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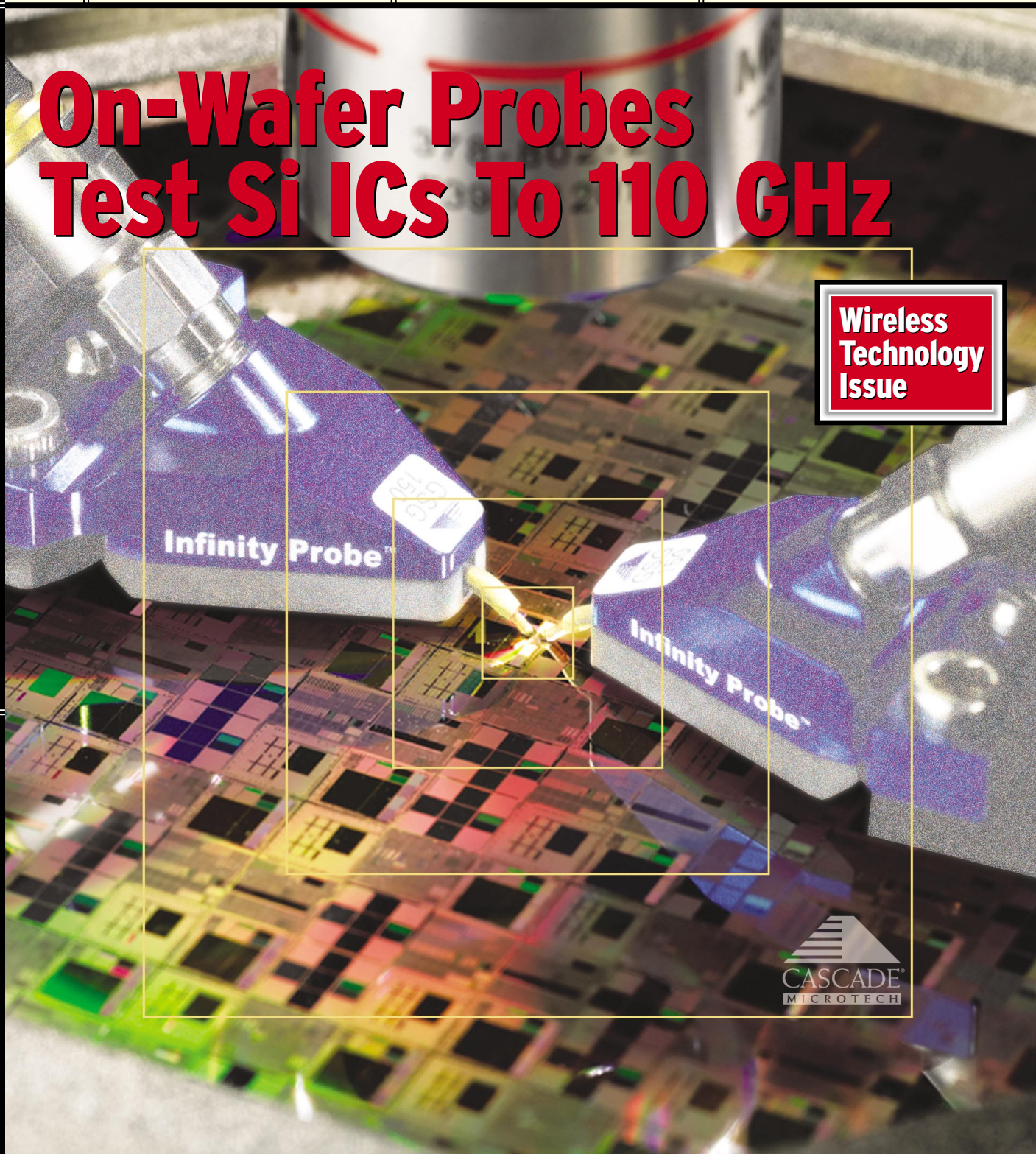
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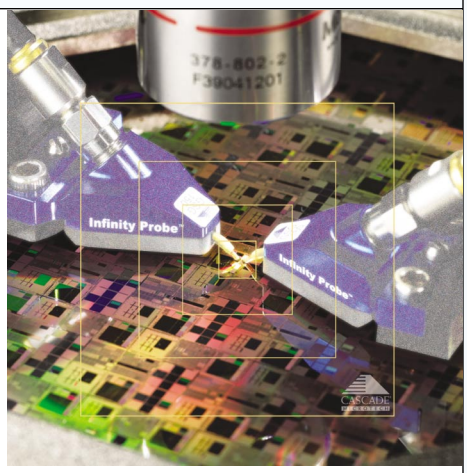
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cover story



On-Wafer Probes Test Silicon ICs To 110 GHz

Thin-film lithographic technology helps to define the precise features of probes with the low contact resistance needed to accurately characterize emerging silicon-based high-frequency devices.

