Title: Method for an improved checking of repeatability and reproducibility of a measuring chain, in particular for the quality control by means of the semiconductor device testing.

DESCRIPTION

Technical Field

The present invention refers to a method for an improved checking of repeatability and reproducibility of a measuring chain, wherein testing steps are foreseen for multiple and different devices to be subjected to measurement or control through a measuring system comprising at least one concatenation of measuring units between a testing apparatus (ATE) and each device to be subjected to measurement or control.

The invention in particular, but not exclusively, relates to a methodology foreseen for quality control through the semiconductor device testing, and the following description is made with reference to this field of application with the sole purpose of simplifying its presentation.

Background Art

As it is well known, R&R (Repeatability and Reproducibility) methodologies, applied to measuring systems, and in particular to quality control through testing of semiconductors, have the purpose of ensuring the repeatability and reproducibility of measuring.

Currently, such R&R methodologies are strongly linked to each individual product that is also part of a plurality of products to be subjected to testing with R&R methodology.

In order to try to better understand the problems of this field of application it is worth noting that a generic measuring system is formed from a chain of systems SC arranged in cascade with each other and that represent a concatenation of measuring units, as schematically illustrated in Figure 1.

For the sake of simplicity of presentation we can consider that each measuring system can actually be represented with a chain of basic units arranged in cascade, but in any case this is not limiting for the purposes of the present invention.

Each unit that forms part of the systems chain can also have a complicated internal structure and interfaces with the other units exchanging information in the form of input/output signals that can be electrical, electronic, luminous or in the form of electromagnetic waves or radiation. The ways in which the information is exchanged between the various units is also not limiting for the purposes of the present invention.

In general, upstream of the systems chain there are measuring and stimulation instruments, represented here by a single overall system or basic unit called ATE (Automatic Test Equipment).

The ATE is formed from at least one resource capable of performing at least one type of measurement.

Each resource of the ATE in general should respect a specification. In its most common formulation the specification foresees that the resource can measure values of a specific magnitude located between a minimum LSL (Lower Specification Limit) and a maximum USL (Upper Specification Limit), as schematically illustrated in Figure 2.

If the measurements are located within the specification range [LSL; USL] it is considered that the considered resource is working correctly (Pass) within its specification. Otherwise, if the measurement does not satisfy the specification, it means that such a resource has an anomalous behaviour (Fail) that must be investigated and evaluated in order to restore the correct operation of the resource itself.

In order to check the specification values of the various resources of the ATE, a calibration tool can be available that, hereafter, we shall call Checker, which can be of the hardware (HW) and/or software (SW) type and that is used following a dedicated procedure.

This calibration tool just checks that the various resources are within the specification and indicates as possibly anomalous only those resources that are not within their specification and that give a "Fail" result.

Downstream of the systems chain SC there is the object or device that should be subjected to measurement, represented by a single overall unit called DUT (Device Under Test) schematically illustrated in Figures 1 and 3.

Of course, the DUT can consist of at least one element on which it is necessary to perform at least one measurement, to obtain at least one parameter that is measured with at least one measuring technique, or the value of which is estimated from at least one measurement.

In general, it is also possible to perform the measurements of a plurality of DUTs in parallel, as shown in Figure 3, obviously if the measuring chain has this ability.

However, for the purposes of the present invention, it should be considered that all of the DUTs measured in parallel are like a single overall DUT.

Between the ATE and the DUT there can be at least one unit of the systems chain SC that acts to adapt and/or interface together the ATE and the DUT. This unit can also expand the measuring potentials and capabilities of the ATE, or focus/size the capabilities of the ATE to the specific DUT.

It may also be the case that, even if the resources of the ATE respect their specification, this may not be sufficient to satisfy the quality requirements required for the testing of the DUT.

Indeed, the last purpose of the measuring system as a whole is that of identifying the DUTs that are defective, performing at least one measurement on the DUT itself and determining whether or not the DUT is defective based upon some criteria.

Downstream of the measurement the defective DUTs shall be separated from the others and discarded.

In the case in which an ATE incorporates at least two different resources of the same type, even if such resources satisfy their specification, it can be foreseen for such resources to provide even considerably different measurements of the same magnitude measured whilst operating on the same DUT.

In short, the testing system should overall satisfy not only its own specification, but are also to be taken into account requirements of repeatability and reproducibility of the measurement. In this field by repeatability we mean the variation of the measurement obtained with a single measuring resource ATE, which at different times carries out the measurement of the same characteristic on the same DUTs; therefore,

the measurement variation on the same ATE is measured.

By reproducibility we mean the variation in the average of the measurements made by different ATEs that measure the same characteristic on the same DUTs.

