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(54) Title: METROLOGY SYSTEM, METHOD, AND COMPUTER PROGRAM PRODUCT EMPLOYING AUTOMATIC TRANSITIONING BETWEEN UTILIZING A LIBRARY AND UTILIZING REGRESSION FOR MEASUREMENT PROCESSING

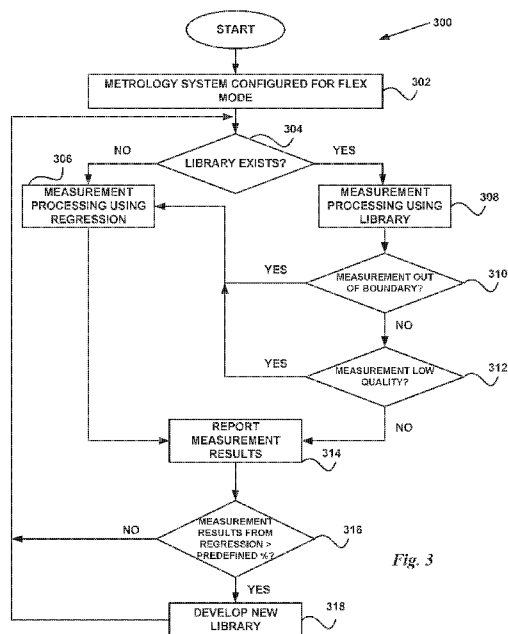


Fig. 3

(57) Abstract: A metrology system, method, and computer program product that employ automatic transitioning between utilizing a library and utilizing regression for measurement processing are provided. In use, it is determined, by the metrology system, that a predetermined condition has been met. In response to determining that the predetermined condition has been met, the metrology system automatically transitions between utilizing a library and utilizing regression for measurement processing.



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**METROLOGY SYSTEM, METHOD, AND COMPUTER PROGRAM PRODUCT
EMPLOYING AUTOMATIC TRANSITIONING BETWEEN UTILIZING A
LIBRARY AND UTILIZING REGRESSION FOR MEASUREMENT
PROCESSING**

RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/155,339 filed April 30, 2015, the entire contents of which are incorporated herein by reference.

F I E L D O F T H E I N V E N T I O N

[0002] The present invention relates to metrology systems, and more particularly to measurement processes used in metrology systems.

B A C K G R O U N D

[0003] Metrology generally involves measuring various physical features of a target component. For example, structural and material characteristics (e.g. material composition, dimensional characteristics of structures and/or critical dimensions of structures, etc.) of the target component can be measured using metrology systems. In the example of semiconductor metrology, various physical features of a fabricated semiconductor component may be measured using a metrology system.

[0004] Currently, metrology systems employ either libraries or regression for performing the measurement. However, each of these measurement processes inherently exhibit their own respective limitations, such that there is a need for addressing these and/or other issues associated with the prior art.

[0005] For example, when making a measurement, non-linear least square is often used to fit a set of observed signals collected from one or a combined set of metrology tools with calculated signals from a non-linear model containing a set of floating parameters, including those characteristics to be measured. If Maxwell's equations are solved vigorously in real-time to obtain the calculated signals for a corresponding floating parameter set, it is referred to measurement with real-time regression (or RTR). On the other hand, a parametric non-linear model may be created offline to approximate the solutions of Maxwell's equations. During the measurement, the parametric model can be used for fast and accurate approximation to the calculated signals. The parametric model is called a library, and its corresponding measurement is denoted as a library measurement.

[0006] RTR measurement generally uses a large computing farm to evaluate theoretical signals for given set of parameters by vigorously solving Maxwell's equations in real-time. RTR measurement can quickly adapt to process changes without a need of lengthy library changes. Therefore, the time to make process changes and to keep measurement is short. Unfortunately, however, it requires a more expensive computing platform to support real-time computations. Furthermore, overall throughput of the metrology system is slowed down by the calculations linked to solving Maxwell's equations in real-time. This results in a high cost of metrology using RTR, both from the perspective of computations and a number of metrology tools required.

[0007] Library measurement is generally very fast and only needs a workstation or a server to provide adequate computing power. However, in the event of large process changes that are beyond the pre-defined range of parameters in the library, it will take a significant amount of time to change and re-qualify a new library in order to recover the measurement credibility. Until the measurement creditability is recovered, the measurement process is at risk of an excursion that cannot be detected since no metrology is available (i.e. the measurement is generally skipped), possibly impacting the yield on a significant number of components under measurement.

SUMMARY

[0008] A metrology system, method, and computer program product that employ automatic transitioning between utilizing a library and utilizing regression for measurement processing are provided. In use, it is determined, by the metrology system, that a predetermined condition has been met. In response to determining that the predetermined condition has been met, the metrology system automatically transitions between utilizing a library and utilizing regression for measurement processing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 shows a schematic of an exemplary metrology tool, in accordance with the prior art.

[0010] Figure 2 illustrates a method that employs automatic transitioning between utilizing a library and utilizing regression for measurement processing, in accordance with an embodiment.

[0011] Figure 3 illustrates a method of operation of a metrology system configured to operate in a flex mode enabling automatic transitioning between measurement processing utilizing a library and measurement processing utilizing regression, in accordance with another embodiment.

[0012] Figure 4 illustrates a method for transitioning from measurement processing utilizing a library to measurement processing utilizing regression by identifying fixed parameters to be added as floating parameters for the measurement processing utilizing regression, in accordance with another embodiment.

[0013] Figure 5 illustrates a method for transitioning from measurement processing utilizing a library to measurement processing utilizing regression by providing as input to the measurement processing utilizing regression a measurement resulting from the measurement processing utilizing the library, in accordance with yet another embodiment.

[0014] Figure 6 illustrates graphs of quality of measurements resulting from library measurement processing and regression measurement processing, in accordance with still yet another embodiment.

DETAILED DESCRIPTION

[0015] In the field of semiconductor metrology, a metrology tool may comprise an illumination system which illuminates a target, a collection system which captures relevant information provided by the illumination system's interaction (or lack thereof) with a target, device or feature, and a processing system which analyzes the information collected using one or more algorithms. Metrology tools can be used to measure structural and material characteristics (e.g. material composition, dimensional characteristics of structures and films such as film thickness and/or critical dimensions of structures, overlay, etc.) associated with various semiconductor fabrication processes. These measurements are used to facilitate process controls and/or yield efficiencies in the manufacture of semiconductor dies.

[0016] The metrology tool can comprise one or more hardware configurations which may be used in conjunction with certain embodiments of this invention to, e.g., measure the various aforementioned semiconductor structural and material characteristics. Examples of such hardware configurations include, but are not limited to, the following.