Silicon-device technologies were once considered appropriate for digital and/or RF applications at best. But with the steady development of such advanced technologies as silicon complementary metal-oxide semiconductor (CMOS) and silicon-germanium (SiGe) bipolar CMOS (BiCMOS), millimeter-wave silicon devices are becoming a reality.

Testing such high-frequency, high-speed devices offers a serious challenge to suppliers of on-wafer probes, a challenge that has been taken up by Cascade Microtech (Beaverton, OR) with the introduction of their Infinity Probes™. The new technology enables low and stable probe contact resistance while supporting on-wafer measurements on silicon devices through 110 GHz.

Although silicon CMOS and SiGe devices for millimeter-wave *operation* are not common, an essential part of characterizing and modeling such devices involves the extraction of transition frequencies (f_T's). Since the International Technology Roadmap for Semiconductors (ITRS) projects the f_T of analog CMOS devices to increase from a current high of 150 GHz to a frequency of 370 GHz by 2007, with a similar track for SiGe, there is a strong need for a probe technology that can accurately measure on-wafer signals without degrading the electrical quality of those signals.

A wafer probe, of course, provides the critical signal path between a device under test (DUT) and the measurement equipment, typically a vector network analyzer (VNA). To improve measurement integrity

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Publisher/Editor

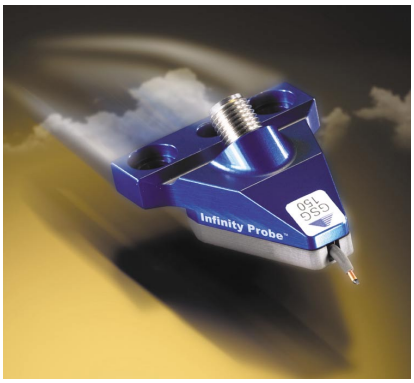
when testing silicon devices, the design of the Infinity probes has been optimized for probing aluminum pads. This is the most commonly used metalization for silicon process wafers, in contrast to the gold metalization usually found on III-V semiconductor devices, such as gallium arsenide (GaAs). In a silicon process, gold (Au) is a contaminant that can cause deep level traps in a CMOS process, for example.

The Infinity probes **(Fig. 1)** benefit from a new technology that delivers excellent high-frequency performance while maintaining extremely low contact resistance on the aluminum pads of silicon devices. One of the challenges in making good electrical contacts on an aluminum pad is penetrating the thin layer of aluminum oxide (about 60 Anstroms thick) that immediately forms on a bare aluminum surface when it is exposed to air. Unfortunately, aluminum oxide will form on any aluminum surface exposed by probing, making it difficult to maintain good and consistent electrical contact resistance for any length of time without cleaning the aluminum and aluminum oxide that accumulates on the probe tips. In addition, any measurement that is sensitive to series resistance will be affected by variations in the contact resistance. This includes measurements of high-quality-factor (high-Q) passive devices and tests that require long duration (more than a few minutes each).

Conventional RF coaxial probes use tungsten tips to penetrate the aluminum-oxide barrier. But tungsten also oxidizes, and the aluminum and aluminum oxide accumulate on the probe tips after only a few contacts, increasing the contact resistance and resulting in poor measurement repeatability. The solution requires frequent cleaning of the probe tips, at a cost of measurement integrity and accuracy, as well as a reduction in the lifetime of the probes. Due to this limitation, measurements are often performed manually, using skilled operators to sense when a contact resistance problem has occurred. However, this results in a considerable increase in test time, test cost, and a reduction in productivity.

Often, the probe overtravel is increased as a way of reducing contact resistance, although with limited success. This approach leads to a greater deformation of the aluminum device pads and serious pad damage. The Infinity probes blend thin-film and coaxial probe technologies to achieve new levels of performance for testing devices with aluminum pads. The thin-film technology is used to lithographically define the microwave interconnections and probe tips on a multilayer polyimide membrane. The thin film consists of two layers. The first layer is a metal ground-plane layer. The second layer routes signal conductors. The microstrip-to-coplanar-tip connections are routed by means of photoprocessed via holes. Nonoxidizing nickel-alloy probe tips are plated and connected to different conductor layers by means of the via holes. The fabrication approach ensures a tightly controlled 50-Ω impedance while maintaining excellent signal integrity. This structure also ensures that the electromagnetic (EM) fields are confined within the dielectric material, thereby suppressing microwave-transmission lodes and reducing coupling to adjacent structures.