The R&R technique in itself combines repeatability and reproducibility and it is calculated using ANOVA (ANalysis Of VAriance) statistical techniques, as schematically illustrated in Figures 4A-4C, where the word Appraiser indicates the measuring chain.

According to the current prior art technique, the so-called golden samples, or reference units, are used, which are inserted into the systems chain in place of the DUT, on which the various ATEs (each with its own measuring chain) perform the measurement of at least one characteristic for N (N>1) times that we shall call Cycles, in M (M>1) different time periods that we shall call Runs, on the different measuring systems chains, as schematically illustrated in Figure 5.

These golden samples are generally linked to the required specifications for the end product, and usually are samples of the same end product.

In particular, in the technical field of semiconductor devices, if the DUT consists of chips on a wafer, the measuring systems chain generally comprises the ATE that is interfaced with the DUT through a Jig unit (or a DIB - Device Interface Board) and a probe card, as illustrated in Figure 6A.

The Jig unit is optional and may not be present in the measuring chain. The Jig unit comprises circuits that interface the ATE with the device DUT through a probe Card; the latter comprises different probes that make contact with the terminal pads of at least one chip on the wafer.

If the device DUT comprises at least one chip encapsulated in a package, or more than one chip encapsulated in the same package (System in a Package), the measuring systems chain comprises the ATE that is interfaced with the DUT through a Jig unit (or DIB) and a board with at least one socket in which the package that contains the chip or chips is housed.

Therefore, the golden samples can be some chips present on the

wafer or in a package, in various forms, and quality control foresees that the R&R, in other words the Repeatability and Reproducibility, of the entire measuring chain be evaluated.

The evaluation of the R&R is always carried out as the measuring chain varies, i.e. as the ATE varies with its adapters and interfaces. The evaluation is therefore carried out on the various measuring chains using the golden samples, performing the measurement of at least one feature or characteristic parameter of such golden samples.

In general, it is suitable to measure a few tens of different characteristic parameters, which are monitored with suitable statistical techniques, like for example the methodology known as "ANOVA", to ensure the R&R, i.e. the Repeatability and Reproducibility of the various measuring systems.

Based upon the various and different types of DUT, the family and/or configuration type of the ATE and the consequent measuring chain shall of course change. In any case, checking the R&R of measuring systems in normal working conditions is generally a required quality requirement that should be satisfied, and it should be considered ever more critical the higher the required quality levels, for example for products in the automotive sector.

Given that the golden samples are linked to each product, in the cases in which there are many different products the repeatability and reproducibility of the measuring systems should be checked on different products, i.e. it is a great burden, for the large number of golden samples that have to be identified and certificated.

Moreover, for each group of golden samples it may be necessary to provide a specific setup of the measuring chain, to obtain the data from which to calculate repeatability and reproducibility.

Consequently, it becomes a great burden both in terms of time and costs and in terms of resources, to check repeatability and reproducibility on the different measuring chains, using the various types of golden samples.

If then the measuring chains are used in a production context, this means to dedicate part of the time of the various measuring chains to carrying out measurements on the golden samples to check

repeatability and reproducibility.

Moreover, there will also be a plurality of types and families of golden samples that will not always be the same, since for each new product new golden samples, that add to the existing ones, should be identified and certificated.

In performing the check of repeatability and reproducibility the golden samples can become damaged and therefore new golden samples are introduced, and this has an impact upon costs, time and resources.

The greater the human involvement to carry out the measurements, the lower the repeatability and reproducibility of the measuring system, and this can often be partially solved with the introduction of automation of the measuring process.

Considering various measuring chains, if one of them is not repeatable and reproducible with respect to the others, then it will not be known which part of the measuring chain does not satisfy repeatability and reproducibility, and therefore it will not be known *a priori* on which elements of the measuring chain there needs to be an intervention to restore repeatability and reproducibility of the entire measuring chain to thus align it with the other measuring chains.

In particular, in the field of semiconductors, the golden samples are frequently damaged and would often be replaced.

For example, if the golden samples are chips still on a wafer, they are interfaced with the measuring chain through a probe card the probes of which damage the contact terminal pads. In general, the contact between probe and pad is not repeatable and reproducible, since the probe that makes contact with the pad changes and damages the pad itself, and this can bring problems in the electrical measurements carried out by the measuring chain on the device of the wafer.

Particles can build up or can form oxides on the probes as well that alter the measurements and that decrease the reliability of the evaluation of repeatability and reproducibility of the overall system.

Indeed, all of this can for example translate into a random variation in contact resistance (in general impedance) between probe and pad, which alters the value of the measurements.

The probe card is subject to wear and deterioration, and this influences the measurements taken for repeatability and reproducibility; indeed, the probes wear out over time and change their mechanical parameters, like: the alignment of the probes, their planarity, their length, the force exerted on the pad, the shape of the tip.

