**EUROPEAN PATENT SPECIFICATION**

| (45) Date of publication and mention of the grant of the patent: | (51) Int Cl.: |
| | G01H 1/00 (2006.01) |
| | H01L 21/00 (2006.01) |

| (21) Application number: | (86) International application number: |
| 00910106.4 | PCT/US2000/003224 |

| (22) Date of filing: | (87) International publication number: |

| (54) A NON-INVASIVE SYSTEM AND METHOD FOR DIAGNOSING POTENTIAL MALFUNCTIONS OF SEMICONDUCTOR EQUIPMENT COMPONENTS |
| NICHT-INVASIVES SYSTEM UND VERFAHREN ZUR DIAGNOSTIZIERUNG VON MÖGLICHEN FEHLERN IN BAUGRUPPEN VON ANLAGEN ZUR HALBLEITERHERSTELLUNG |
| SYSTEME ET PROCEDE NON INVASIFS POUR DIAGNOSTIQUER DES DEFAUTS DE FONCTIONNEMENT POTENTIELS DANS DES COMPOSANTS D’EQUIPEMENTS DE FABRICATION DE SEMI-CONDUCTEURS |

| (84) Designated Contracting States: |
| AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE |

| (30) Priority: |
| 09.02.1999 US 247143 |

| (43) Date of publication of application: |
| 03.04.2002 Bulletin 2002/14 |

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| (56) References cited: |

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates generally to equipment diagnostic systems and methods, and more particularly, a system and method for non-invasively diagnosing potential malfunctions of semiconductor equipment components under vacuum, enabling a more efficient manner of inspecting moving mechanical parts in a vacuum system.

BACKGROUND OF THE INVENTION

[0002] Semiconductor manufacturing of integrated circuits is a long, complex, and expensive process. As new demands and technologies are introduced and integrated into semiconductor manufacturing the cost of manufacturing has only increased. A typical semiconductor manufacturing process may require between 200-300 steps. Since equipment malfunctions are inevitable, timely identification of these malfunctions is necessary to maintain profitability of the manufacturing process.

[0003] One solution, embraced by semiconductor manufacturers has been a structured approach in which a series of experiments is performed to understand equipment processing conditions. A typical example of this process is illustrated in FIGURE 1. FIGURE 1 represents a plasma enhanced chemical vapor deposition process. The process outputs of interest are the film thickness of the deposited films, film refractive index, stress on the wafer due to the deposited film, and the film non-uniformity. The process inputs manipulated to get the desired values of the outputs are, three gases G1, G2, G3; radio frequency (RF) power used to create the plasma; and the pressure in the vacuum chamber. Suppose that due to a miscalibration in one of the gas delivery systems the delivered gas flow is different from the requested flow. This could cause one or more of the process outputs to be different from the desired values. Since the future processing steps depend on previous steps, and the functionality of the integrated circuit relies on each set performing to specifications, one would like to quickly identify the miscalibrated gas flow and correct it before it prevents a large amount of semiconductor material from being correctly manufactured.

[0004] The diagnosis techniques described in this example make use of process models for fault isolation. Process models describe relationships between process inputs and outputs. Process models can be obtained by two main techniques. The first is by modeling the underlying physics of the process, resulting in physically based models. The second technique ignores the underlying physics but models the process implemented by the equipment as a "black box" by fitting a predetermined functional form to process outputs (responses) at carefully selected inputs. Such models are called response surface models (RSM) discussed in a book entitled Empirical Model-Building and Response Surfaces, published by John Wiley & Sons, New York, 1987. The diagnostic techniques described in this example invention have been tested on RSM models, but could in principle be applied to physically based models also.

[0005] This process model illustrated in FIGURE 2, directly examines the process output of the equipment but only indirectly examines the operation of the equipment itself by determining the difference between the expected output and the actual output based on a set of measured process inputs. Furthermore this solution often requires sensors to violate internal pressure boundaries of the semiconductor equipment.

[0006] Measurement and analysis of vibration data is a well-known method of directly monitoring the operating condition of equipment. Vibration occurs as a normal byproduct of the interaction of moving parts within equipment. An individual equipment component may produce a baseline vibration signature. Changes in the equipment component vibration signature indicate a change in the dynamic characteristics of the machine, often caused by a defect or deterioration of moving parts.

[0007] The prior art reveals several methods and apparatus for monitoring vibration. Some devices continuously monitor overall vibration in the time or frequency domain, and provide an indication of an alarm condition when preset vibration levels have been exceeded, (e.g., Shima et al., Judging System For Detecting Failure of Machine, U.S. Pat. No. 4,366,544, Dec. 28, 1982).

