We'll get your new system up and running quickly with services such as installation, setup, configuration, and basic user training.

Consulting Services. Our applications engineers can help you develop test plans, optimize your test processes, or take on time-consuming measurements challenges.

Training Services. We'll deliver in-depth training on system operation, making and optimizing measurements, and system troubleshooting.

Services Contracts. We'll help you avoid unbudgeted maintenance expenses and ensure ongoing system accuracy and performance.

WLR hardware details and specifications

For additional details on instrumentation options for WLR testing, download the online versions of our Series S530 Parametric Test Systems brochure and our Series 2600A System SourceMeter data sheet from www.keithley.com.

All the support you need

For applications assistance, call us on our toll-free hotline at 1-888-534-8453 from 8:00 am to 8:00 pm ET (U.S. only). For assistance beyond those hours, send our Applications Engineering Department a facsimile (440-248-6168) or an e-mail message (product_info@keithley.com). Our worldwide facilities and affiliates offer native language support services.

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KEITHLEY INSTRUMENTS, INC. 28775 AURORA RD. CLEVELAND, OH 44139-1891 440-248-0400 Fax: 440-248-6168 1-888-KEITHLEY www.keithley.com

BELGIUM

Sint-Pieters-Leeuw Ph: 02-3630040 Fax: 02-3630064 info@keithley.nl www.keithley.nl

ITALY

Peschiera Borromeo (Mi) Ph: 02-5538421 Fax: 02-55384228 info@keithley.it www.keithley.it

SINGAPORE

Singapore Ph: 65-6747-9077 Fax: 65-6747-2991 sea@keithley.com www.keithley.com

CHINA

Beijing Ph: 86-10-8447-5556 Fax: 86-10-8225-5018 china@keithley.com www.keithley.com.cn

JAPAN

Tokyo Ph: 81-3-5733-7555 Fax: 81-3-5733-7556 info.jp@keithley.com www.keithley.jp

SWITZERLAND

Zürich Ph: 044-8219444 Fax: 044-8203081 info@keithley.ch www.keithley.ch

FRANCE

Saint-Aubin Ph: 01-64532020 Fax: 01-60117726 info@keithley.fr www.keithley.fr

KOREA

Seoul Ph: 82-2-574-7778 Fax: 82-2-574-7838 keithley@keithley.co.kr www.keithley.co.kr

TAIWAN

Hsinchu Ph: 886-3-572-9077 Fax: 886-3-572-9031 info_tw@keithley.com www.keithley.com.tw

GERMANY

Germering Ph: 089-84930740 Fax: 089-849809731410 info@keithley.de www.keithley.de

MALAYSIA

Penang Ph: 60-4-643-9679 Fax: 60-4-643-3794 sea@keithley.com www.keithley.com

UNITED KINGDOM

Theale Ph: 0118-9297500 Fax: 0118-9297519 info@keithley.co.uk www.keithley.co.uk

INDIA

Bangalore Ph: 080-26771071, -72, -73 Fax: 080-26771076 support_india@keithley.com www.keithley.com

NETHERLANDS

Gorinchem Ph: 0183-635333 Fax: 0183-630821 info@keithley.nl www.keithley.nl