This list is not exhaustive of all of the possible deterioration that can occur on a probe.

Over time, by using the probes the measurement can also be repeated, but the same measurement conditions cannot be reproduced.

Furthermore, after a large number of contacts that damage the pads, some wafers can no longer continue in the production process and therefore are not sold, but must be discarded with a consequent additional cost.

By using production devices like golden samples, if the normal testing methods of semiconductors are used, the various devices can be subjected to electrical and environmental stress that can alter their characteristics, and this reduces the reproducibility of the conditions in which the measurement is carried out.

For example, electrical stress can be used on the chips to check the oxide status, but such electrical stress can alter the oxide at crystal lattice level.

Consequently, both the action of the probes, and the action of stress ensure that it is not possible to carry out in full the repeatability and reproducibility check of the measuring chain on the DUTs that will then be measured in real conditions.

For example, in order to eliminate the effect of stress it is possible to avoid applying such stress during the repeatability and reproducibility check, and in order to eliminate the effect of the probes it is possible to use encapsulated chips as golden samples. However, by using encapsulated chips some interfaces should be introduced in the measuring chain that are different from those used for the measurements on a wafer, and therefore the measuring chain on which the repeatability and reproducibility check will be carried out should be changed in the different conditions in which the measuring chain itself

will operate.

The measuring chains that have ATE with high parallelism are able to measure even hundreds of chips simultaneously, and therefore it is very complex, if not impossible, to use the golden samples approach.

Similarly, it can be said for measuring chains on which repeatability and reproducibility are carried out with golden samples of encapsulated chips that are the normal DUTs the chains should measure.

Indeed, even in these cases there will be contact between the package and the interfaces with the ATE.

It may be considered to solve to problem by welding the encapsulated chip onto a board, but this eliminates the presence of the socket, in which the encapsulated chips are housed to carry out the measurements in normal conditions.

Often for the measurement of the DUT just a part of the potential of the measuring chain is used and therefore also with golden samples only a part of the functionalities of the chain shall be verified.

Basically, if the measuring chain, in particular the ATE, has parts or resources that do not satisfy repeatability and reproducibility, this will be visible only with those types and families of golden samples that require the use of this type of parts or resources to carry out the measurements.

Consequently, a measuring chain can be repeatable and reproducible for a certain class or family or type of golden samples but not for other classes, families or types.

Therefore, certain measuring chains can be used for the measurements of certain classes, families or types of DUTs and not for others, creating economic, managing and production problems, etc..

Moreover, the various golden samples use parts of the chain that are common to many types and/or families of golden samples and this is inefficient.

Therefore, by using golden samples linked to the end product, when considering a plurality of possible end products that are different to each other, it is difficult to ensure repeatability and reproducibility of the various measuring chains as a whole, and in the case of problems it

is not easy to understand the causes that alter repeatability and reproducibility and to put it right.

All of this makes the current check of repeatability and reproducibility ineffective or inefficient, especially in a production context, also because the parameters measured are not many in general.

The technical problem underlying the present invention is that of providing a repeatability and reproducibility checking methodology that is as independent as possible from the features of the individual product on which it is necessary to carry out the check and having functional characteristics such as to allow the limitations and drawbacks still suffered by the methods made according to the prior art to be overcome.

Disclosure of Invention

The idea of solution at the basis of the present invention is to separate the measuring chain into the various basic units, on which repeatability and reproducibility is checked, to then go back to consider the entire measuring chain by carrying out a correlation on the product.

Advantageously, according to the invention, the method for an improved checking of repeatability and reproducibility proposed is no longer focussed on the individual product, and can therefore be applied to a generic group of measuring systems that may still be complex, considering any plurality of products that should be reliably measured independently from the product and from the specific measuring system used.

Based upon such an idea of solution, the technical problem is solved by a method for an improved checking of repeatability and reproducibility of a measuring chain, in particular for the quality control by means of the semiconductor device testing, in which testing steps are foreseen for multiple and different devices to be subjected to measurement or control through a measuring system comprising at least one concatenation of measuring units between a testing apparatus (ATE) and each device to be subjected to measurement or control, characterised in that it comprises the following steps:

- checking repeatability and reproducibility of each type of unit

that forms part of the measuring chain of said concatenation;

- then making a correlation between the various measuring chains as a whole to check the repeatability and reproducibility, using the corresponding device subjected to measurement or control.

Advantageously, said checking step comprises separating the measuring unit that depend upon the device subjected to measurement or control, from those that do not depend upon said device.