[0017] Spectroscopic ellipsometer (SE)

[0018] SE with multiple angles of illumination

[0019] SE measuring Mueller matrix elements (e.g. using rotating compensator(s))

[0020] Single-wavelength ellipsometers

[0021] Beam profile ellipsometer (angle-resolved ellipsometer)

- [0022] Beam profile reflectometer (angle-resolved reflectometer)
- [0023] Broadband reflective spectrometer (spectroscopic reflectometer)
- [0024] Single-wavelength reflectometer
- [0025] Angle-resolved reflectometer
- [0026] Imaging system
- [0027] Scatterometer (e.g. speckle analyzer)

[0028] The hardware configurations can be separated into discrete operational systems. On the other hand, one or more hardware configurations can be combined into a single tool. One example of such a combination of multiple hardware configurations into a single tool is shown in Figure 1, incorporated herein from U.S. Patent No. 7,933,026 which is hereby incorporated by reference in its entirety for all purposes. Figure 1 shows, for example, a schematic of an exemplary metrology tool that comprises: a) a broadband SE (i.e., 18); b) a SE (i.e., 2) with rotating compensator (i.e., 98); c) a beam profile ellipsometer (i.e., 10); d) a beam profile reflectometer (i.e., 12); e) a broadband reflective spectrometer (i.e., 14); and f) a deep ultra-violet reflective spectrometer (i.e., 16). In addition, there are typically numerous optical elements in such systems, including certain lenses, collimators, mirrors, quarter-wave plates, polarizers, detectors, cameras, apertures, and/or light sources. The wavelengths for optical systems can vary from about 120 nm to 3 microns. For non-ellipsometer systems, signals collected can be polarization-resolved or unpolarized. Figure 1 provides an illustration of multiple metrology heads integrated on the same tool. However, in many cases, multiple metrology tools are used for measurements on a single or multiple metrology targets. This is described, for example, in U.S. Patent No. 7,478,019, "Multiple tool and structure analysis," which is also hereby incorporated by reference in its entirety for all purposes.

[0029] The illumination system of the certain hardware configurations includes one or more light sources. The light source may generate light having only one wavelength

(i.e., monochromatic light), light having a number of discrete wavelengths (i.e., polychromatic light), light having multiple wavelengths (i.e., broadband light) and/or light that sweeps through wavelengths, either continuously or hopping between wavelengths (i.e. tunable sources or swept source). Examples of suitable light sources are: a white light source, an ultraviolet (UV) laser, an arc lamp or an electrode-less lamp, a laser sustained plasma (LSP) source, for example those commercially available from Energetiq Technology, Inc., Woburn, Massachusetts, a super-continuum source (such as a broadband laser source) such as those commercially available from NKT Photonics Inc., Morganville, New Jersey, or shorter-wavelength sources such as x-ray sources, extreme UV sources, or some combination thereof. The light source may also be configured to provide light having sufficient brightness, which in some cases may be a brightness greater than about $1 \text{ W}/(\text{nm cm}^2 \text{ Sr})$. The metrology system may also include a fast feedback to the light source for stabilizing its power and wavelength. Output of the light source can be delivered via free-space propagation, or in some cases delivered via optical fiber or light guide of any type.

[0030] The metrology tool is designed to make many different types of measurements related to semiconductor manufacturing. Certain embodiments may be applicable to such measurements. For example, in certain embodiments the tool may measure characteristics of one or more targets, such as critical dimensions, overlay, sidewall angles, film thicknesses, process-related parameters (e.g., focus and/or dose). The targets can include certain regions of interest that are periodic in nature, such as for example gratings in a memory die. Targets can include multiple layers (or films) whose thicknesses can be measured by the metrology tool. Targets can include target designs placed (or already existing) on the semiconductor wafer for use, e.g., with alignment and/or overlay registration operations. Certain targets can be located at various places on the semiconductor wafer. For example, targets can be located within the scribe lines (e.g., between dies) and/or located in the die itself. In certain embodiments, multiple targets are measured (at the same time or at differing times) by the same or multiple metrology tools as described in U.S. Patent No. 7,478,019. The data from such measurements may be combined. Data from the metrology tool is used in the

semiconductor manufacturing process for example to feed-forward, feed-backward and/or feed-sideways corrections to the process (e.g. lithography, etch) and therefore, might yield a complete process control solution.

[0031] As semiconductor device pattern dimensions continue to shrink, smaller metrology targets are often required. Furthermore, the measurement accuracy and matching to actual device characteristics increase the need for device-like targets as well as in-die and even on-device measurements. Various metrology implementations have been proposed to achieve that goal. For example, focused beam ellipsometry based on primarily reflective optics is one of them and described in the patent by Piwonka-Corle et al. (US 5,608,526, "Focused beam spectroscopic ellipsometry method and system"). Apodizers can be used to mitigate the effects of optical diffraction causing the spread of the illumination spot beyond the size defined by geometric optics. The use of apodizers is described in the patent by Norton, U.S. Patent No. 5,859,424, "Apodizing filter system useful for reducing spot size in optical measurements and other applications". The use of high-numerical-aperture tools with simultaneous multiple angle-of-incidence illumination is another way to achieve small-target capability. This technique is described, e.g. in the patent by Opsal et al, U.S. Patent No. 6,429,943, "Critical dimension analysis with simultaneous multiple angle of incidence measurements".

[0032] Other measurement examples may include measuring the composition of one or more layers of the semiconductor stack, measuring certain defects on (or within) the wafer, and measuring the amount of photolithographic radiation exposed to the wafer. In some cases, metrology tool and algorithm may be configured for measuring non-periodic targets, see e.g. "The Finite Element Method for Full Wave Electromagnetic Simulations in CD Metrology Using Scatterometry" by P. Jiang et al (pending U.S. Patent Application No. 14/294,540, filed June 3, 2014, attorney docket no. P0463) or "Method of electromagnetic modeling of finite structures and finite illumination for metrology and inspection" by A. Kuznetsov et al. (pending U.S. Patent Application No. 14/170,150, attorney docket no. P0482).

[0033] Measurement of parameters of interest usually involves a number of algorithms. For example, optical interaction of the incident beam with the sample is modeled using EM (electro-magnetic) solver and uses such algorithms as RCWA, FEM, method of moments, surface integral method, volume integral method, FDTD, and others. The target of interest is usually modeled (parameterized) using a geometric engine, or in some cases, process modeling engine or a combination of both. The use of process modeling is described in “Method for integrated use of model-based metrology and a process model,” by A. Kuznetsov et al. (pending U.S. Patent Application No. 14/107,850, attorney docket no. P4025). A geometric engine is implemented, for example, in AcuShape software product of KLA-Tencor.

[0034] Collected data can be analyzed by a number of data fitting and optimization techniques and technologies including libraries, Fast-reduced-order models; regression; machine-learning algorithms such as neural networks, support-vector machines (SVM); dimensionality-reduction algorithms such as, e.g., PCA (principal component analysis), ICA (independent component analysis), LLE (local-linear embedding); sparse representation such as Fourier or wavelet transform; Kalman filter; algorithms to promote matching from same or different tool types, and others.

