Technical Brief:

Introducing Contact Intelligence™ Technology

Senses, Learns and Reacts to Environments Characterized by Multiple Temperatures and Small Pad Layouts

Trends in the semiconductor industry point to continuing shrinkage of feature size, scribe lines and smaller pad sizes as our daily devices get smaller and more complex (Figure 1). In device characterization and high-volume engineering applications there is an increasing need to reduce operator intervention by automating thermal transitions and probe-to-pad realignment, enabling "unattended" test over multiple temperatures. The twin challenges brought on by expanding temperature ranges and shrinking feature sizes can significantly prolong the time required for accurate probe placement during many types of wafer-level testing.

FormFactor has responded with Contact Intelligence technology, which provides research and engineering labs with an unprecedented level of automation when moving through multiple temperature points during test runs. This new technology enables probe systems to sense, learn and react to the extremely complex environments characterized by multiple temperatures and small pad layouts.

Figure 1. New semiconductor application trends continue with shrinking pad sizes and the need to test under a broader set of temperature ranges.

The Need to Manage the Wafer Test Cycle Over Wider Temperature Ranges

As integrated circuit products continue to move into more heat-intensive environments, such as automotive applications, it becomes increasingly critical to characterize device behavior and durability over an ever-wider range of temperatures. Previously, most chips underwent wafer-level testing at only two temperature points, typically 20˚C (room temperature) and 90˚C. Today, that range has expanded to -40˚C to 125˚C, and may involve a complete set of tests at each of four temperature steps within this range. Some cases call for even wider ranges, such as -55˚C to 200˚C, and wafer reliability testing may call for temperatures as high as 300˚C.

This ongoing expansion in the number of required temperature steps during wafer-level testing can quickly consume a significant share of valuable lab time. The issue is compounded by the demand for increasingly large amounts of data to be extracted at each temperature step. A complete set of test cycles at all required temperature points might now take up to 72 hours, or more.

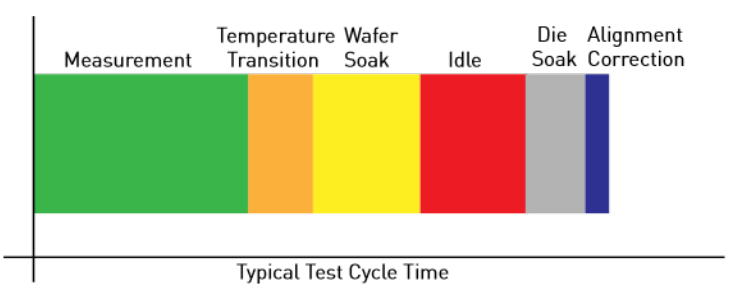

Figure 2. At each temperature set point, a new test cycle must be initiated to accommodate the effect of heat on probe placement. When a measurement is complete, a significant time interval is required to adjust the probes to the next set point.

FORMFACTOR™

As a result, it becomes imperative to automate transitions between setpoint temperatures, automate wafer realignment at each temperature, and automate probe-to-pad realignment at each die. Figure 2 depicts the basic phases in each cycle, along with a typical apportionment of the time spent during each phase. The measurement phase includes all the time that the test probes are in contact with the wafer pads. Wafer (transition) soak refers to the interval required to reach a stable relationship between probes and wafer surface at the new temperature point. Idle time is that spent while waiting to move to the next die on the wafer, or to a new temperature set point. Die soak refers to time spent to accommodate thermal drift due to position changes. Realignment accounts for the operator input to readjust the probes after wafer soaks and die soaks.

