Q & A

CASCADE MICROTECH

Innovating Test Technologies®

The Infinity Probe™ for On-Wafer Device Characterization and Modeling to 110 GHz

Why is this announcement important?

Continuing demand for more bandwidth in all communications systems: Cellular phones, wireless LANs, optical fiber links, satellite links, wired Internet connections, and automotive communication systems continue to benefit from faster and more reliable connections. For example, the demand for low power wireless communication systems has rapidly increased the pace of RF technology development. To remain competitive, products need to be brought to market, faster, cheaper and with higher performance. To reach this goal engineers must reduce cycle time and cost.

RFICs going to silicon: The evolution of silicon CMOS and SiGe technologies now enables them to address many new RF applications. The International Technology Roadmap for Semiconductors (ITRS) projects analog CMOS Ft continue to increase from 150 GHz today to 370 GHz by 2007. Silicon CMOS technology has the following advantages: low-cost, process maturity, and high integration levels, essential ingredients for low-cost wireless communication systems on a chip. SiGe BiCMOS technology will allow RF front-end, baseband, and DSP circuitries for telecommunication systems to be integrated on the same chip.

Silicon wafer processing maturity combined with the transition to 300 mm wafers makes silicon technology potentially more cost effective than III-V semiconductors. Aluminum is the most commonly used pad metal on silicon ICs, with some processes now migrating to copper pads. (Gold is a contaminant in CMOS causing deep level traps.)

Silicon RFICs bring new probing challenges: Devices with aluminum pads are much more difficult to probe than devices with gold pads, which are typically on III-V semiconductors. The productivity of characterization engineers is significantly affected due to the lack of confidence in the precision of the measured data when probing devices with aluminum pads.

Cycle time and engineering cost reduction require accurate device models and their statistics. The requirement for accurate high frequency testing to 110 GHz combined with the need to probe aluminum pads with low contact resistance has created an under-satisfied need and a performance gap in the marketplace.

The Infinity Probe™: Cascade Microtech has developed a new technology, the Infinity Probe, that offers both high-frequency performance and low, stable contact resistance on aluminum pads. The Infinity Probe sets a new standard for the device characterization and modeling community.

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Why is aluminum pad probing a challenge?

A thin layer of aluminum oxide (about 60 angstroms thick) immediately forms on a bare aluminum surface when exposed to air. This layer must be penetrated by deforming the relatively soft underlying aluminum, to directly contact aluminum metal with a probe tip. Aluminum oxide forms on any aluminum exposed by probing, so the electrical contact resistance is difficult to maintain for a long measurement or for many contact cycles without cleaning the aluminum and aluminum oxide that accumulates on the probe tips.

Any measurement that is sensitive to a series resistance is effected by contact resistance variations. Such measurements include characterizing high-Q passive structures (such as inductors, capacitors, or resonators), and long characterization tests that require repeatable device contact for time periods beyond a few minutes (such as transistor S-parameter mapping of many bias conditions). Further implications are that measurements of the same structure are repeatable for very few contacts. When repeatedly probing a single transistor, contact resistance changes will modify the operating point so that each time a different case will be measured.

These problems lead to a lack of confidence due to the inconsistency in the data. The result is poor correlation of data between measurements from different measurement systems.

How do test engineers perform their tests today?

On aluminum pads, a probe has to break through the naturally forming aluminum oxide every time it makes contact. Conventional RF coaxial probes use tungsten tips to penetrate the aluminum oxide layer. Unfortunately, tungsten also oxidizes, and the aluminum and aluminum oxide accumulate on the probe tips after only a few contacts, which significantly increases the contact resistance and results in poor measurement repeatability. To remedy this, frequent cleaning of the probe tips is obligatory. The test engineer is usually unsure of the precision of the measurements due to the non-repeatable nature of the contact resistance. Statistical models are often created to take in account the variations in the measured data. This methodology is time consuming and does not necessarily result in accurate data.

Another method used to improve consistency is to perform these measurements manually, using skilled operators to sense when a contact resistance problem has occurred. However, this results in a considerable increase in test time, cost of test, and an overall reduction in the productivity of the characterization laboratory.

A typical method of reducing contact resistance is to increase the probe overtravel, thus causing more deformation of the aluminum pads. Continual probing of the pad in order to get low and stable contact resistance using current coaxial RF probes can lead to severe pad damage. Pad damage is a major concern if these devices are to be packaged, since it can impair the reliability of wirebonds to the pads.

What factors affect contact resistance?

