

SEMI G78-0699 (Withdrawn 1011)

TEST METHOD FOR COMPARING AUTOMATED WAFER PROBE SYSTEMS UTILIZING PROCESS-SPECIFIC MEASUREMENTS

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NOTICE: This Document was balloted and approved for withdrawal in 2011.

1 Purpose

1.1 To define the terms and provide a means of comparative, or relative measurement for the automated wafer prober functions: Accuracy, Repeatability and Throughput.

2 Scope

2.1 This method may be used to evaluate the performance of a single automated wafer prober, or as a means to compare many probers. The probers that this document addresses are defined as fully automated; that is, having automatic material handling, alignment and probing capabilities.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This test and comparison method is not intended to represent a statistically complete methodology for measuring the performance of an automated wafer prober. Its correct use is a practical means to compare the stepping capabilities of wafer probers within a specific end user's environment.

3.2 The definitions of the terms "Repeatability" and "Accuracy" as used in this Document are not in accordance with those of the National Conference of Standards Laboratories (NCSL) nor are they intended to be. They are to be used solely for the purpose of this document and have no other intended uses.

3.3 It is difficult to characterize and eliminate high temperature contributions to positional error such as probe needle 'float.' Therefore, it is strongly recommended that the same probe card be used to evaluate all of the probers being considered.

3.4 It is recommended that the probe card is verified to be in the same condition (i.e., evaluated for positional accuracy and overall functional condition) both before and after the conclusion of each test.

3.5 Bump placement on a semiconductor device is generally located ± 0.001 inch with respect to their nominal location. Vertical probe cards used to probe bumps have an inherent amount of needle drift. Therefore care must be exercised in using vertical probe cards on bump devices as a means of prober accuracy measurement.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability and Maintainability (RAM)

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Definitions

5.1.1 3σ limit — a statistically derived measurement of process variation. A process that allows a $\pm 3\sigma$ deviation will allow 2.7 parts per thousand to be outside the established bounds.

5.1.2 *accuracy* — the ability of an automatic wafer prober to index its chuck, and attached wafer, from an initial position to a subsequent position and make contact with a static probe tip at a nominal location on the wafer. In the context of this method, accuracy is defined as average die offset.

5.1.2.1 Average die offset is the perpendicular distance measured from the centerline of the die pad to a parallel line that statistically represents the scrub mark data point distribution center (see Figure 1). Each data point shown in this figure represents only the center value of accumulated scrub marks produced by operation of this method.

5.1.2.2 It should be noted that accuracy established by this method is characteristic of the system, which in total represents both the automated prober as well as its probe card. Finally, this method establishes two accuracy values, a value for pads along the X and Y axes of the die. These axis directions are arbitrary.

5.1.2.3 It should be noted that if fully automated prober set-up modes are not used for probe-needle-to-pad alignment during testing, the possibility of operator error should be considered as a variable when evaluating system accuracy.

5.1.3 *automatic wafer prober* — device that automatically and repeatedly aligns the die bonding pads or interconnect bumps on a semiconductor device to a set of test needles attached to a probe card.

5.1.4 *bonding pad* — exposed metallic contact area on a semiconductor device that is surrounded by dielectric passivation. This is the point at which a temporary interconnect is made for wafer level test, and permanent interconnect for packaging.

5.1.5 *bumps* — metallic elevated contact area on a semiconductor device that is used in place of a bonding pad. A die that is designed to use this type of connection is commonly called a ‘flip chip’ or direct chip attach.

5.1.6 *die* — individual semiconductor device. For the purposes of this method, the dice have not been singulated, and are still in the form of a wafer. Used interchangeably (in the context of wafer sort) with the acronym device under test (DUT).

5.1.7 *overdrive* — distance in Z which the wafer is driven beyond a user defined initial contact point, typically ‘first electrical contact.’

5.1.8 *overhead test* — semiconductor test method where the test head is mounted directly over the prober, with the goal of shortening the distance between the pin electronics and the probe card. The connection between the test head and the prober is generally through a device called a prober tester interface (PTI)

5.1.9 *pin electronics* — tester hardware that creates the test signals used to challenge the DUT.

5.1.10 *probe card* — printed wiring board or ceramic substrate with permanently attached needles or contacts that are aligned at the time of manufacture to match the contact pattern on a Die. Common types of probe cards are:

- Blade
- Peripheral/Cantilever (AKA Epoxy Ring)
- Vertical (AKA Area Array or Cobra™)

5.1.11 *probe card planarity and alignment* — a user-specified position of the probe tips in ‘x’, ‘y’ and ‘z.’