Moreover, a procedure is provided that comprises the use of a software and/or hardware type Fixture associated with said testing apparatus, and possibly incorporating a testing protocol, for checking repeatability and reproducibility of each individual measuring resource or groups of measuring resources that belong to the measuring unit, to evaluate the repeatability and reproducibility of the unit itself. The various groups of resources can also at times comprise common resources, by common resources meaning at least one measuring and/or stimulation tool, like for example at least one signal feeder or generator. In this field, it is also provided a measuring of at least one characteristic of said apparatus for N times or Cycles, carried out in M different time periods that we shall call Runs and on different apparatuses, through a statistical method of the "ANOVA" type.

The characteristics and advantages of the method according to the invention shall become clearer from the description, made hereafter, of an example embodiment thereof given for indicating and not limiting purposes with reference to the attached drawings.

Brief Description of Drawings

In such drawings:

Figure 1 schematically illustrates a measuring chain, in particular for the semiconductor device testing, realised according to the prior art;

Figure 2 schematically illustrates a specification to be used in a measuring chain of the type illustrated in Figure 1;

Figure 3 schematically illustrates a measuring chain together with a device under testing according to the prior art;

Figures 4A-4C schematically illustrate the progression of variables for analysing variance according to a known statistical

technique of the "ANOVA" type;

Figure 5 schematically illustrates a repeatability and reproducibility methodology applied to two measuring chains according to the prior art;

Figure 6A schematically illustrates an embodiment of a measuring chain for testing chips on a wafer, realised according to the prior art;

Figure 6B schematically illustrates a further embodiment of a measuring chain for testing chips which are encapsulated in a package, also realised according to the prior art;

Figure 7 schematically illustrates a division of a measuring chain carried out by the method for an improved checking of repeatability and reproducibility according to the invention;

Figure 8 schematically illustrates an embodiment of a measuring chain that uses the method for an improved checking of repeatability and reproducibility according to the invention;

Figures 9A-9D schematically illustrate alternative embodiments of the chain of Figure 8;

Figure 10 schematically illustrates a specification to be used in the method for an improved checking of repeatability and reproducibility according to the invention for Checkers and the repeatability and reproducibility measurements of the apparatus (ATE);

Figure 11 schematically illustrates the method for an improved checking of repeatability and reproducibility according to the invention applied to two ATEs;

Figure 12 schematically illustrates a measuring chain that uses golden samples for the method for an improved checking of repeatability and reproducibility according to the invention when applied to a Jig unit;

Figure 13 schematically illustrates a measuring chain for EWS testing of wafers that uses the method for an improved checking of repeatability and reproducibility according to the invention; and

Figure 14 schematically illustrates the flow diagram of the method for an improved checking of repeatability and reproducibility according to the invention.

Modes for Carrying Out the Invention

With particular reference to the example of figure 7, a method for an improved checking of a repeatability and reproducibility checking of a measuring chain is now described, in particular for the quality control by means of the semiconductor device testing, in which testing steps are foreseen for multiple and different devices to be subjected to measurement or control through a measuring system comprising at least one concatenation of measuring units between a testing apparatus (ATE) and each device to be subjected to measurement or control.

To understand the general idea forming the basis of the present invention, firstly consider a generic measuring chain on which it is necessary initially to evaluate and check over time repeatability and reproducibility, like for example the one illustrated in Figure 1 and described in relation to the prior art.

Advantageously according to the invention, the proposed method for an improved checking of repeatability and reproducibility (R&R), instead of considering the various measuring chains as a whole, provides for breaking down the measuring chains into their basic units, checking repeatability and reproducibility on the various basic units when considered separately, to then carry out a correlation between the various chains.

In particular, the method comprises separating the basic units that depend upon the device subjected to measurement or control, in other words upon the DUT and therefore upon the product, from those that do not depend upon such a device.

Furthermore, considering all of the units that do not depend upon the DUT, the repeatability and reproducibility check is carried out on them independently from the specific DUT.

Given that in general the most complex part of the chain is the apparatus ATE, which does not depend upon the particular DUT, the proposed method firstly ensures that the various resources of the ATE are repeatable and reproducible.

The method therefore comprises a check of repeatability and reproducibility, where applicable, on the units that depend upon the device DUT subjected to measurement or control, which in general are

less complex with respect to the ATE.

Hereafter, the method according to the invention considers the measuring chains as a whole and carries out a correlation between the various units of the measuring chains, or between the measuring chains themselves, using the various devices subjected to measurement or control in whatever form they may be.

Considering the specific field of semiconductors, the measuring chains are separated into their basic units, separating the units that depend upon the DUT from those that are independent from it.

If the DUTs are chips on a wafer, there will be measuring chains for EWS testing, as schematically illustrated in Figure 7.