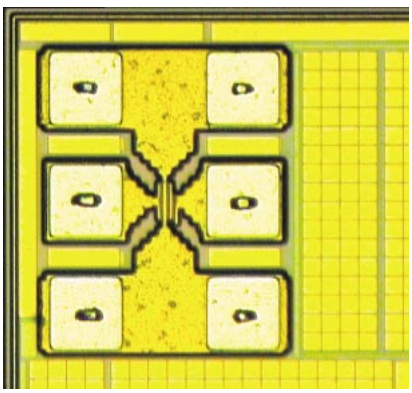
The Infinity probes feature typical and consistent contact resistance of less than 0.05 Ω. The probe contact area is about 12 × 12 µm, with clear contact marks to enable probing of devices with miniature 50 × 50-µm aluminum pads **(Fig. 2)**. An innovative force delivery technique requires that only a small horizontal scrubbing movement is needed to break through the typical 60-Angstrom aluminum-oxide barrier. The vertical overtravel is about 50 to 75 µm, resulting in a required scrub movement of only about 25 µm. Since these minimal movements provide good electrical contacts to aluminum pads, excellent repeatability is possible with negligible pad damage.



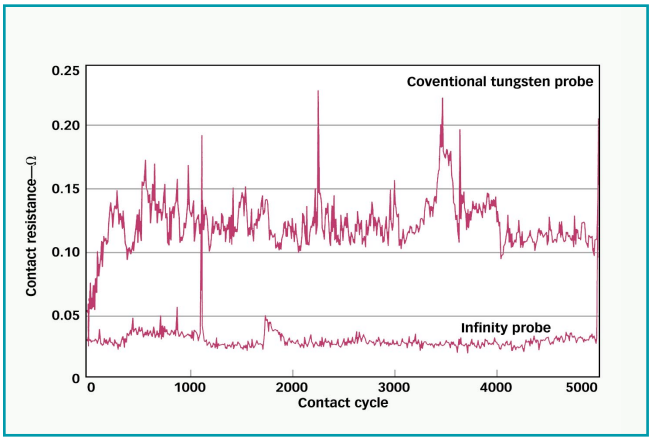
1. The Infinity probe is an ideal solution for on-wafer probing of current and next-generation high-frequency silicon devices through 110 GHz.

Tests performed on the Infinity probes show consistent typical contact resistance of less than 0.05 Ω over 100,000 probing cycles on aluminum pads **(Fig. 3)**. During a five-hour, single-contact test on aluminum pads, the typical contact-resistance variations were less than 10 mΩ **(Fig. 4)**. The measured attenuation is less than 1.5 dB to 110 GHz, with more than 12 dB return loss to 110 GHz.

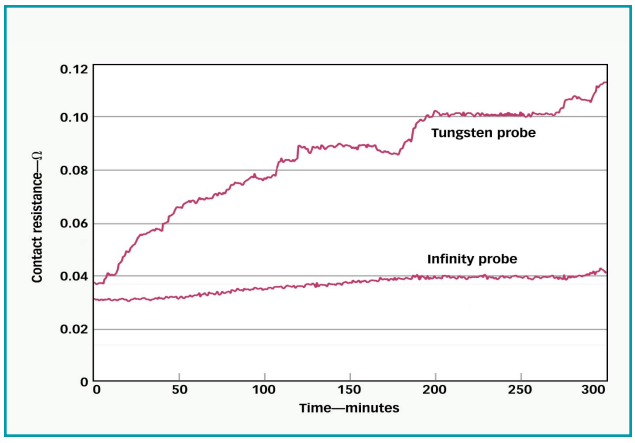
The Infinity probes offer tremendous benefits in test productivity and measurement accuracy, along with considerable reduction in cost of ownership. The company currently offers the Infinity probe models i40 (DC to 40 GHz), i50 (DC to 50 GHz), i67 (DC to 67 GHz), and i110 (DC to 110 GHz) with coaxial connec-



2. A combination of excellent tip visibility and small contact marks enable reliable and repeatable on-wafer probing of silicon devices with 50 × 50-µm pads.



3. The improved repeatability of the Infinity probe is apparent from this comparison with a conventional tungsten probe on aluminum-device pads.



4. Compared to a tungsten probe, only 10-mΩ variations in contact resistance occurred for an Infinity probe during a 5-h continuous contact cycle at 100 mA.

tors. The probes are available in ground-signal-ground (GSG) and ground-signal/signal-ground (GS/SG) configurations, with pitches of 100, 125, 150, 200, or 250 µm. Calibration is performed with the help of the company's line of impedance standard substrates (ISS) which have been verified for accuracy at millimeter-wave frequencies. In addition, the company offers WinCal software for accurate calibrations to 110 GHz. Although designed for probing semiconductor devices with aluminum pads, the Infinity probes are also suitable for testing gold-metallized devices. **Cascade Microtech, Inc., 2430 NW 206th Ave., Beaverton, OR 97006; (800) 550-3279, (503) 601-1000, FAX: (503) 601-1002, e-mail: sales@cmicro.com, Internet: www.cascademicrotech.com.**

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