5.1.12 *probe needles* — the contact points between the probe card and the bonding pads. These are typically manufactured from one of the following materials:

- Beryllium copper
- Tungsten
- Tungsten-rhenium alloy
- Paliney

5.2 *prober communications protocol* (see § 9.6) — means of transmitting data between the tester and the prober. Common methods are:

- TTL

- RS-232c
- GPIB

5.2.1 *prober tester interface (PTI)* — signal-transmitting electro-mechanical device that connects the pin cards in the tester to the probe card.

5.2.2 *repeatability* — Figure 1 is empirical data and represents a statistically significant sample of scrub marks. This data reveals that probe needles may not make contact consistently to the same point die to die. Recall that accuracy is defined in this method as average die offset. Thus, repeatability simply represents the three-sigma distribution value for average die offset. Repeatability will represent 99.7% or a three-sigma distribution value for the accumulated offset data points obtained through use of this method.

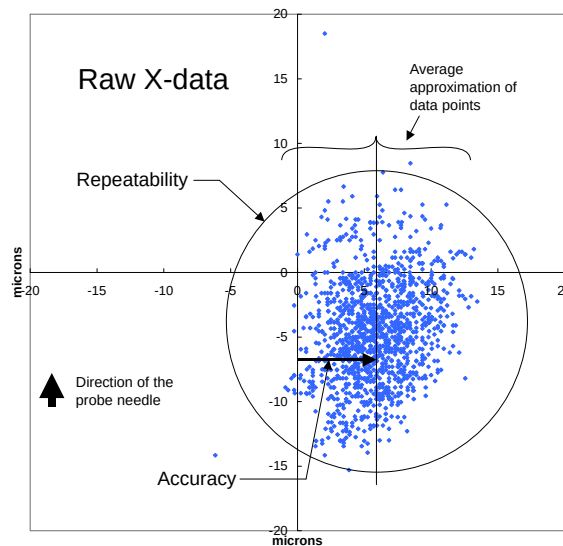


Figure 1
Raw X-Data

5.2.2.1 The X-Y plotted centroids of these scrub marks will be found to form a “cloud” of points, densest in the center, and thinning out towards the edges.

5.2.2.2 Repeatability is the radius of that cloud or “cluster” of probe marks, as defined by the 3σ or other user defined limit of that cloud. The error in the placement of the center of that cloud, relative to its nominal target, is defined as the automatic wafer prober’s “Accuracy”. (See Figure 1)

5.2.3 *set point* — the value to which a control system’s input device has been set, as opposed to the actual value to which the control system has driven the controlled variable. For example, the input setting to the wafer chuck temperature controller, as opposed to the actual, independently measured temperature of the wafer chuck.

5.2.4 *soak time* — time between a piece of equipment’s reaching the set point temperature and use of that piece of equipment.

5.2.5 *scrub mark* — mark left by the probe in the bonding pad or bump after the probe card has touched down on the wafer.

5.2.6 *temperature testing* — testing of devices at a controlled temperature level other than ambient.

5.2.7 *test* — one complete run-through of the data collection portion of this Document on one automated wafer prober.

5.2.8 *tester* — specialized computer controlled system designed to test integrated circuits.

5.2.9 *test head* — package of electronics (part of the tester) which interacts both electrically and mechanically with the probe card, typically through the PTI.

5.2.10 *throughput* — rate at which die can be cycled, by the automatic wafer prober, for the purpose of being tested. It is inherent in the functionality of an automatic wafer prober (or any other motorized positioning device) that accuracy, repeatability and throughput are intimately and inseparably related.

5.2.11 *touch down* — contact between the probe card and the wafer. This user may choose to define this as either first electrical or first mechanical contact.

5.2.12 *wafer* — semiconductor substrate upon which multiple die are fabricated.

5.2.13 *wafer boat or wafer cassette* — carrier for multiple wafers.

5.2.14 *wafer chuck* — platform within an automatic wafer prober that supports and transports the wafer. The chuck may contain the means for controlled temperature testing.

5.2.15 *x, y, z and θ* — motions relative to the center of the probe card when standing in front of the prober:

- Motion to the right is motion in the positive X-direction.
- Motion towards the back of the prober is motion in the positive Y-direction.
- Motion away from the floor is the positive Z-direction.
- Motion revolving around a Z-axis passing through the center of the probe card is θ -motion. Motion in the counter-clockwise direction when facing down from above the prober is motion in the positive θ -direction.

5.2.16 *z-clearance* — distance between the user defined initial contact point and the top surface of the wafer during that portion of the wafer prober's cycle when the wafer chuck is moving the wafer between DUTs.