[0035] Collected data can also be analyzed by algorithms that do not include modeling, optimization and/or fitting e.g. U.S. Patent Application No. 14/057,827.

[0036] Computational algorithms are usually optimized for metrology applications with one or more approaches being used such as design and implementation of computational hardware, parallelization, distribution of computation, load-balancing, multi-service support, dynamic load optimization, etc. Different implementations of algorithms can be done in firmware, software, FPGA, programmable optics components, etc.

[0037] The data analysis and fitting steps usually pursue one or more of the following goals:

[0038] Measurement of CD, SWA, shape, stress, composition, films, band-gap, electrical properties, focus/dose, overlay, generating process parameters (e.g., resist state, partial pressure, temperature, focusing model), and/or any combination thereof;

[0039] Modeling and/or design of metrology systems;

[0040] Modeling, design, and/or optimization of metrology targets.

[0041] The following description discloses embodiments of a metrology system, method, and computer program product (embodied on a non-transitory computer readable medium) which may be implemented in the context of the semiconductor metrology tool described above, or which may be implemented in the context of other metrology tools.

[0042] Figure 2 illustrates a method **200** that employs automatic transitioning between utilizing a library and utilizing regression for measurement processing, in accordance with an embodiment. Optionally, the method **200** may be performed by a metrology system when the metrology system is configured (e.g. by a user) to operate in a flex mode enabling the automatic transitioning. Of course, in other embodiments the method **200** may be performed by the metrology system when operating in a default mode, or as the only mode of operation configured for metrology system. Furthermore, the method **200** may be performed with respect to measurement processing relating to a particular target component.

[0043] As shown in operation **202**, it is determined, by the metrology system, that a predetermined condition has been met. In this way, the metrology system may monitor for the predetermined condition. In an embodiment where the metrology system can automatically transition from measurement processing utilizing a library to measurement processing utilizing regression, and vice versa, the predetermined condition may be specific to a type of measurement processing just performed.

[0044] For example, where the measurement processing just performed utilizes a library, then the predetermined condition may be a measurement being obtained that is outside of a range predefined within the library. As another example, where the

measurement processing just performed utilizes a library, then the predetermined condition may be a measurement being obtained that has a quality that is below a predefined threshold. In these cases, the metrology system may automatically transition from utilizing the library to utilizing regression for measurement processing, as described in more detail below.

[0045] As another example, where the measurement processing just performed utilizes regression, then the predetermined condition may be that a new library has been developed. In this case, the metrology system may automatically transition from utilizing regression to utilizing the newly developed library. Of course, it should be noted that other conditions that are identifiable by the metrology system are contemplated as being criteria for the automatic transitioning between the library-based measurement processing and the regression-based measurement processing.

[0046] To this end, in response to determining that the predetermined condition has been met, the metrology system automatically transitions between utilizing a library and utilizing regression for measurement processing, as shown in operation **204**. As noted above, where the measurement processing performed just prior utilizes the library, then the metrology system may automatically transition to measurement processing utilizing regression. On the other hand, where the measurement processing performed just prior utilizes regression, then the metrology system may automatically transition to measurement processing utilizing the library. In this way, the metrology system may be capable of transitioning from measurement processing utilizing the library to measurement processing utilizing regression, and vice versa, in accordance with the determination by the metrology system that the respective condition has been met.

[0047] In the context of the present description, the library may be a predefined parametric model for the target component, which when utilized during measurement processing approximates a solution to Maxwell's equations given a set of parameter values for the target component. In particular, the parametric model (i.e. library) can be used for fast and accurate approximation to calculated signals. A library may also be a predefined model that directly maps signals to critical dimension parameters to be

measured. Also in the context of the present description, regression refers to solving Maxwell's equations in real-time during measurement processing to obtain the calculated signals for a corresponding set of floating parameters. This regression may also be referred to as real-time regression (RTR). In this way, measurement processing generally refers to operations utilized to analyze measurements obtained by a metrology tool, where such analysis is performed utilizing the library or regression in accordance with the type of measurement processing being performed.

[0048] As described above with respect to operation **202** and the various examples of monitored conditions, where the measurement processing performed just prior utilizes the library, then the metrology system may automatically transition to measurement processing utilizing regression when a measurement is obtained that is outside of a range predefined within the library and/or that has a quality that is below a predefined threshold. In another example, where the measurement processing performed just prior utilizes regression, then the metrology system may automatically transition to measurement processing utilizing the library when such library has been newly developed.

[0049] In one embodiment, the measurement processing utilizing the library may be executed by a general purpose computer (e.g. desktop, server, etc.). In such embodiment, the library may be stored in memory of the general purpose computer. Of course, such general purpose computer may optionally be dedicated to performing the library-based measurement processing. In further embodiments, the measurement processing utilizing regression may be executed by the same general purpose computer, a different general purpose computer, or even a dedicated regression processing (e.g. computer) cluster. In any case, the one or more subsystems executing the library-based measurement processing and the regression-based measurement processing may be components of the aforementioned metrology system.

[0050] For each measurement, the general purpose computer may make the determination of whether the predetermined condition has been met (see operation **202**), and may perform the automatic transitioning (see operation **204**). For example, upon

determining that the predetermined condition has been met, the general purpose computer may instruct the measurement processing to be performed, regardless of whether the measurement processing is to be performed by the general purpose computer itself (e.g. in the case of using the library) or a remote subsystem (e.g. in the case of using regression). Of course, an embodiment is also contemplated where the method **200**, or any operation thereof, is performed specifically by the subsystem that performed the just prior measurement processing.

[0051] To this end, the metrology system may be configured to perform the method **200** for providing flexibility in measurement processing, namely through the condition-based automatic transitioning between the faster yet accurate library-based measurement processing and the more expensive yet versatile regression-based measurement processing. This method **200** may allow a user of the metrology system to measure characteristics of a target component in a fast-changing process development with swift parameter adaptation and evolution. Moreover, when the process is stable and its variation is small, the method **200** allows for a smooth transition from a more expensive regression (i.e. in real-time) to fast yet accurate library measurement with a high volume production.

[0052] Figure **3** illustrates a method **300** of operation of a metrology system configured to operate in a flex mode enabling automatic transitioning between measurement processing utilizing a library and measurement processing utilizing regression, in accordance with another embodiment. It should be noted that the method **300** may be carried out in the context of the method **200** of Figure **2**. Thus, the definitions and descriptions set forth above may equally apply to the method **300** of Figure **3**. Of course, however, the method **200** may be implemented in any desired context. Further, the method **300** may be performed by the metrology system at measurement time.

[0053] As shown in operation **302**, a metrology system is configured to operate in a flex mode. In one embodiment, a user of the metrology system may provide input to configure the metrology system to operate in the flex mode. In another embodiment, the

metrology system may be configured by default to operate in the flex mode. As noted above, the flex mode enables the metrology system to automatically transition between measurement processing utilizing a library and measurement processing utilizing regression. Further details regarding this automatic transitioning are set forth below with reference to the subsequent operations of the present method **300**. It should be noted that when the metrology system is not configured to operate in the flex mode, the metrology system may solely perform measurement processing utilizing the library or may solely perform measurement processing utilizing regression (i.e. without automatic transitioning between the two).