There are numerous factors that can affect the probe contact resistance on aluminum. These can be grouped into 3 categories:

1. **Probe factors:** tip contact area, force applied, tip metallurgy, scrub, and cleaning process.
2. **Device factors:** pad metallurgy, pad thickness, pad size, wafer cleanliness, surface contaminants, dielectric compliance, and pre-existing pad damage.
3. **Environmental factors:** temperature, mechanical vibrations, and probing system thermal stability.

The first category specifies the factors related to the probe:

- **The contact area.** This interacts with the probe force to set the pressure exerted on the pad. Probes for aluminum pads typically use an area of 100 to 400 μm^2.
- **The force on the probe tip and how this affects the scrub.** Typical force per tip ranges from 5 to 10 grams for aluminum pads. Only a small horizontal tip motion (scrub) is necessary to break through the 60 angstroms of aluminum oxide.
- **Tip material.** Tungsten is the conventional material, but a non-oxidizing metal is better.
- **Cleaning.** Depending upon the pad metallurgy, aluminum and aluminum oxide must be periodically removed from the tips. This is usually done abrasively, but the abrasion ideally removes only aluminum and oxides without changing the tip size or shape.

Any type of contact resistance comparison testing requires careful consideration of all these factors.

How does the Infinity Probe reach this new performance level?

Thin-film technology: Cascade Microtech's proprietary thin-film technology is used to lithographically define the microwave interconnects and the probe tips of the Infinity Probe on a multi-layer polyimide membrane. Cascade Microtech's recent probe card developments based on this thin-film technology have achieved outstanding production performance on aluminum pads. The typical contact resistance is less than 0.1 ohms and the pad damage is minimized.

The thin film consists of two metal layers. Layers of polyimide encapsulate the conductors so that the only exposed conductors are the probe tips. The first metal layer is the ground plane layer. The second layer is used to route the signal conductor. Photo-processed vias route the microstrip to coplanar tip connections. This construction ensures that 50-ohms controlled transmission line impedance can be maintained ensuring unsurpassed signal integrity. Non-oxidizing nickel alloy probe tips are plated and connected to different conductor layers through vias.

The Infinity Probe combines thin-film technology with coaxial probe technology resulting in a probe that has superior electrical and mechanical performance as compared to conventional RF probes.

Superior mechanical performance: A core benefit is that the Infinity Probe is the first characterization probe that provides both low (< 0.1 ohms) and consistent contact resistance when probing aluminum pads. The contact area of the probe tips is approximately 12 microns x 12 microns, which allows probing of very small pads. The force delivery innovation ensures only a small horizontal tip motion (scrub) is necessary to break through the 60 angstroms of aluminum oxide. The vertical overtravel required is approximately 50-75 microns (2-3 mils), resulting in about 25 microns (1 mil) of scrub. This small size and scrub minimizes the damage to the aluminum pad. The more consistent contact resistance minimizes the damage from reprobing.

Superior RF performance: The transmission lines on the thin-film confine fringing fields more tightly than conventional flexible coplanar tips. Better field confinement reduces unwanted couplings to nearby devices or other probe tips, increasing RF measurement accuracy. The Infinity Probe's RF characteristics are equal or superior to all other probe technologies in return loss, attenuation, crosstalk, and calibration verifications.

How does the Infinity Probe improve productivity of the test engineering staff?

The Infinity Probe sets a new standard by ensuring better measurements on aluminum pads, reducing reprobing and errors in measured data. The Infinity Probe is a key component of an integrated test solution from Cascade Microtech that includes the probing station and its control system, measurement software, along with turnkey installation and training.

The Infinity Probe expands characterization capabilities through these features:

- Typical contact resistance of < 0.1 ohms over 100,000 cycles on aluminum pads
- Typical contact resistance variation of < 10 mΩ during a 5-hour single contact test on aluminum pads
- Ability to test devices with shrinking pad geometries (50 µm x 50 µm)
- Reduced damage to aluminum pads
- Superior RF measurement accuracy
- Improved Ground – Signal RF performance
- Accuracy to 110 GHz

In addition, the overall Cascade Microtech test solution expands characterization performance and productivity through:

- **MicroChamber® enclosures for low-current and low-temperature measurement.** Available on 200 mm and 300 mm stations, this capability eliminates the need for re-configuration of the test system between RF and parametric tests on the same wafer, thus improving test engineer and test equipment asset productivity. It also reduces the possibility of damage to expensive 1 mm coaxial cables and millimeter-wave modules. In addition, system integrity is ensured and there will be no need for continual re-qualification of the system.
- **Thermal test range capability (-65°C to 200°C)** permits modeling of 110 GHz devices over-temperature ensuring a more accurate and comprehensive device model.
- **Thermally isolated auxiliary chuck:** The calibration substrate is located on this chuck. The thermal isolation from the main chuck ensures the accuracy and integrity of the calibration is maintained during over temperature test. The load impedance on the substrate remains 50 ohms in spite of changes to the main chuck temperature.
- **Impedance Standard Substrates (ISS):** verified at millimeter-wave frequencies.
- **WinCal™ Calibration Software:** Cascade's patented, advanced calibration technique has been demonstrated to be the most accurate method for calibration to 110 GHz.
- **Wavevue™ Measurement Software** integrates the microwave measurement hardware necessary to characterize RF semiconductor devices and share these results. Wavevue Instrument Edition drives Cascade Microtech wafer probing systems, leading network analyzers, bias supplies, and other instruments that gather data. Wavevue Office Edition allows S-parameter data management and parameter transformations, and many plotting and reporting functions. Wavevue has enough flexibility and features for the advanced characterization engineer, yet is intuitive enough for less experienced operators.

These advantages set a new standard in increased measurement accuracy and repeatability. In addition, they significantly increase the productivity of characterization engineers while at the same time greatly improving the return on the substantial investment RF semiconductor companies must make in wafer-based test systems. This approach also ensures automation and correlation of data between different measurements and measurement systems, subsequently reducing modeling, design cycle time and time-to-market.

What is the range of available Infinity Probe configurations?

At introduction, there are 40, 50, 67 and 110 GHz versions of the Infinity Probe available. The probe tip configurations are ground-signal-ground (GSG) and GS/SG in pitches 100, 125, 150, 200 and 250 µm.

There are two different body styles. One body style has the coaxial connector positioned vertically and the other has the coaxial connector at a 45-degree angle. Both body styles are compatible with all Cascade RF probe stations and a full complement of accessories. These include RF cables, positioners and calibration standards.

How does the Infinity Probe help RF semiconductor companies meet their strategic objectives?

As part of turnkey device characterization and modeling solution, the Infinity Probe provides:

- Significantly improved characterization engineering productivity
- Improved asset utilization
- The most advanced test system capability available

All of which combine to reduce a manufacturer's time-to-market of next generation chips.

What kind of companies can benefit from this solution?

This solution is well suited for companies:

- Using Si or SiGe technology or any technology using aluminum pads
- Characterizing passives – inductors, capacitors
  - Lower and more consistent contact resistance
  - Smaller pads to minimize pad parasitics
- Doing on-wafer device characterization and modeling between DC and 110 GHz
- Wishing to shrink their probe pad geometries to 50 µm x 50 µm
- Needing to increase productivity by automating tests
- Desiring a more productive and complete integrated measurement solution to maximize return on their overall investment

Can the Infinity Probe be used to probe devices with gold pads?

Probing ICs with aluminum pads is significantly more difficult than probing ICs with gold pads. By meeting the challenges presented by aluminum pad probing, the Infinity Probe can also be successfully used for characterization of devices with gold pads.

Can the Infinity Probe be used to probe copper?

Bare copper oxidizes gradually over time and will eventually become thicker and even more difficult to probe than aluminum pads. The industry is still learning how to probe copper, and our recommendation is to probe the copper within a few days of exposure to atmosphere. The Infinity Probe will have similar benefits on copper as it has on aluminum.

When should the Air Coplanar® Probe be chosen instead of the Infinity Probe?

The Air Coplanar Probe should be chosen for aluminum pads only in the cases where the requirements include non-planar pads, dc currents above 500 mA, or pitches larger than 250 µm.

Whom do I contact for more information?

Customers who are interested in this new probe as part of a device characterization and modeling solution should contact Cascade Microtech. See the contact information at the end of this document.

Who is Cascade Microtech?

Cascade Microtech, Inc. is the worldwide leader in providing high frequency and parametric on-wafer test solutions. Engineers use our solutions to test and characterize integrated circuits (ICs) and photonic devices. These devices are then used in semiconductor applications, such as personal computers, servers, cell phones, consumer and automotive electronics, fiber-optics, PDAs, and other wireless products. Cascade Microtech also produces thin-film probe cards for production-level on-wafer testing of fine pitch, high-speed IC devices for broadband communications and networking, wireless and cell phones as well as other market applications. For more information visit www.cascademicrotech.com.

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