6 Summary of Method

6.1 *Objective* — A SEMI Probe Standards task force has defined this method. That task force consisted of members from semiconductor wafer probe system users and wafer probe system suppliers. This method, in part a guide to collection of data, is aimed at a specific set of wafer probe system parameters: accuracy, repeatability and throughput. This method is a tool that creates comparative data. That data will act as a criterion by which multiple wafer probe systems can be judged competitively.

6.2 *Probe System Accuracy and Throughput* — A wafer probe system will have needle placement error due to the probe system electromechanical systems, and additional needle placement error due to the probe card physical alignment of the needles. The degree of accuracy to which the probe system can place the chuck, the effectiveness of the probe system's bond pad to needle alignment, the physical alignment of the probe card needles in their X and Y plane, and the probe system's vision resolution and accuracy (x microns of distance per pixel) will be the factors that influence a probe system's overall placement performance.

6.2.1 Probe system comparative accuracy and repeatability are established in this method using probe mark data acquired manually with a vision system or, if available, through use of an automated probe mark data analysis system. Acquired data is analyzed with the probe mark data analysis algorithm contained in this method.

6.2.1.1 The intention of this data collection exercise is not to make a deterministic conclusion establishing a probe system's accuracy. Data analysis results are only meaningful in the context of a comparative analysis of multiple probe systems.

6.2.2 Probe system throughput is best determined using time measurements made using a stopwatch. Other approaches can be applied, such as:

- the time stamp and log file (if available) on the probe system under evaluation.
- time tracking within the device test program employed for testing the prober.

6.2.3 Any of these approaches is viable for measuring time intervals during probe system operation. That data is to be entered into the data collection table as part of the application of this method.

6.2.4 The algorithm collects data from nine wafers out of a lot of ten. Three setups are performed using three wafers per setup. All dice will be probed, but data will be taken only on twelve of the die on each wafer. Twenty-four pads on each die are evaluated (see Figure 4). Overall, 2592 die pads are analyzed in a lot.

6.2.5 When all the data is collected and analyzed, each probe system will have an average die offset value. This will be a comparative representation of accuracy consisting of average offsets for all evaluated die. This comparative representation of accuracy is a measure of how accurate the probe systems place the chuck, and thus the probe needles, to the center point on the die pads, consistent with normal operation of the probe systems.

6.2.6 In general, when the probe marks are viewed across all dice, there will be a data spread, or distribution of error points for each wafer. Repeatability is the $\pm 3\sigma$ variation of all die offsets, identified in this method as the 3σ calculation of *normalized die offset*.

6.3 *Probe Card Issues* — Probe card construction variability and probe card usage at temperatures other than ambient are important considerations. The following sources of error should be kept in mind:

- In a hot chuck environment the probe card and needles will experience a high percentage of the elevated chuck temperature. The material selection for the probe card will determine how it expands and contracts due to the temperatures applied. Probe systems can be equipped with programmable preheat (soak) times. Longer preheat times will reduce probe card variability while decreasing throughput.
- Needle construction can result in excessive error due to bending of the needles when excessive probe system z-stage overdrive is applied. The number of needles and the selection of needle technology, that is, cantilever versus vertical, is another variable, having a noticeable influence on measurement results.
- Since each user of this method is not confined to a standard for probe card construction, the user of this method is advised to choose a probe card and vendor with good integrity, and to use that same probe card when evaluating multiple probe systems. The assertion here is that the same probe card used to evaluate multiple systems will react in a repeatable manner under varying environmental conditions. This assumes there is no excessive probe card needle wear during the multiple evaluations, and that needle alignment is verified or achieved before each execution of the procedure.

6.3.1 Probe mark scrub length can vary due to several factors including:

- variations in the flatness of the chuck and stage travel that are not compensated by the z-sensor mapping algorithms
- by hard spots in the aluminum pads, or
- by variations in probe tip geometry, etc.

6.3.2 To minimize the impact of this variation in the probe mark analysis algorithm, use only scrub mark location data that is taken normal to the direction of scrub. Distances measured normal to the orientation of the scrub mark are generally accepted to be significantly more stable than that which is taken parallel to the scrub mark (see Figure 2).

6.3.3 In summary, the probe card itself can be a limiting factor when making needle placement accuracy measurements, especially at varying environmental conditions. Material selection, vendor to vendor variation, construction of a probe card (blade, epoxy ring, vertical, etc.), especially with varying environmental conditions, will create inconsistent analysis results, unless care is taken with the application of this method. The precautions discussed here are meant to promote consistent and accurate evaluation results for this method.