[0054] When the metrology system is configured to operate in the flex mode, the metrology system determines whether a library exists, as shown in decision **304**. For example, the metrology system may determine whether a library is stored in memory for use by the metrology system in performing measurement processing. When the metrology system determines that a library does not exist, the metrology system automatically performs measurement processing using regression (operation **306**). When the metrology system determines that a library does exist, the metrology system automatically performs measurement processing using the library (operation **308**).

[0055] During the measurement processing using the library, the metrology system determines in decision **310** whether the measurement being processed is outside of a boundary of the library. In particular, where the library has a predefined value range for a particular parameter, the measurement for that parameter may be outside of the boundary of the library when the measurement is outside of the value range predefined within the library.

[0056] When the metrology system determines in decision **310** that the measurement is outside of the boundary of the library, the metrology system automatically performs measurement processing using regression (operation **306**). Namely, when the measurement is outside of a corresponding value range predefined within the library, the library may be incapable of being used to process the

measurement, such that the metrology system may automatically perform measurement processing using regression (operation **306**).

[0057] When the measurement is within the boundary of the library, the metrology system further determines in decision **312** whether a quality of the measurement is below a predefined threshold quality. For example, a goodness of fit (NGOF) may be determined for the measurement with reference to the library (e.g. within a range of 0 to 1), and compared to a predefined threshold NGOF that indicates a threshold quality.

[0058] When the metrology system determines in decision **312** that a quality of the measurement is below the predefined threshold quality, then the metrology system automatically performs measurement processing using regression (operation **306**). Otherwise, when the metrology system determines in decision **312** that a quality of the measurement is not below the predefined threshold quality, then measurement processing using regression is not executed.

[0059] Accordingly, as described above, the metrology system only executes the measurement processing using regression, which requires additional resources, when a library is unavailable, or when an existing library is incapable of being used to process a measurement or a quality of the measurement is below the predefined threshold quality. In this way, the additional resources required when executing the measurement processing utilizing regression may be employed in limited circumstances, where otherwise the measurement processing utilizing the library may be employed.

[0060] Once measurement processing performed via the library or regression is complete, a result of such measurement processing is reported, as shown in operation **314**. This result may be reported through a user interface of the metrology system. For example, a user may configure which parameters are to be subjected to the measurement processing, and thus which measurement processing results are to be reported via the metrology system.

[0061] The metrology system further determines in decision **316** whether an amount of measurement processing results determined through regression has exceeded a

predefined threshold. As shown, this predefined threshold may be a percentage amount (i.e. measurement processing results determined through regression versus measurement processing results determined using a library). When the metrology system determines that the amount of measurement processing results determined through regression has not exceeded the predefined threshold, the metrology system returns to decision **304** for a next measurement. However, when the metrology system determines that the amount of measurement processing results determined through regression has exceeded the predefined threshold, the metrology system initiates the development of a new library for use in subsequent measurement processing (see operation **318**). For example, in operation **318** the metrology system may automatically give to a user a notification that a new library should be developed for future measurement processing (e.g. to reduce the resources otherwise required to be utilized when performing measurement processing using regression). When a new library is available, the metrology system identifies this in decision **304** and accordingly proceeds with the measurement processing using the newly developed library.

[0062] Figure 4 illustrates a method **400** for transitioning from measurement processing utilizing a library to measurement processing utilizing regression by identifying fixed parameters to be added as floating parameters for the measurement processing utilizing regression, in accordance with another embodiment. As shown, the method **400** is implemented in the context of the method **300** of Figure 3. For example, the method **400** may be an optional extension to the method **300** of Figure 3. Of course, however, the method **400** may be implemented in other desired contexts. Further, it should again be noted that the definitions above may equally apply to the following description.

[0063] As shown, during measurement processing utilizing a library, the metrology system may determine that a quality of a measurement being processed is below a predefined threshold quality (e.g. operation **312** of Figure 3). When the metrology system determines that a quality of a measurement being processed is below the predefined threshold quality, the metrology system identifies fixed parameters that are to be added as floating parameters for the subsequent measurement processing to be

executed utilizing regression, and those fixed parameters are added accordingly (see operation **313**).

[0064] In one embodiment, a user of the metrology system may select (e.g. in advance) the fixed parameters that are to be processed as floating parameters. The user may make the selection based on a sensitivity ranking of the model parameters, or a pre-existing statistical knowledge of the process excursions.

[0065] In another embodiment, the fixed parameters may be selected automatically by the metrology system. For example, the fixed parameters may be selected automatically based on a predefined correlation with one or more floating parameters (i.e. a predetermination that the fixed parameter influences to a high degree one or more floating parameters). As another example, the metrology system may pre-calculate a change rate of signals with respect to one of more fixed parameters, and compare the change rate of a fixed parameter with the misfit resulting in the low quality to select a best fitted fixed parameter or set of the fixed parameters that are to be processed as floating parameters.

[0066] Once the fixed parameters are added as floating parameters, the metrology system executes the regression-based measurement processing utilizing the floating parameters (e.g. operation **306** of Figure **3**). In this way, for each measurement processed using regression, the floating parameter set to which regression is applied may be customized (i.e. configured specifically for that measurement).

[0067] Figure **5** illustrates a method **500** for transitioning from measurement processing utilizing a library to measurement processing utilizing regression by providing as input to the measurement processing utilizing regression a measurement resulting from the measurement processing utilizing the library, in accordance with yet another embodiment. It should be noted that the method **500** may be carried out in the context of the method **200** of Figure **2** and optionally as an alternative to the method **300** of Figure **3**. Further, the definitions and descriptions set forth above may equally apply to the

method **500** of Figure **5**. Of course, however, the method **500** may be implemented in any desired context.

[0068] As shown in operation **502**, a metrology system is configured to operate in a flex mode. When the metrology system is configured to operate in the flex mode, the metrology system determines whether a library exists, as shown in decision **504**. For example, the metrology system may determine whether a library is stored in memory for use by the metrology system in performing measurement processing. When the metrology system determines that a library does not exist, the metrology system automatically performs measurement processing using regression (operation **506**).

[0069] When the metrology system determines that a library does exist, the metrology system automatically performs measurement processing using the library (operation **505**). After performing measurement processing using the library in operation **505**, the metrology system automatically transitions to performing measurement processing using regression (operation **506**). This transition may be made responsive to the metrology system identifying that a predetermined condition has been met (e.g. a setting configured within the metrology system). In particular, the transition may be made by providing a result of the library-based measurement processing to the regression-based measurement processing as input.