[0008] Another method of vibration analysis is "Vibration Signature Analysis," which is most often accomplished in the frequency domain. Under this method, time-domain vibration data are converted to the frequency domain using a Fourier Transform. The unique frequency spectrum obtained is often termed the "signature" of the machine. A signature of a machine under test may be analyzed and compared to a signature for a normal machine. Differences in the two spectra may indicate an abnormal condition. Prior art devices capable of providing a frequency spectrum are known. One such device includes a handheld probe for collecting vibration data, and the capability of executing a Fast Fourier Transform to provide a frequency spectrum, (e.g., Microlog IMS, available from Palomar Technology International, Carlsbad, Calif.). Morrow also discloses a data acquisition system which performs an automatic frequency spectrum analysis whenever a probable or actual malfunction is detected (Morrow, Data Acquisition System, U.S. Pat. No. 4,184,205, Jan. 15, 1980).

[0009] A common problem associated with most of the prior art monitoring equipment is that they usually require a human operator to analyze and compare the signatures.

[0010] Prior art inventions lack the sophisticated electronic circuitry and data processing necessary for automatic comparison of the spectra and for rendering a decision regarding the condition of the machine under test, with only minimal human interface.
SUMMARY OF THE INVENTION

The present invention provides a system and a corresponding method for diagnosing potential malfunctions of semiconductor manufacturing equipment components as defined in the appended claims.

The present invention provides another technical advantage by establishing tool vibration baseline or signature. This is accomplished by recording.

The present invention provides another technical advantage by monitoring tool vibration and identifies any deviation from the base-line.

The present invention provides yet another technical advantage by analyzing data and notifying required personnel of repair action.

The present invention provides another technical advantage by vibration analysis of a vacuum pump indicates changes in vacuum load and exhaust. This provides a very sensitive tool to monitor the vacuum system process.

The present invention provides another technical advantage by eliminating catastrophic failure of equipment before more expensive damage occurs and preventing the loss of semiconductor product due to unscheduled equipment failure.

The present invention also reduces unscheduled down time for equipment repair or replacement by allowing a predictive schedule rather than unscheduled occurrences.

The present invention provides another technical advantage by providing a quality assurance check. New component installations/ refurbishments can be checked against acceptance criteria and past performance.

The present invention provides another technical advantage by allowing better management of production schedules and resources resulting from known equipment condition.

The present invention provides another technical advantage by automating the data collection over an entire factory. Manual collection of this data would require some disassembly of some manufacturing tools. This repeated disassembly would generate additional particulate contamination in a clean room environment leading to depressed yields of manufactured product.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numerals indicate like features and wherein:

FIGURE 1 illustrates an example of measured process inputs and output variables of a typical semiconductor process;

FIGURE 2 is a simplified flow diagram comparing measured process outputs to expected process outputs;

FIGURE 3 provides a simplified rendition of a semiconductor processing tool and its components;

FIGURE 4 illustrates an embodiment of the present invention to measure semiconductor equipment component vibration;

FIGURE 5 is a three dimensional representation of a typical transducer;

FIGURE 6 provides a block diagram of the electrical circuit discussed in FIGURE 4;
FIGURE 7 shows a second embodiment of the present invention to measure semiconductor equipment component vibration coupled to a computer network;

FIGURE 8 is a flow diagram describing the operation of a software application used to evaluate frequency spectrums from semiconductor equipment components;

FIGURE 9 illustrates a Frequency Amplitude Spectrum for a typical semiconductor equipment component;

FIGURE 10 annotates frequency spikes which may indicate potential equipment component failures;

FIGURE 11 presents a table of the Western Electric rules for statistical control; and

FIGURE 12 illustrates a time series of events which effect measured vibration amplitudes and there assigned causes.

DETAILED DESCRIPTION OF THE INVENTION

[0027] Preferred embodiments of the present invention are illustrated in the FIGURES, like numerals being used to refer to like and corresponding parts of the various drawings.

[0028] The object of the present invention is to create a vibration analysis system that is both cost effective and functionally effective in predicting mechanical failures of semiconductor equipment components. Furthermore, the system should be easily installed with minimal impact on functioning equipment or incorporated into new equipment design.

[0029] FIGURE 1 illustrates a semiconductor manufacturing process wherein the manufacturing equipment receives inputs such as gases G1, G2 and G3, RF power and pressure (P) and produces a plasma reaction where in the measured outputs are stress, non-uniformity, refractive index and film thickness.