Then the apparatus ATE, which does not depend upon the end product, is separated from the rest of the measuring chain that depends upon the end product.

Therefore, there will be repeatability and reproducibility R&R at the ATE tester level, and repeatability and reproducibility R&R at the product level, where applicable.

For EWS testing, where the DUTs are chips on a wafer, and for FT testing, where the DUTs are encapsulated chips, it is possible to use the same apparatuses ATE.

What changes in the measuring chain between EWS and FT are the interfaces between the ATE and the DUT, as schematically illustrated in Figure 6A (for the EWS) and in Figure 6B (for the FT).

At the ATE tester level, it will be necessary to create a procedure having a specific protocol for controlling the testing operations for the purposes of checking repeatability and reproducibility.

Advantageously, according to the invention, such a procedure provides for the use of a Fixture that can be software (SW) and/or hardware (HW), and must be a reference able to align the different ATEs of the same family, or of the same type or with the same configuration with each other. For example, the Fixture can be an electronic structure comprising at least one electronic circuit on which at least one testing software routine carries out at least one measurement associated with the apparatus ATE; such a fixture can also incorporate a testing protocol for checking repeatability and reproducibility of each individual

measuring unit.

Such a procedure that provides for the use of a Fixture that can be software (SW) and/or hardware (HW), associated with the testing apparatus ATE or with a measuring unit, and possibly incorporating a testing protocol, checks the repeatability and reproducibility of each individual measuring resource or groups of measuring resources inserted in said measuring unit or apparatus ATE, where the various groups can, at times, also comprise common resources that are at least one measuring and/or stimulation tool, like for example at least one signal feeder or generator. Such resources are necessary to carry out at least one measurement to evaluate the repeatability and reproducibility of the measuring unit.

The SW Fixture shall be used by the ATE as if it were a normal testing program, whereas the HW Fixture shall be connected to the ATE, and to do this it is preferred to use the same connections used by the ATE of the normal measuring chain to carry out the measurements on the DUTs, as schematically illustrated in Figure 9A.

As well as the normal connections used by the ATE in the chain, there can be other connections used for the calibration and checker of the ATE itself.

For repeatability and reproducibility it is possible to use the same connections used by the ATE for the measurements on the DUT and/or the connections used for the calibration and checker of the ATE itself.

If, for some reason, it is decided not to use same connections used by the ATE for the measurements on the DUT, there is the risk that the different electrical path followed weighs upon repeatability and reproducibility, lowering its reliability; consider, for example, RF (radio frequency) measurements.

In the embodiment described here for indicating and not limiting purposes, it is provided for the HW Fixture to be outside the ATE so that such a Fixture is common to many ATEs and can be a single common reference for them.

This Hardware Fixture does not have to depend upon the particular end DUT, and should be able to stimulate all of the resources of the ATE so that the repeatability and reproducibility check has good

coverage, such as to be able to stimulate and measure up to 100% of the resources of the ATE itself.

In general, it is preferred to stimulate just those resources of the ATE that are critical for the measurements of the various DUTs, i.e. it is preferred to stimulate and check repeatability and reproducibility of those resources of the ATE that can have a drift over time.

It does not make much sense to check repeatability and reproducibility of resources that are known to be stable over time and aligned with each other with respect to the different measuring chains, given that such resources do not drift over long time periods, also because to do so is not economically advantageous.

The Hardware Fixture can also be inside the ATE, as schematically illustrated in Figure 9B, but in this way such a Fixture would no longer have the role of the single reference through which to align the different ATEs with each other.

Moreover, such a HW Fixture would be checked and recalibrated periodically, but it would be very difficult to ensure that at each moment in which R&R is checked all of the HW Fixtures inside the ATE are aligned with each other, and are an unequivocal reference considering the ATEs as a whole.

In a hybrid manner the Fixture can be in part inside the ATE and in part outside of the ATE itself, as schematically illustrated in Figure 9C.

It is thus possible to have a single Fixture used at times on ATEs of different families, types or configurations, and obviously as the number and type of resources incorporated in an ATE changes the set of characteristics of the ATE that are measured can be changed.

Therefore ATEs that have identical and different parts can be compared with each other considering the common parts with the same characteristics and requirements thanks to the uniqueness of the Fixture.

Of course, ATE apparatuses that are very different to one another can need different Fixtures, or else it is possible to use the same HW Fixture that is connected to the specific ATE through an Adapter, which mechanically and electrically (or even in another way) adapts the HW

Fixture to the ATE, as schematically illustrated in Figure 9D.

The HW Fixture and the Adapter can be considered like an overall HW Fixture

In this way, it is possible to reuse the same HW Fixture as a common reference between ATEs that are even quite different to each other.