[0070] The regression-based measurement processing, shown in operation **506**, may then use the result of the library-based measurement processing as a starting point. To this end, the metrology system may perform both library-based measurement processing and further regression-based measurement processing for a single measurement. Once the library-based measurement processing and the regression-based measurement processing is complete, measurement processing results are reported, as shown in operation **508**. The method **500** then returns to decision **504** for a next measurement to be processed.

[0071] Figure **6** illustrates graphs of quality of measurements resulting from library measurement processing and regression measurement processing, in accordance with still

yet another embodiment. The graphs demonstrate that the measurement credibility does not suffer during the large process parameter variation when the metrology system operates in the flex mode.

[0072] The graphs in the first column show that the library measurement can provide the accurate results when the process range is unchanged. In the event of process shift, the graphs in the middle column show the large parameter deviation between the library-based measurement processing and the regression-based measurement processing, such that the regression-based measurement processing gives a better result than the library-based measurement processing. The graphs in the right column show that the flex mode of operation can cover both cases (i.e. allowing for the desired regression-based measurement processing when the library-based measurement processing otherwise would give an undesirable result).

[0073] While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

CLAIMS

What is claimed is

1. A method, comprising:
determining, by a metrology system, that a predetermined condition has been met;
and
in response to determining that the predetermined condition has been met,
automatically transitioning, by the metrology system, between utilizing a library and
utilizing regression for measurement processing.
2. The method of claim 1, wherein the determining and the automatic transitioning
are performed by the metrology system when the metrology system is configured by a
user to operate in a flex mode enabling the automatic transitioning.
3. The method of claim 1, wherein the metrology system automatically transitions
from measurement processing utilizing the library to measurement processing utilizing
regression.
4. The method of claim 3, wherein the predefined condition is a measurement being
obtained that is outside of a range predefined within the library, such that the metrology
system automatically transitions from measurement processing utilizing the library to
measurement processing utilizing regression when the measurement processing utilizing
the library results in a measurement that is outside of the range predefined within the
library.
5. The method of claim 3, wherein the predefined condition is a measurement being
obtained that has a quality that is below a predefined threshold, such that the metrology
system automatically transitions from measurement processing utilizing the library to
measurement processing utilizing regression when the measurement processing utilizing

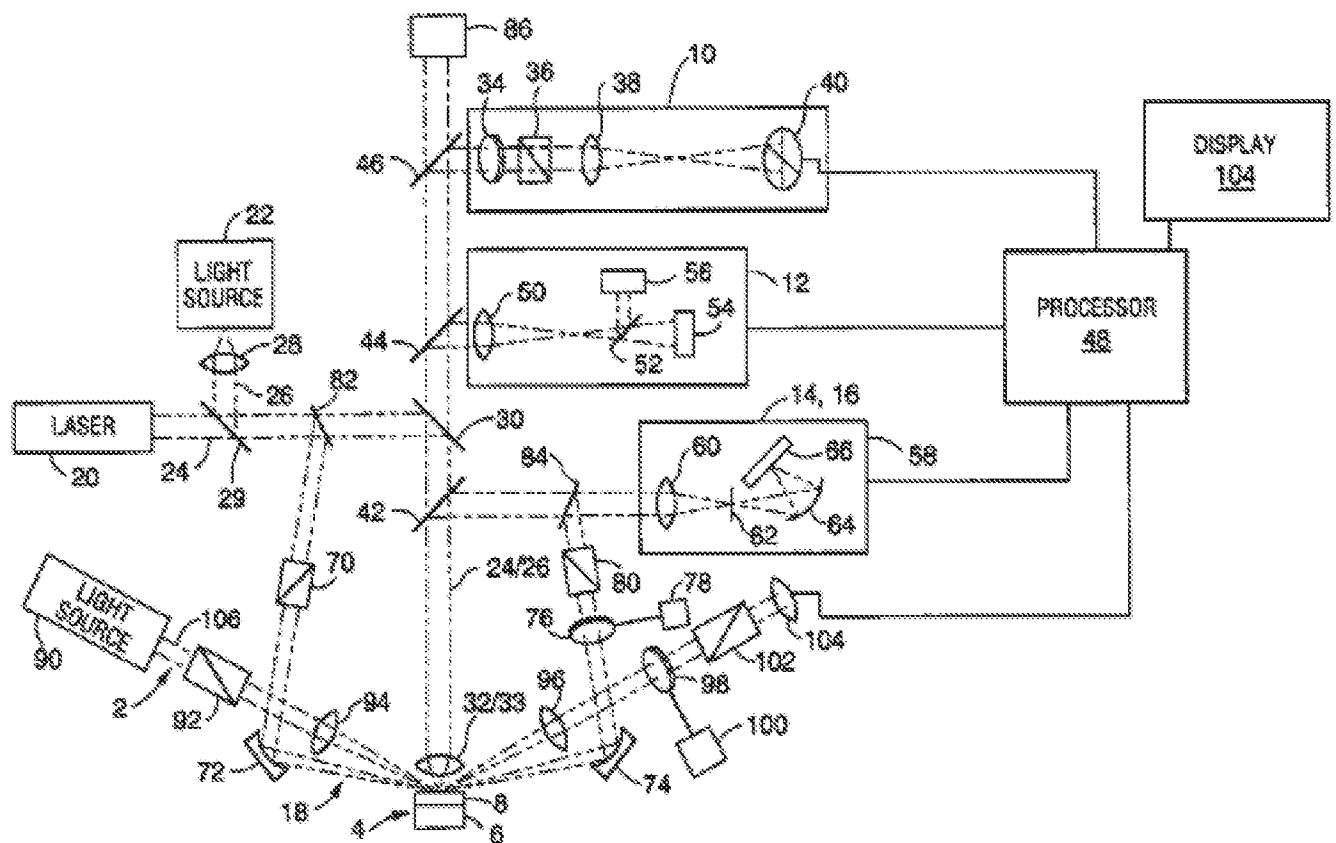
the library results in a measurement having a quality that is below the predefined threshold.