[0030] FIGURE 2 is a flow diagram for a simplified monitoring system wherein the inputs to the manufacturing equipment are measured and recorded. These values are then inputted into a mathematical process model of the semiconductor manufacturing process to provide an expected value or range of values for the process outputs. The expected process outputs can be compared to the measured outputs. A significant difference between the expected and measured variables indicates that there may be: 1) a problem with the measured data, 2) a problem with the mathematical model representing the process, or 3) an indication that a problem exists within the process itself. The desired indication is that this system will identify a problem associated with the process. Unfortunately, since the measurements of the process outputs are typically performed after the process has been completed, the semiconductor product associated with poor measurements must be scrapped as unsatisfactory product at great expense.

[0031] The present invention presents a solution that reduces the risk of scrapping the semiconductor product by monitoring not only the process output variables but the semiconductor manufacturing equipment and its components moving pieces which are most likely to fail. These components typically are wheels, valves or bearings and the like.

[0032] FIGURE 3 presents a simplified semiconductor manufacturing equipment. Many semiconductor processes are conducted in a processing chamber or chambers 10 which are maintained at a vacuum. Hi-Vac pumps 20 are used to draw these vacuums. These pumps contain many high speed moving parts and historically have been the subject of unexpected processing equipment down time. Furthermore, the failure of these Hi-Vac pumps 20 during semiconductor processing can and does result in the costly scrapping of product.

[0033] An embodiment of the present invention to directly monitor the performance of moving parts within these Hi-Vac pumps 20 is presented in FIGURE 4. Hi-Vac pump 20 is equipped with one or more transducer mounts 22. These transducer mounts may be incorporated into the design of the pump casing 21 or affixed to the pump casing 21 after the pump has been manufactured and installed as part of the semiconductor manufacturing tool. The transducer mounts 22 can be positioned to provide orthogonal monitoring of the Hi-Vac pump 20 vibration along any axis of concern. The transducer 24 will be mounted on the transducer mount 22 with a mechanical clasp, glue bond, tape, magnetic or other bonding means connecting the transducer mount 22 to the mounting surface 25 of the transducer 24. The embodiment depicted in FIGURE 4 uses an accelerometer for transducer 24.

[0034] A typical accelerometer is illustrated in FIGURE 5. There are many variations of accelerometers. The basic function is to convert vibration or motion along an axis of concern into an electric signal that can be analyzed. Most vibration analysis is concerned with specific vibration levels and frequencies. Hence, complicated calibration schemes are developed to insure that the accelerometer is operating properly.

[0035] One embodiment of the present invention compares vibration data gathered using a set of transducers 24 to historical or baseline data gathered using the same set of transducers 24. Hence, the concern is repeatability, but not necessarily accuracy with respect to calibration standards. This embodiment of the present invention measures the change in vibration frequency and amplitude, not specific levels of vibration. Using this approach, embodiments of the present invention have been able to use accelerometers mass produced for automotive airbag operation and hence significantly lower in price.

[0036] The transducer 24 will generate an output signal 27 which can be read by electrical circuit 28. Electrical circuit 28 is electrically connected to the transducer 24 with cable 26 attached at connection receptacle 38 shown in FIGURE 6. Electrical circuit 28 will comprise a connection receptacle 38 to receive cable 26. The output
signal 27 will be amplified, processed and converted into a data signal 29.

[0037] FIGURE 6 shows the output signal 27 being converted into a digital data signal by an analog to digital converter 40' and then being filtered by anti-alias filter 42' to improve the signal to noise ratio of the data signal 29. Transmitter 30 is coupled to the output connection 44' to receive the data signal 29. Transmitter 30 will modulate an electromagnetic carrier signal 32 with data signal 29. This electromagnetic carrier signal may be a conventional radio wave, an optical signal transmitted with a laser with or without a fiber optic carrier, an infrared carrier signal or any other means as known by those skilled in the art.

[0038] The electromagnetic carrier signal 32 will be collected and received by a receiving unit 34. The receiver 34 will contain a system to demodulate the data signal 29 from the electromagnetic carrier signal 32. A computer system 36 will be configured with both hardware and software to process data signal 29 and extract the desired vibration data. This computer may include a storage device operable to store gathered data. A memory location which may store the software application, coupled to a processor and storage device wherein the processor can execute the software application. One embodiment of this process is presented in FIGURE 11.

[0039] FIGURE 7 presents an embodiment of the present invention similar to that described in FIGURE 4 with the addition of an interface between the computer system 36 and a computer network 38 wherein a user may have broader access to the data and analysis.

[0040] FIGURE 8 presents a flow diagram of a process used by the software to evaluate the vibration data gathered by the present invention. First in step 100 the vibration data is collected on a periodic basis (hourly, daily, etc.) from a semiconductor equipment component as illustrated by the Hi-Vac pump 20 and supplied to the computer system 36 as described above. The raw vibration data may be stored in a raw vibration data database in step 102 and identified with the time and equipment component from which the data was collected. In step 103, the raw vibration data may be saved for future analysis.