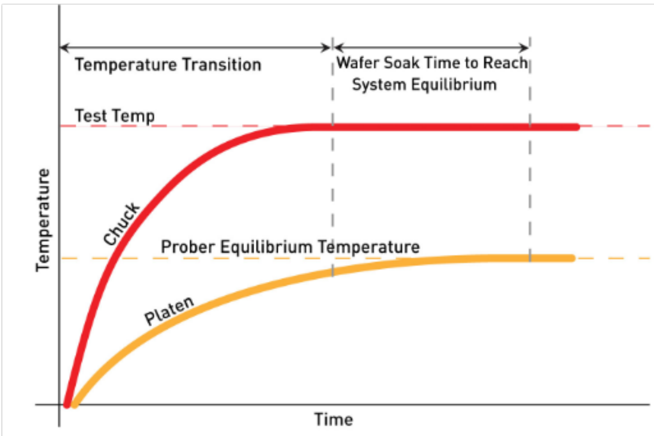

Figure 3. Once the chuck reaches the test temperature, the onset of probing is delayed until the platen responds to the chuck heat and stabilizes. This delay defines the wafer soak time.

Any approach to automating the test cycle must account for the thermal drift introduced during the wafer soak and die soak phases. Both alter the spatial relationship between the chuck, which holds the wafer, and the platen, which holds the test probes. In either case, heat-induced expansion changes their relative alignment, which in turn impacts the position of the probes on the wafer surface. During wafer soak, the chuck first reaches the required temperature, which in turn heats the platen until equilibrium is reached between the two. The time required to reach this equilibrium is called the wafer soak time (Figure 3).

During die soak, the heated chuck is moving between different probe locations on the wafer, which causes shifting "hot spots" on the platen. The time required to reach equilibrium with a new hot spot is termed the die soak time (Figure 4).

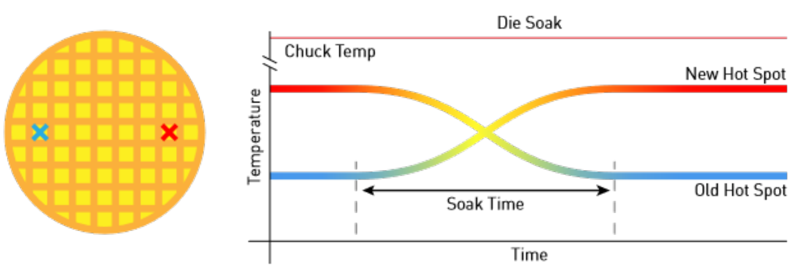

Figure 4. When the heated chuck travels to a new probe location across the die, it affects the platen above, creating a "hot spot." Probe placement is delayed until the platen's hot spot temperature reaches equilibrium and expansion ceases.

Any approach to automating and minimizing the test cycle at each temperature point must address three major issues. First, it must automate the manual realignment process required to compensate for thermal drift. Second, it should eliminate the idle time by managing the transition times and soak times with maximum efficiency by automatically realigning probes to pads after a thermal transition, or after a die step move is complete including soaking. Third, the system architecture should readily accommodate various components that minimize the impact of thermal drift at high temperatures.

On-Site PTPA Approach

The VueTrack™ on-site PTPA correction utilizes a single downward-looking microscope to measure the probe tips and wafer locations with the chuck in the same position that the electrical measurement (or probe contact) will be made. On-site probe tip and wafer location measurements enable the best possible alignment to be maintained throughout a wafer test plan.

This on-site PTPA correction method operates in two distinct modes: Probe tip training mode – used during setup to allow a user to define proper PTPA and then train on a user-selected set of probe tips and wafer fiducials. Probe tip tracking mode – used during run time to measure and correct the probes and wafer at every test site.

Contact Intelligence: A Synthesis of Multiple Technologies

FormFactor has integrated a number of its proprietary technologies to produce Contact Intelligence, which enable automation and compress cycle times to an absolute minimum.

Contact Intelligence automation targets the realignment process required to synchronize the probe tips with the target pads on the wafer surface. In many instances, manual probe adjustments can be time-consuming, especially in cases where they are needed not only after a temperature transition, but also after stepping to a new probe location. This is especially true when the transitions involve widely separated probe points on the wafer surface, which amplifies the "hot spot" effect.