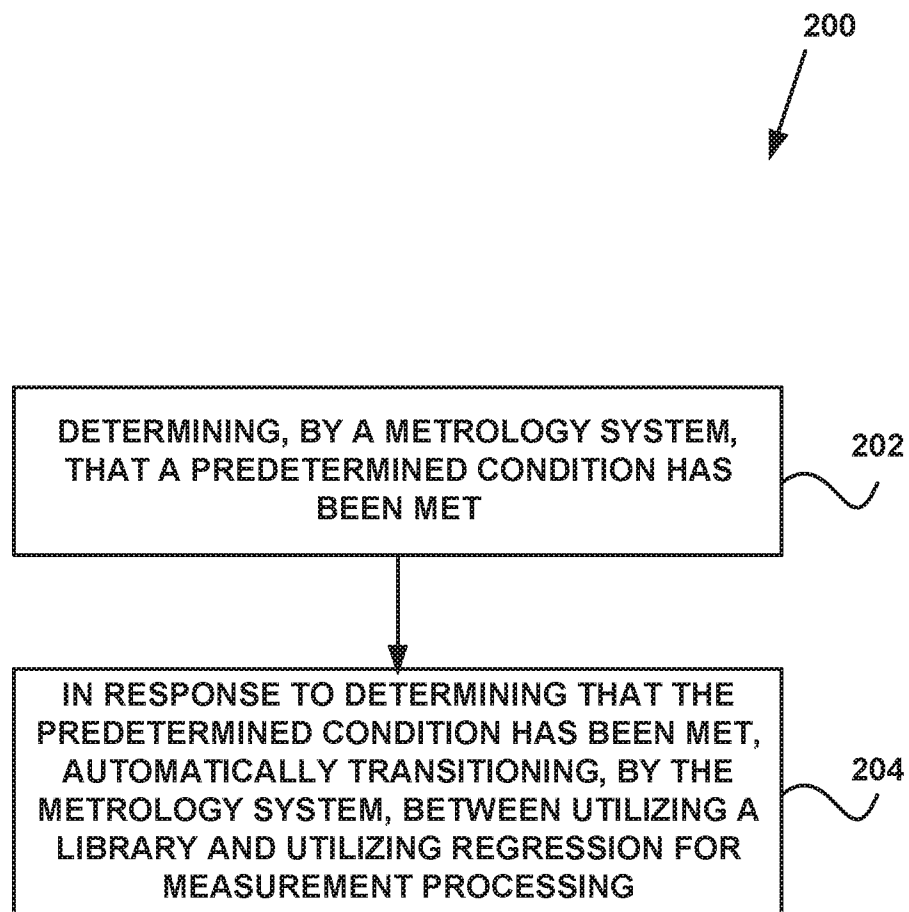
6. The method of claim 5, further comprising:
identifying one or more fixed parameters;
adding the identified one or more fixed parameters as floating parameters for the measurement processing utilizing regression.
7. The method of claim 6, wherein the fixed parameters are selected by a user.
8. The method of claim 6, wherein the fixed parameters are selected automatically based on a predefined correlation with one or more floating parameters.
9. The method of claim 1, wherein the metrology system automatically transitions from measurement processing utilizing regression to measurement processing utilizing the library.
10. The method of claim 9, wherein the predefined condition is that the library has been newly developed, such that the metrology system automatically transitions from measurement processing utilizing regression to measurement processing utilizing the library when the library has been newly developed.
11. The method of claim 10, wherein the new library is developed after a percentage of measurement results from measurement processing utilizing regression exceeds a predefined percentage.
12. The method of claim 1, wherein measurement processing utilizing the library is executed by a general purpose computer.

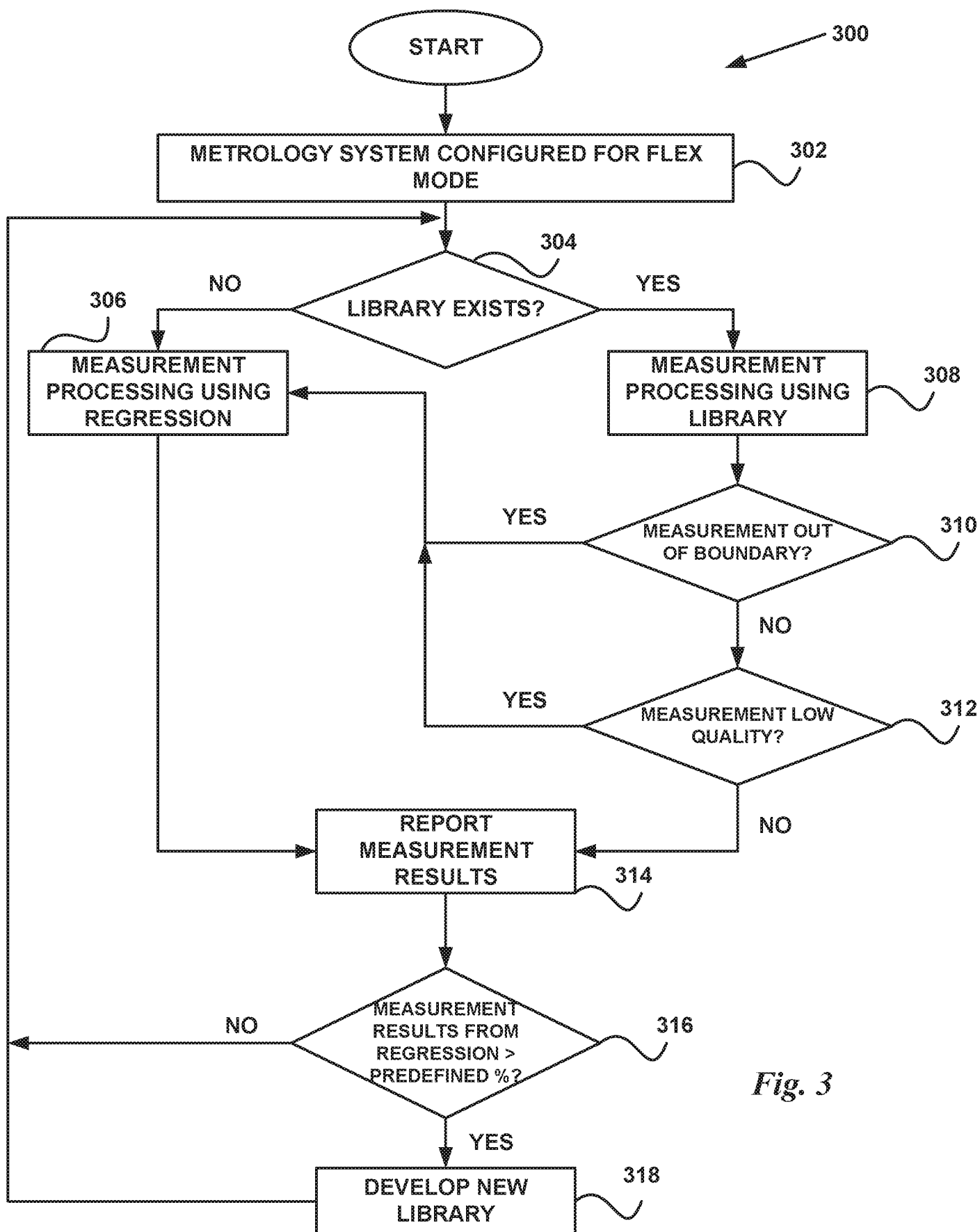
13. The method of claim 12, wherein the general purpose computer automatically transitions between utilizing the library and utilizing regression for the measurement processing.
14. The method of claim 12, wherein measurement processing utilizing regression is executed by the general purpose computer.
15. The method of claim 12, wherein measurement processing utilizing regression is executed by a dedicated regression processing cluster.
16. A non-transitory computer readable medium storing a computer program product including computer code adapted to be executed by a processor to cause the processor to perform a method, comprising:
- determining, by a metrology system, that a predetermined condition has been met;
 - and
 - in response to determining that the predetermined condition has been met, automatically transitioning, by the metrology system, between utilizing a library and utilizing regression for measurement processing.
17. A metrology system, comprising:
- a general purpose computer for:
 - determining that a predetermined condition has been met; and
 - in response to determining that the predetermined condition has been met, automatically transitioning, by the metrology system, between utilizing a library and utilizing regression for measurement processing.
18. The metrology system of claim 17, wherein the general purpose computer automatically transitions from measurement processing utilizing the library to measurement processing utilizing regression, and wherein the measurement processing utilizing regression is instructed by the general purpose computer for execution by a dedicated regression processing cluster separate from the general purpose computer.