The HW Fixture used for R&R can also form part of the tool that is used to executing the Checkers of the ATE, but for R&R such a HW Fixture is used in a substantially different way with respect to the Checkers, as schematically illustrated in Figure 10.

Indeed, as stated previously, the Checkers, through a value or a precise measurement, check that the generic resource is within its specification and indicate only those resources that are within their specification (Fail) as anomalous.

Here the repeatability and reproducibility of a generic measurement of a characteristic are evaluated by observing their overall variance between the various ATE apparatuses (or Appraiser) over time.

Observing a variance, the specification limits for R&R can be different from the normal specification limits of the resources of the ATE, which refer to precise values and not to variability ranges.

Consequently, it is very important to establish the LSL and USL limits of the repeatability and reproducibility of a generic resource of the ATE, because this can affect the various mathematical indicators, through which the status of the R&R is evaluated, based upon predetermined criteria.

Therefore, the check of repeatability and reproducibility at ATE tester level in the EWS and FT test for semiconductor devices can follow the same approach.

However, it is possible to have repeatability and reproducibility at tester level which are different between EWS and FT considering the same families, types and configurations of ATE due to economic reasons, or with a different group of resources deemed critical.

In any case, in the field of semiconductors the approach for R&R of the ATE can be the same.

In this way, the measurement of at least one characteristic of the

ATE shall be carried out for N (N>1) times, which we shall call Cycles, in M (M>1) different time periods that we shall call Runs, on the different ATEs, and through a statistical method such as ANOVA the R&R shall be calculated, as schematically illustrated in Figure 11.

In practice, through the Fixture (SW or HW), the ATE is able to measure its same characteristics.

Given that the most complex part of the measuring chain is the ATE this is where the most effort shall be made to evaluate R&R.

Initially, to evaluate R&R a certain number M of Runs will have to be carried out each formed from a certain number N of measuring Cycles.

After having noted that the various ATEs satisfy the R&R criteria, to periodically check that such ATEs still adhere to the R&R criteria, at each check a certain number (B) of Cycles will have to be carried out for a certain number (A) of periods or Runs.

If an ATE is modified on its inside or the environmental conditions are changed in a non-negligible way, the evaluation of R&R should be carried out again by performing suitable (D) Cycles for suitable (C) periods or Runs.

The Jig unit or DIB is generally dependent upon the specific product, and R&R has to be evaluated using, for example, golden samples, which are connected to the Jig unit through an Interface, as schematically illustrated in Figure 12.

The interface can be a board on which there are the golden samples, which can be welded onto the board itself or inserted into a socket.

In order to evaluate the R&R of Jig units similar to each other, it is provided to use the same ATE and the same golden samples, avoiding applying stress to the golden samples that could change their characteristics.

It may also be possible to evaluate the R&R of the Jig unit without the use of golden samples, but using a Special Board, similar in concept to the Fixture used for the ATE.

For the Jig units, instead of carrying out the R&R, it may be useful sometimes to carry out a correlation exercise, equipped with suitable

criteria for evaluating the results of the correlation.

For the probe card or for the socket, since the concept of R&R is not fully applicable, it is possible to consider the normal mechanical, electrical or other type of measurements that are already normally carried out at the current time, evaluating the reliability of the specific probe card or socket based upon them.

Finally, it is necessary to carry out a correlation exercise between the various measuring chains, in their standard operating conditions.

In the case of EWS testing let us consider normal production wafers on which their testing is carried out on a measuring chain and then the retesting is carried out on another measuring chain of the same type in the same conditions, as illustrated in Figure 13.

Following the testing and retesting results, by applying criteria that can be linked:

- to the classification of the various chips of the wafer,
- and/or to the variation in yield between testing and retesting,
- and/or to particular measured parameters,

it is established whether the measuring chains are reliable.

These criteria should take into account the differences due to the different contact conditions between testing and retesting and the effect of possible stress carried out during the test and possibly repeated in the retest.

At the product level, the various criteria and the rules can depend upon the product itself that is being considered.

If the correlation has a successful outcome the measuring chains are qualified to measure the specific product, according to this method for evaluating R&R.

In greater detail, the following flow chart shows one of the possible ways to proceed to initially evaluate and check over time that the measuring chains are and continue to be in accordance with the R&R criteria, based upon what is described above, as shown in Figure 14.

This general flow can in any case be changed and improved based upon specific requirements and the field of application of the new methodology for evaluating and checking R&R described previously.

Considering a group of K different apparatuses ATE for which the

R&R Fixture is applicable, at different times it is possible to carry out Z Runs each of N measuring Cycles through the Fixture associated in common or with each ATE, to acquire the measurements of the characteristics of interest of the K apparatuses ATE in order to obtain the initial evaluation of R&R.

