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Cost Effective Semiconductor Lab Automation

SEMICONDUCTOR test engineers face a number of challenges in the semiconductor lab. For one, a range of unique measurements and novel techniques for emerging technologies is making testing ever more challenging. In addition, the demands for more testing and data collection with less time and fewer resources highlight the need for flexible, reconfigurable test systems that are capable of wafer and cassette level automation.

Traditionally, there are two methods to bring together advanced or novel measurement techniques and fully automatic wafer probing; one can either adapt an expensive production grade parametric tester or handcraft a rack-and-stack solution with third-party software. Provided the cost of a production parametric tester is not prohibitive, the system must still be adapted to the new measurement technique, which further increases the cost of the solution. Alternatively, custom or third-party software must be adapted to interface with a semi or fully automatic wafer prober and control the array of test equipment to realize the new technique. In either case, the robustness of the system may not be suitable for unattended operation.

In order to address these challenges, Keithley now offers integrated test systems for semiconductor characterization, reliability, and wafer level reliability (WLR), as well as parametric and component functional test. These Automated Characterization Suite (ACS) integrated test systems are designed for semiconductor characterization at the device, wafer, and cassette level. They provide faster measurements and greater system flexibility under one uniform software suite to fit unique test application needs. ACS systems are ideal for semiconductor parametric characterization in R&D, technology development (TD), quality / reliability assurance (QRA), and small-scale production test. They offer characterization with lab-grade automation for memory testing with pulse I-V, component functional testing on wafer, and wafer-level reliability.

Software

ACS integrated test systems feature a powerful and flexible software suite that ties together a range of testing capabilities. A single software suite eliminates the need to bring together a number of third-party software packages, speeding development time and increasing efficiency. The ACS software features five major functions; wafer description, test setup, prober control, automation, and a summary report generator. The software lets users switch between lab use or manual operation and production or fully automatic mode with the same test plan.

The ACS solution is a test plan development and execution platform centered around wafer-level device characterization and optimized for both the Keithley's Model 4200-SCS (Semiconductor Characterization System) and the Series 2600 System SourceMeter® instruments that provide the core measurement capability of every ACS test system. The test plan manager and wafer map are tightly integrated together, so that test plans can associate specific die with specific test sequences. It also supports many external instruments controlled via GPIB, including C meters, pulse generators, and switch matrices, among others. A full range of drivers offers seamless integration with a range of probers.

There are several types of test modules available based on the test instruments being used and the specific application. With the Series 2600 hardware platform, users can choose the interactive test module with a point-and-click style setup interface. It supports all necessary functions such as sweep, step, and bias and allows for setup of an I-V sweep test within seconds. Alternatively, if a more complicated test is called for, the script test module can be used for writing customized test scripts in Keithley's Test Script Processor (TSP™). ACS includes some sample script-based test modules for users to get started, including some complicated wafer-level reliability tests, such as time-dependent dielectric breakdown (TDDB), hot carrier injection (HCI), and negative bias temperature instability (NBTI).

Every test module, regardless of the module type, includes tabular and graphical data displays. A point-and-click "formulator" provides a simple interface to perform complex mathematical calculations on test results. The output of the formulator is displayed in the tabular data, and the source conditions, measured results, and formulator data can be selectively plotted with the integrated plotting tool. Data from each test module can

also be plotted in real time during automatic operation. The real-time plotting capability is useful when running longer term testing, such as WLR tests.

Another powerful feature of the ACS software is integrated parallel test support for Series 2600 System SourceMeter instruments. ACS takes advantage of every element of the Series 2600 architecture to maximize throughput and parallel test. These features allow a user to define a test for a single device under test (DUT) and, with a click of a mouse, execute the same test on a large array of DUTs. The embedded test script processors of the Series 2600 take advantage of the power of distributed processing to execute true parallel test without relying on the test engineer to master a complex multi-threading test language.

Automation

ACS integrated test systems can simplify measurement tasks by automating much of the process at the device, wafer, or cassette level. Cassette level automation features unattended testing of an entire wafer lot. This allows engineers to collect large statistical samples of data for modeling and process qualification as well as maximize tool utilization during off hours. A fully automatic, cassette-level test with automatic probers can be performed with only a few mouse clicks, and an HTML-based summary report can be generated after the test.