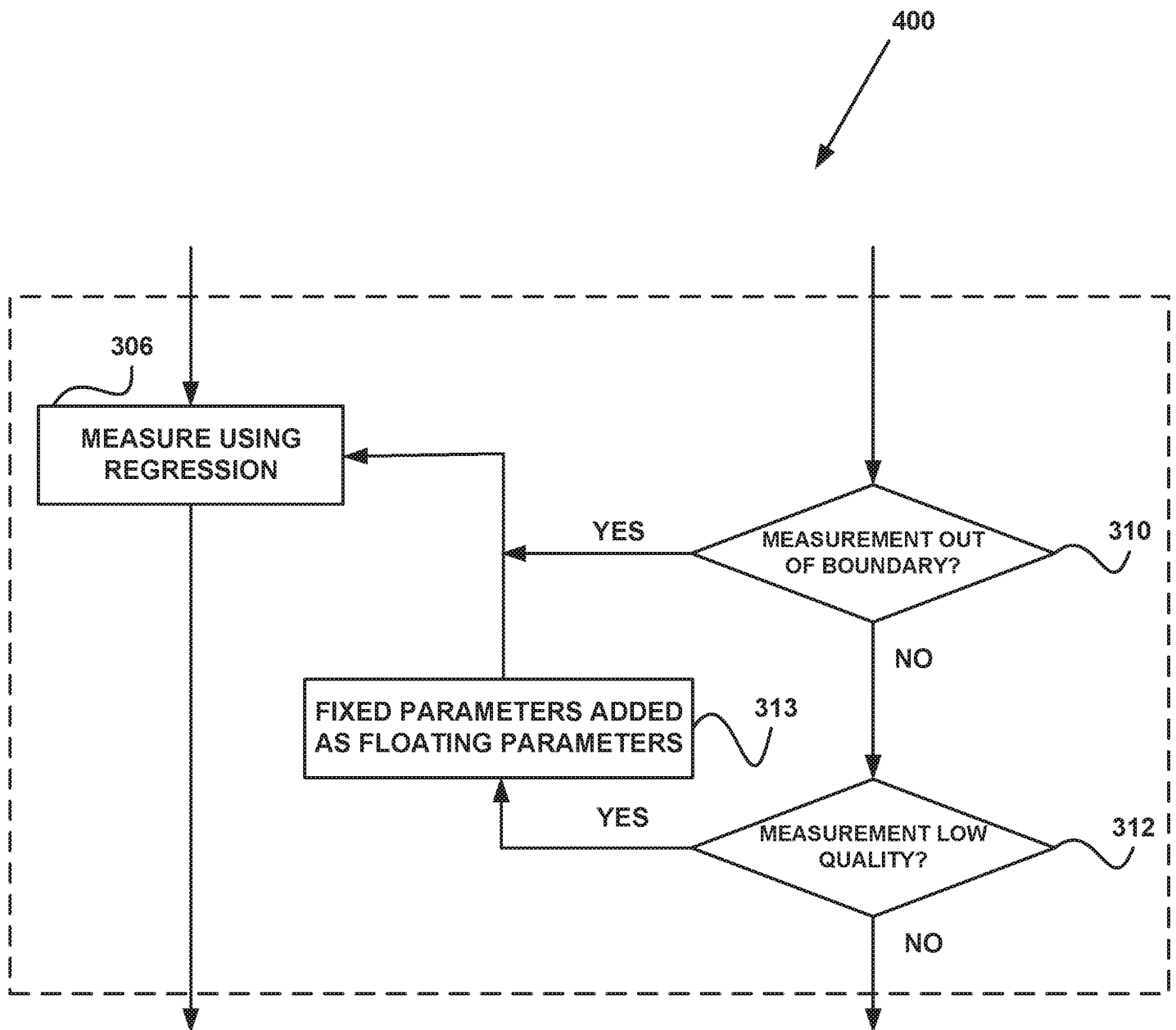
19. The metrology system of claim 17, wherein the general purpose computer automatically transitions from measurement processing utilizing the library to measurement processing utilizing regression, and wherein the measurement processing utilizing regression is executed by the general purpose computer.

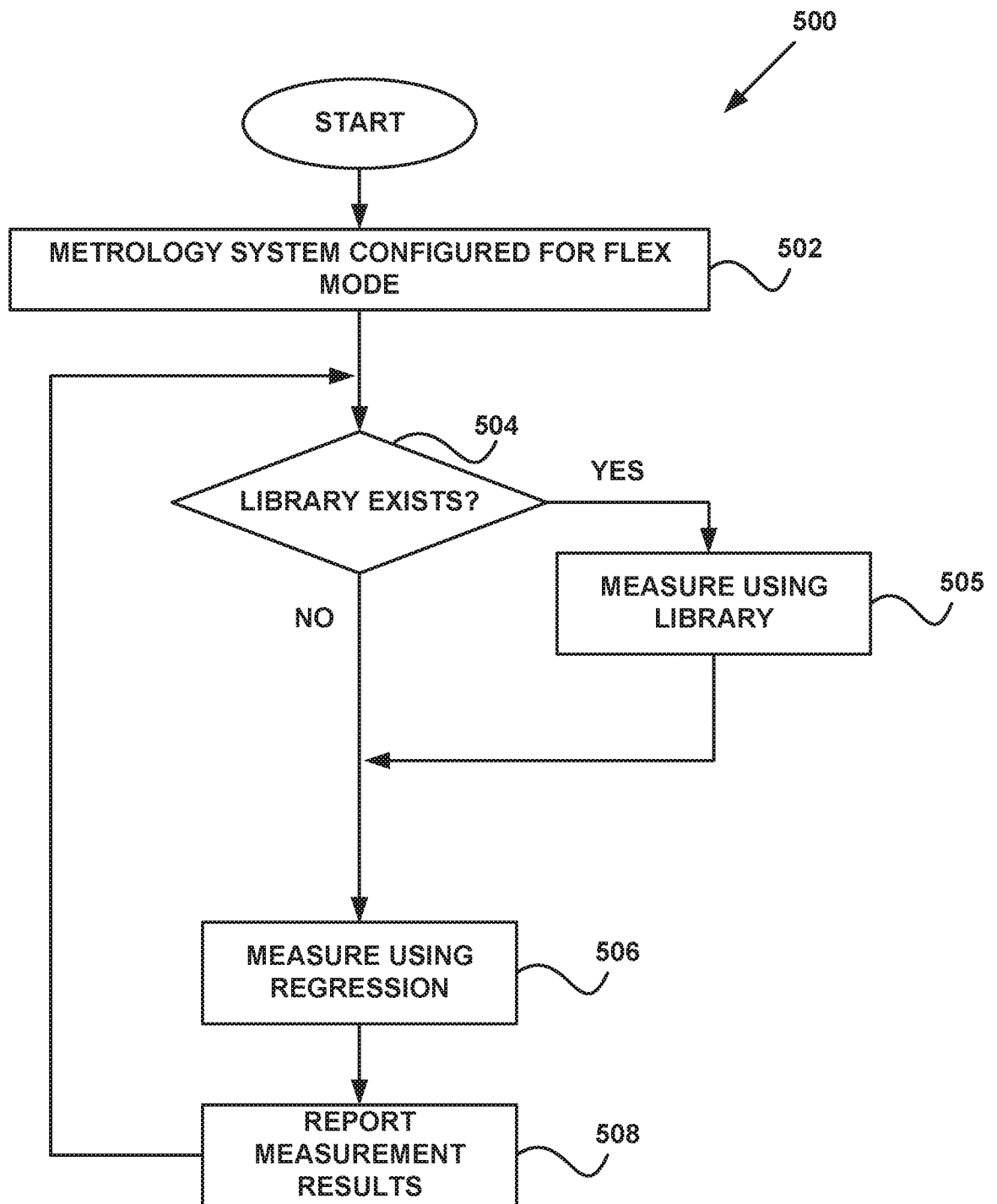
20. The metrology system of claim 17, wherein the general purpose computer automatically transitions to measurement processing utilizing the library from measurement processing utilizing regression by executing the measurement processing utilizing the library subsequent to measurement processing performed utilizing regression.