Let it be assumed that to carry out the individual Run on the K ATEs the Fixture is gradually applied on the K ATEs, and a data file is thus obtained for each ATE containing all of the information and measurement data useful for calculating R&R.

Therefore, Z*K data files shall be obtained to which to apply the ANOVA analysis and to obtain R&R.

Based upon selected evaluation criteria it is possible to establish that the R&R of the group of ATEs is good, or else is acceptable or worse is unacceptable.

If the R&R is unacceptable, this may be due to a subgroup M of apparatuses ATE that have some characteristics not aligned with the other apparatuses ATE of the entire measuring system.

It is thus possible to intervene on the M apparatuses ATE and on their component parts that are misaligned based upon an OCAP (Out of Control Action Plan) aimed at solving these specific problems.

After having solved these problems, the M ATEs must once again carry out Z Runs each of N Cycles, and reperform the ANOVA analysis of the last Z data files of the K ATEs of the group, and consequently evaluate the new R&R.

If, on the other hand, the R&R is acceptable, there will be H apparatuses ATEs for which some characteristics could be slightly misaligned with respect to the other ATEs of the group, but this is in any case considered acceptable.

This can indicate that some ATEs have some of its parts drifting and consequently they should be kept under surveillance with specific monitoring.

Therefore, there is the possibility of identifying the drift of an apparatus ATE and of thus being able to predict its malfunction or its breaking in the future.

If, on the other hand, the R&R is good or in any case is acceptable,

the step of evaluating R&R at ATE tester level is over, and it is possible to move on to the step of evaluating R&R at the product level, which comprises the qualification of the chains for the specific product considered, to measure such a product with these chains.

For the step of evaluating the product R&R, it is considered that all of the units of the measuring chain depending upon the product have already been qualified according to what has been stated previously.

For each type of unit it is possible to follow a flow that can basically be very similar to the one presented for the ATE.

After this it is possible to carry out the correlation using at least one device DUT from those subjected to the quality control.

For example, if the generic DUT is represented by a chip on a wafer, the testing and retesting of at least one wafer is carried out on at least two different measuring chains in the same conditions and based upon some criteria it is decided whether the correlation is valid or not for the group of measuring chains to be considered R&R for the product, which can consequently be measured on the group of measuring chains themselves.

In any case, at regular intervals it is checked that the apparatuses ATE of the group still conform to the R&R criteria already achieved, and therefore at least one Run should be carried out for the K ATEs and the ANOVA analysis should be redone at least for the last Z * K data files to determine whether there are still the R&R conditions based upon the established criteria.

If there is a significant change of M ATEs of the group it should be checked that the ATEs of the group are still R&R, and then at least one Run should be carried out for the M ATEs and the ANOVA analysis should be redone for the last Z*K data files to determine whether there are still the R&R conditions based upon the established criteria.

If P ATEs are added to the group of ATEs it should be checked that the ATEs of the group are still R&R, and then Z Runs should be carried out on the P ATEs and the ANOVA analysis should be redone for at least the last Z*K data files (where K = K + P i.e. the new value of K is increased by P with respect to the old value of K) to determine whether there are still the R&R conditions based upon the established criteria.

If the group of ATEs on which a certain Fixture is applicable is divided into at least two subgroups in at least two different geographical locations sufficiently distanced from one another, it is possible to have a single Fixture for the entire overall group, or a Fixture for each subgroup.

If there are many identical Fixtures for the various subgroups it is necessary to periodically carry out the R&R of the Fixtures, to check that such Fixtures are aligned with each other, and to do this it is necessary to use the same ATE on which the evaluation or the check of R&R of the various Fixtures is carried out.

The use of ANOVA analysis should not, however, be considered limiting, and in the literature there are already alternative criteria for evaluating R&R.

Everything that has been stated for EWS testing is valid in an analogous manner for FT, WLBI and parametric testing.

The proposed method for evaluating and checking R&R can also be applied in a similar way in different fields to that of semiconductors, with embodiments in accordance with the specific field of application.

In conclusion, the method according to the invention allows an improved evaluation of R&R to be obtained on the measuring chain by separating the units of the chain that do not depend upon the product from those that depend upon the product.

Effort is concentrated above all on the most complex unit which is the ATE, and by using the Fixture it is possible to obtain an evaluation of the R&R that does not depend upon the specific product, checking the R&R of all of the resources considered critical of the ATE and thus having higher coverage of the test, allowing the measurement of many thousands of characteristic parameters of the ATE to be carried out.

In this way, all of the ATEs of the group on which a certain Fixture is applied are actually aligned with each other.

Thanks to this it is possible to do a capillary evaluation of the ATE that allows those parts that are or are about to drift or, in the worst case, that are subject to breaking over time to be identified.