At the wafer level, a Wafer Description Utility and wafer map allows users to build wafer description files with integrated test plans. Color-coded wafer maps are updated in real-time during test execution to show pass/fail or binning metrics, providing clear visibility into test results and assuring that test outcomes will be productive.

An interactive prober controller lets users control wafer movement using the ACS software during test development to validate test setups on actual structures and during lot disposition to navigate to a problem area of the wafer and execute testing manually.

Hardware Platforms

At the center of an ACS integrated test system are instruments that make important and unique measurements. The physical form of the test system can range from a simple bench-top arrangement to a full-height integrated rack of instrumentation with a power distribution unit, emergency off switch, integrated PC, cable routing, and more.

ACS integrated test systems incorporate a variety of test hardware and software solutions, depending on the application. These systems can take advantage of a number of Keithley's instrument platforms. The Series 2600 SourceMeter instruments have high speed test sequencing capabilities and are flexible, configurable, and scalable. Series 2600 instruments provide the features needed to make challenging measurements, such as TDDB and bias temperature instability (BTI) measurements on high-κ metal gate structures using sophisticated techniques such as arrested breakdown for TDDB and on-the-fly techniques for BTI.

Likewise, Keithley's Model 4200-SCS semiconductor characterization systems offer parallel measurement capability along with advanced pulse measurement for semiconductor parametric characterization in R&D, technology development, quality and reliability assurance, and small-scale production test. The Model 4200-SCS's integrated pulse generator and scope options provide high speed pulse I/V capability for characterizing silicon on insulator (SOI) devices in an isothermal regime, "trappy" materials and interfaces using single pulse charge trapping techniques, and providing time resolved visibility into many transient behaviors such as BTI recovery.

Application Examples

Engineers working with leading edge CMOS technology need a broad range of test capability to match their various applications. This is especially true today, because there is no one specific way, for example, to perform a test for NBTI. A test stand can deliver automation at the wafer or cassette level and provide the full set of test capabilities needed for the leading-edge challenges of reliability engineers. The combination of the Model 4200-SCS pulse + PIV (pulse IV) and the Series 2600 fast DC measurement capability, together with a deep memory buffer to ensure that no information is lost, are at the core of such ACS integrated test systems.

Other test systems may be designed for throughput and flexibility. They are based around traditional single-site probe cards with a source-measure unit (SMU) channel for each pin on the test structure. Because the duration of WLR tests can be long, testing all transistors within the site at one time can deliver significant timesavings to the engineer and provide statistically significant amounts of data.

With the SMU-per-pin approach and the flexibility of ACS, users can create other types of characterization or parametric tests. Today's test engineers are always looking for systems that can be repurposed once a specific project is completed. The additional benefit of SMU-per-pin is seen with NBTI or TDDB testing of leading edge devices where a gang-stress sequential measure system misses key measurements.

Another example is a characterization test system. An MMIC (Monolithic Microwave Integrated Circuit) device, with active and passive components on one substrate, does not involve any RF measurements. Instead, the device is characterized using DC and pulsed I-V, primarily for the purpose of device or wafer sorting. An ACS integrated test system is especially suited for this application for a number of reasons. First, a Series 2600-based system offers speed, coordination, and parallel test to increase throughput. Another is the precision and repeatability of the measurements. The Series 2600 instrument also offers electrical source-measure specifications that can be reached through standard features and scripts, as well as through custom pulse scripts. The flexibility of the ACS software, along with its other features and benefits such as control of wafer prober, wafer map utility, and multiple test module development tools, makes an ACS integrated test system an ideal solution for this type of testing demand.

Summary

With ever-changing test challenges in the semiconductor industry, Keithley's new ACS integrated test systems fill the need for a solution that is between individual bench-top instrumentation and large-scale rack systems. These ACS integrated test systems are designed for semiconductor characterization at the device, wafer, and cassette level. They provide faster measurements and greater system flexibility under one uniform software suite to fit unique test application needs. KEITHLEY

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