*Fig. 1*

*Fig. 2*

*Fig. 3*

*Fig. 4*

*Fig. 5*

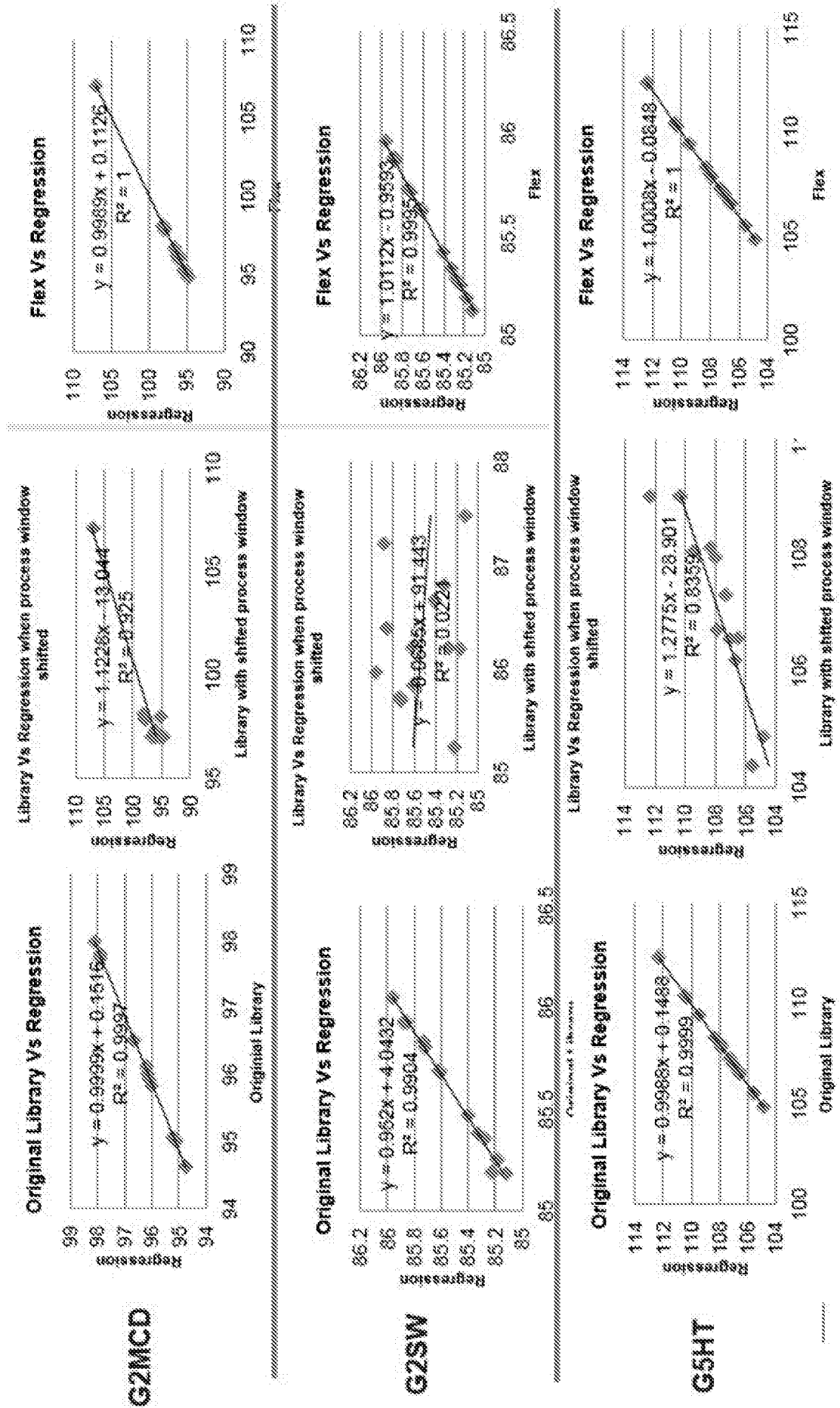


Fig. 6

A. CLASSIFICATION OF SUBJECT MATTER**G01N 21/956(2006.01)I**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01N 21/956; G01R 31/26; G01Q 10/04; G01B 7/00; G01Q 30/06; G01N 21/88; G01N 21/00; G06N 5/02; G01N 21/86

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: metrology, predetermined condition, library, flex mode, regression and computer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6768983 B1 (JAKATDAR et al.) 27 July 2004 See abstract, claims 1-29 and figures 1-9.	1-20
A	US 6721045 B1 (HUNTER, REGINALD) 13 April 2004 See abstract, claims 1-8 and figures 1A-1C.	1-20
A	US 8904560 B2 (SHI et al.) 02 December 2014 See abstract, claims 16-19 and figures 5-8.	1-20
A	US 8762100 B1 (CHU et al.) 24 June 2014 See abstract, claims 1-5 and figures 1-3B.	1-20
A	US 6188078 B1 (BELL, JR. et al.) 13 February 2001 See abstract, claims 1, 6-14 and figures 3-7B.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

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Information on patent family members

International application No.

PCT/US2016/030269

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