Software Drives Automation to Manage and Accelerate Test Cycles

To bypass all these points of manual intervention, Contact Intelligence employs FormFactor's VueTrack software in combination with our eVue Pro™ digital imaging technology in a two-step process. First, the system is "trained" to recognize the correct probe-to-pad alignment as manually entered by an operator. Next, the system employs pattern recognition software to automatically maintain this alignment by adjusting the chuck position or using the motorized positioners. The motorized positioners with frictionless EMI shielding allow the precise compensation of thermally-induced drift without compromising low-noise environment conditions. Contact Intelligence technology includes on-axis probe needle tracking capability to deliver accurate probe placement on pads as small as 30 µm x 30 µm.

Contact Intelligence management addresses the need to initiate test measurements as quickly as possible once thermal stability is achieved after moving to a new temperature set. Velox™ probe station control software can manage the required soak time at any given temperature set. A soak time at 90˚C will be of substantially shorter duration than one at 200˚C. Velox manages the soak times according to the actual chuck temperature. It can operate based on either a fixed soak time or a temperature-dependent soak time where the required soak time is automatically calculated based on the increase in temperature from the previous soak time. The user enters the required soak times for each temperature set only once and the system then automatically manages the transitions going forward (Figure 5).

To ensure that the benefits of Contact Intelligence extend to the widest possible range of test scenarios, FormFactor has incorporated a number of high-temperature stability (HTS) components into the CM300xi and SUMMIT200 probe stations. They include a special high-temperature platen, microscope transport mechanism and probe card holder. With these HTS components in place, we have successfully tested from -40˚C to 150˚C in a series of system characterization tests at 30 x 30 µm.

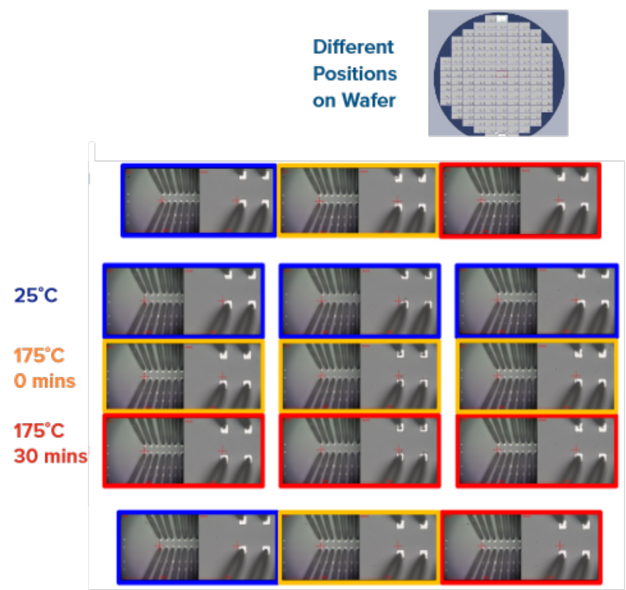

Figure 5. HTS test on probe card with pad size 30 µm x 30 µm with 2 hour system soak and 10 minute die soak. All pads in all positions were contacted successfully before and after temperature change. This is a test scenario, and results will vary depending on your application and setup.

Conclusion

Integrated circuit research and development faces the dual challenges brought on by expanding temperature ranges and shrinking feature sizes. These issues are compounded by the need to extract data at various temperature steps. In combination, these factors can significantly prolong the time required for accurate probe placement during many types of wafer-level testing due to the amount of operator intervention required. All contribute to the difficulty of managing an efficient lab.

FormFactor has developed Contact Intelligence technology and incorporated it into the CM300xi and SUMMIT200 probe systems, which sense, learn and react to alignment issues over multiple temperatures and small pad layouts. Contact Intelligence automatically adapts and adjusts to provide the most accurate probe-to-pad alignment for a broad array of wafers, materials and devices. It applies an unprecedented level of machine intelligence to the acceleration of test cycles, while providing the highest levels of accuracy, reliability and stability in increasingly complex test environments.

Corporate Headquarters
7005 Southfront Road
Livermore, CA 94551
Phone: 925-290-4000
www.formfactor.com

ContactIntelligence-TB-0618