6.3.4 Nevertheless, the precautions mentioned here could ALSO be an important basis for using this method. As an example, a probe card is typically designed for XY positional placement and planarity, and is expected to meet customer specification requirements in normal operation at room temperatures. This method could serve as a means of establishing numerical results that represents the effects that temperature or probe card construction variability have on probe card specification requirements.

6.4 *The PMA Algorithm* — A best-fit rectangle can be drawn around the scrub mark and the passivation opening for each pad, reference Figure 3.

NOTE 1: Applying a best-fit rectangle around the passivation opening may prove difficult for certain vision systems. Application of the best-fit rectangle around the die pad metal is an acceptable alternative. The center position of the best-fit rectangle around

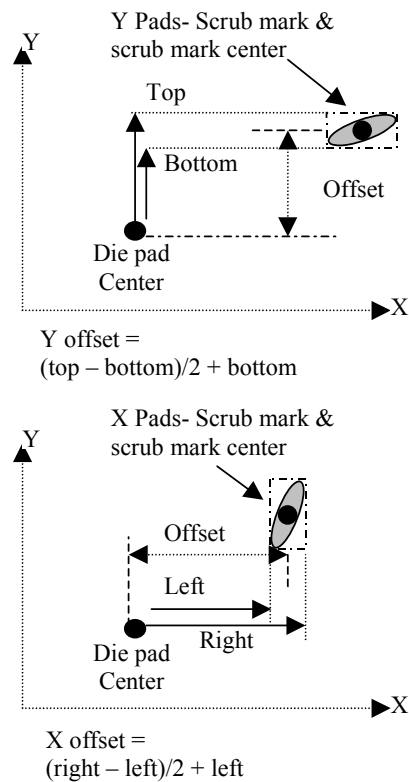


Figure 2
X and Y Offset

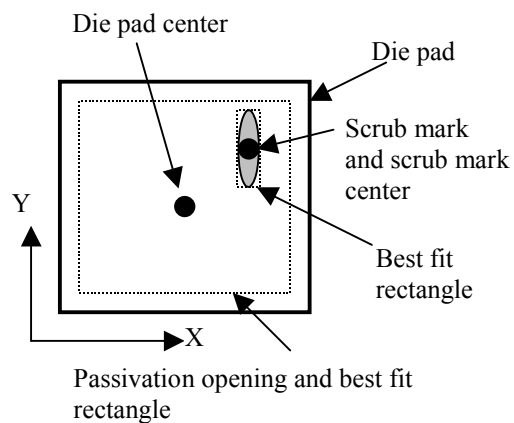


Figure 3
Scrub Mark Analysis

6.4.1 Vision system measurements will be made establishing offset distances from the die pad center to the scrub mark. The stability of the measurement is greater when made perpendicular to the direction of the scrub mark. This will establish X and Y offsets via measurement of offsets for pads in the X and Y plane of the die.

6.4.2 Once the offsets are established, a two-step procedure will manipulate 1296 X and 1296 Y offset values. The end result of the algorithm will be a relative measure of the total probe system accuracy and repeatability for the pads analyzed. Figure 5 represents a visual summary of the method.

6.5 *Considerations of Scale* — When evaluating the suitability of a particular probe system to probe a particular size of bond pad, or to probe accurately at a particular pad-to-pad pitch, a good rule of thumb is that the prober's positional accuracy, as stated in its specifications, should be 1/10 that of the scale of the features to be probed. For example, if the probe system being evaluated has an overall placement accuracy of 5 μm , it would be inappropriate to analyze wafers using this method and this probe system for dice that have pads less than 50 μm square (this would be less than 10 $\times$).

6.5.1 Regardless, when this method is used for evaluation of multiple systems, it is essential that die and bond pad size/pitch consistency be maintained from evaluation to evaluation if the results are to be meaningful.

6.5.2 The same 10 $\times$ rule applies to the vision system or automated probe mark analysis system employed to make the pad offset measurements. These systems should have a pixel resolution that is at least 10 $\times$ finer than the die pad dimensions associated with the scrub marks being measured.

6.6 *Conclusion* — It is assumed that the user of this method has a wafer probe system or systems, or is planning to make a selection from the various systems available in the market place, and requires objective comparative analysis for accuracy, repeatability and throughput.

6.6.1 It should be clear that this method employs a three-step process of probing, probe mark data collection, and data analysis.

6.6.2 When probing, every die on each of the ten wafers is to be “tested” and probed. Of those ten wafers, the last nine with 12 die per wafer will be used for scrub mark data collection. At least 24 pads per die will be used for the analysis. The first wafer is meant only to allow stabilization for the probe system and its probe card.