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The Basics of Probe Measurements on Wafers and Other Substrates

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Here is an introduction to the applications and technical issues for microwave probe measurements of various circuit types

Microwave measurements often require that a probe (Fig. 1) be used to contact the circuit conductors on the substrate upon which the circuit is constructed: typically a semiconductor wafer, ceramic substrate or microwave laminate material. This tutorial reviews some of the applications for these measurements, and presents the key issues affecting measurement accuracy and repeatability.

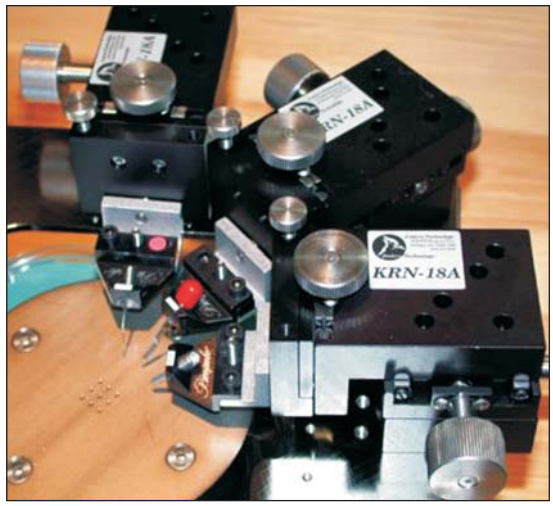

Figure 1 · Probes for microwave device measurements, mounted in adjustable probe holders (1).

Common Probe Measurements

On-wafer testing—Production testing of semiconductor die is often performed after dicing and packaging, but a sample must be tested for two main reasons: verification that fabrication was completed satisfactorily, and for characterization of the bare die before packaging. Device characterization at the die level is essential, since packaging necessarily affects performance. Knowing the device performance before packaging allows the test engineer to determine how various packaging options affect device performance.

Developmental on-wafer circuits—It is common practice to use sections of production wafers for fabrication of test die for devices in development. The ability to do on-wafer testing eliminates the need for packaging the devices, or mounting them to some other test fixture.

Characterization of passive components—Individual circuit elements are combined for any practical RF/microwave/high speed function. With the present strong reliance on modeling and simulation prior to actual fabrication and prototyping, accurate characterization of capacitors, inductors, resistors and transmission lines are needed to develop the necessary mathematical models for inclusion in the software tools. The components may be segments of a monolithic circuit or separate discrete devices.

Package characterization—Not can individual devices be characterized, but packages can be tested to determine their specific performance-modifying effects. Figure 2 shows two types of packages that might be used with single transistors or multi-function ICs.

Non-monolithic integrated circuits—Whether integrated on ceramic, microwave laminate, or other substrate, microwave circuits require testing. Today, very small-size assemblies are common, with miniature discrete components and thick film fabrication

techniques. These circuits are often tested using probing techniques rather than the connectorized fixtures that were used in the past.

Any of the above measurements may be use for either R&D or quantity production.

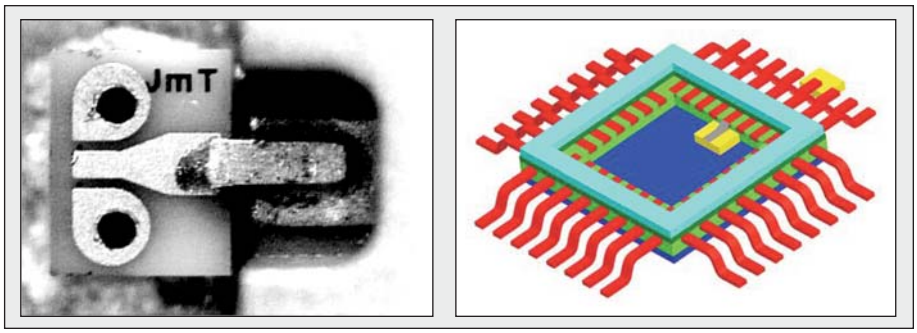

Figure 2 · Two types of packages that can be characterized using microwave probe testing (1).

Key Issues for Probe Measurements

1. Probe performance

Whether the chosen probe is coaxial or coplanar in structure, the following issues must be considered.

Contact pressure—The probe must have sufficient force to make reliable electrical contact, but must not deform either the probe structure or the DUT contact point. Commercial probes are built with these factor in mind, and the manufacturers provide data on setup and maintenance.

Repeatability—The probe characteristics should remain constant over a significant number of placements and measurements.

RF performance—The probe must have known RF characteristics, with constant impedance (minimal discontinuities) from the probe tip to the instrumentation connector.

Calibration procedures—This is the most-referenced issue with probe measurements. Like all microwave measurements, instrument interconnections can have a large effect. Standard TRL (Termination, Reflection and thru-Line) calibration methods are more difficult to make at the probe tip than with connectors. The choice of termination, short circuit and line section must match the intended use of the probe. See References [3, 4] to begin your in-depth study of probe calibration.

2. Fixture performance

Reference plane de-embedding—With the DUT mounted on a carrier substrate or clamped fixture, the calibration of the probe must be extended to the actual DUT connection. This may be done with TRL calibration, but matching DUT connection points may be difficult. Calibration may be simplest using probes to measure the characteristics of the segment from the probe contact to the DUT placement point.

Parasitics—Any fixture must have the best possible impedance match, low inductance and low stray capacitance. A fixture should be designed for low radiation loss as well, especially at the higher microwave frequencies.

Device mounting—The method placing the DUT into the fixture by clamping or soldering should not modify the electrical characteristics. Otherwise, the measurements cannot be trusted. This is a minor issue with a well-designed commercial fixture, but must be addressed thoughtfully with in-house fabricated fixtures and adapters.

3. System factors

Probe mounting—Probes must be securely fixed in position. The probe station or probe card must also have flexible mounting options, to accommodate the range of devices to be tested.

Connection to instruments—High quality connectors and support for interconnecting cables, with minimum bending, are essential for any probe measurement system. This is good practice for all microwave measurements, not just with probes.

DUT mounting—As noted above, the DUT must be reliably mounted. In automated production test systems, accurate positioning is essential since there are multiple connections that must be maintained during the series of tests.

Summary

Probe testing of microwave devices and circuits is a big part of both development and production. In development, it is the means for obtaining good models for simulation, and for verifying performance of prototypes and pre-production samples. In production, accurate probe measurements are needed to verify process yield and consistent performance from one batch to the next. Accuracy, reliability and repeatability require knowledge and attention to the performance factors described in this note.

References

1. "Precise, Repeatable RF Measurements: Applying CPW Probes to Everyday Test Problems," available at www.jmicrotechnology.com

2. E. Strid, R. Gleason, K. Jones, "40 GHz On-Wafer Measurements with the HP 8510 Network Analyzer and Cascade Microtech Wafer Probes," www.hparchive.com/seminar_notes/a-133.pdf

3. D. F. Williams and R. B. Marks, "Calibrating On-Wafer Probes to the Probe Tips," at www.nist.gov

4. Extensive references on probe calibration and measurements are available at: www.nist.gov/pml/electromagnetics/rf_electronics/