Consequently, it is possible to monitor and intervene on the ATE itself even predictively to organise in the best possible way preventive

maintenance or to restore correct functionality, without having to wait for it to break.

Having concentrated on the most complex part of the measuring chain, the evaluation of R&R on the remaining part of the chain that depends upon the product is simplified, up to the point of managing to qualify a group of measuring chains on which a certain Fixture is applicable, thanks to a correlation exercise.

The golden sample concept of measuring chains is thus unnecessary, with a saving in economic terms as far as the creation, certification or replacement of the golden samples themselves is concerned.

By separating the chain into its various units to evaluate R&R, it is simpler to identify and solve the problems and difficulties that weigh down upon R&R itself, and this also makes the group of measuring chains more reliable.

Moreover, the proposed method makes the evaluation of R&R efficient and effective, which is not currently possible with the current methodology in the field of semiconductors due to certain parts of the measuring chain on which the R&R methodology is not applicable.

This method, as well as the increase in reliability of the group of measuring chains, increases the production yield, the efficiency and the production capacity, and the R&R also becomes a truly useful tool, which requires less overall effort than the current methodology, with better results.

The proposed method evaluates the R&R of each unit of the chain, in accordance with the individual unit considered, which is not done with the existing approach.

It is worth highlighting the fact that the proposed method can be applied in general wherever it is necessary to ensure the repeatability and reproducibility of any electrical or electronic measuring system.

It particularly applies:

- to the electrical testing process of wafers (Electrical Wafer Sort or more generally Wafer Sort)

- to the Final Test FT (where the chips are encapsulated in the package)

- to the Wafer Level Burn-In WLBI (electrical testing that carries out tests, also of temperature, with stress)

- to the parameter testing carried out on TEGs (Test Element Group, which are a group of elementary structures present on wafers, arranged in the scribe lines).

In any case, the same principle can also be applied in different ways to other types of measuring systems.

CLAIMS

1. Method for an improved checking of repeatability and reproducibility of a measuring chain, in particular for the quality control by means of the semiconductor device testing, wherein testing steps are provided for multiple and different devices to be subjected to measurement or control through a measuring system comprising at least one concatenation of measuring units between a testing apparatus (ATE) and each device to be subjected to measurement or control, characterised in that it comprises the following steps:

- checking repeatability and reproducibility of each type of unit that forms part of said measuring chain of said concatenation;
- then making a correlation between the various measuring chains as a whole to check the repeatability and reproducibility, using a corresponding device subjected to measurement or control.

2. Method according to claim 1, characterised in that said checking step comprises separating the measuring units that depend upon a device (DUT) subjected to measurement or control from those that do not depend upon said device (DUT).

3. Method according to claim 1, characterised in that it comprises a procedure that comprises the use of a Fixture of the software (SW) and/or hardware (HW) type, associated with said testing apparatus (ATE) or with a measuring unit, to check the repeatability and reproducibility of at least one measuring resource.

4. Method according to claim 1, characterised in that it comprises a procedure that provides for the use of a software (SW) and/or hardware (HW) type Fixture, associated with said testing apparatus (ATE) or with a measuring unit, for checking the repeatability and reproducibility of at least one group of measuring resources, where at least two groups can also at times comprise common measuring resources.

5. Method according to claims 3 or 4, characterised in that said software (SW) and/or hardware (HW) type Fixture comprises a testing protocol.

6. Method according to claim 1, characterised in that it comprises a measurement of at least one characteristic of said

apparatus (ATE) for N times or Cycles, in M different time periods or Runs and on different apparatuses (ATE), through a statistical method.

7. Method according to claim 6, characterised in that said measurement is carried out each time that said apparatus (ATE) is modified on its inside or the environmental conditions are modified by a not negligible amount.

8. Method according to claim 6, characterised in that it uses the statistical method for analysing variance of the "ANOVA" type.

9. Method according to claim 1, characterised in that when the device to be subjected to measurement or control is a chip on a semiconductor wafer, a testing and retesting step of the wafer is carried out on at least two different measuring chains in the same operative conditions before carrying out the correlation step.

10. Method according to any one of the previous claims, characterised in that said step of checking repeatability and reproducibility involves just those measuring resources of measuring units of said testing apparatus (ATE) that are critical for measuring said devices to be subjected to measurement or control.

11. Method according to any one of the previous claims, characterised in that it comprises a step of evaluating repeatability and reproducibility at apparatus (ATE) level followed by a step of evaluating repeatability and reproducibility at product (DUT) level.

12. Method according to claim 11, characterised in that said step of checking repeatability and reproducibility for the apparatus (ATE) is repeated at regular intervals.