[0041] Step 104 is the transformation of the raw vibration data using various mathematical techniques -- Fast Fourier Transform, Gabor Transform, Wavelet Transform and the like as known by those skilled in the art -- to produce a first frequency spectrum. An individual machine may have a unique frequency spectrum or signature comprising vibrational amplitude and frequency over time. Vibration energy is identified by frequency, time, and amplitude as illustrated by FIGURE 9.

[0042] FIGURE 9 presents a typical frequency spectrum 40 taken at a discrete moment in time. This spectrum presents the equipment components vibration amplitude along the y axis and frequency on the x axis. Amplitude spikes 42 represent tonals associated with the equipment components. A tonal may be defined as a vibration at a specific frequency. A set of tonals may be characteristic of the operation of an individual piece of equipment. By comparing several frequency spectrums, one can observe vibration changes with respect to time.

[0043] The frequency spectrums can then be stored in a temporary location of the historical database in step 106.

[0044] This historical database will contain a baseline frequency spectrum, recently gathered frequency spectrums as well as a location for user defined or a means for performing statistical analysis. This historical database is then accessed in step 108 for a set of values to which the present frequency may be compared.

[0045] Step 110 compares the first frequency spectrum to the baseline frequency spectrum, to a series of historical frequency spectrums or to a set of limits derived from historical or empirical data. This comparison may for example consist of calculating the euclidian distances between the individual points comprising the first frequency spectrum and the baseline spectrum or an average spectrum based on historical data.

[0046] Step 112 alerts the user to potential malfunctions. There are several ways a potential malfunction may be identified.

[0047] FIGURE 10 illustrates an embodiment of the present invention where a user defined limit 45 has been set and the amplitude spikes 44 would be noted as differences. The user in this embodiment would be informed of such spikes. This embodiment only illustrates the comparison to one limit. However, the present invention may involve a series of limits either present or based on a comparison of euclidian distances between each individual data point of the frequency spectrum to a prior spectrum.

[0048] Another method of comparison may involve a statistical analysis on the first frequency spectrum to a series of historical frequency spectrums according to a set of statistical process control rules such as the Western Electric Rules (shown in FIGURE 11) presented by Nelson in "The Shewhart Control Chart - Tests for Special Causes," Journal of Quality Control Technology (1984) and the like. Further, the series of historical frequency spectrums may be used to determine statistical limits for each individual data point on the frequency spectrum. The statistical methods used need not be limited to those of the Western Electric Rules; there are a variety of methods for conducting statistical analysis as known to those skilled in the art.
When a limit 45 is exceeded as depicted in FIGURE 10, the computer will generate a warning or alarm to the user as illustrated in Step 112. Similarly the computer may generate a non alert indicating that the comparisons have been performed with no discrepancies.

The present invention also allows for the gathering of vibrational data during specific functions of the semiconductor equipment. This allows the vibration not only of a component to be observed, but also the vibration signature of a specific evolution to be observed.

A time series of vibrational amplitudes or waterfall plot is presented in FIGURE 12 for typical semiconductor manufacturing tool. The graph presents amplitude on the y axis and time on the x axis. Events are illustrated and marked on the x axis. These events describe functions and movements inside the processing chamber 10 of a typical semiconductor equipment. However, these events need not be limited to functions within the processing chamber.

The present invention may analyze the vibrational signature of the evolution and compare that signature to a baseline or historical signature for the evolution and alert a user of required maintenance.

In summary, the present invention provides a non-invasive system and method for diagnosing potential malfunctions of semiconductor equipment components that diagnoses potential malfunctions in semiconductor manufacturing equipment components.

The present invention provides several benefits including providing a means to establish a semiconductor equipment component vibration base-line signature. Further, the present invention allows the semiconductor equipment component vibration signature to be monitored and deviation from the semiconductor equipment component vibration base-line signature to be analyzed and used to notify required personnel of upcoming required repair action. This will reduce spare parts inventories and unscheduled down time for equipment repair or replacement by allowing a predictive schedule for maintenance rather than a reaction to an unscheduled failure. This predictive schedule will also allow a more efficient use of repair personnel manpower. Further, this predictive scheduling ability may eliminate catastrophic failure of equipment before more expensive damage occur and prevent the loss of semiconductor product due to unscheduled equipment failure.

The present invention also evaluates and monitors impact from structural, environment, or system load changes. The vibration signature can be monitored during specific functions or load conditions within the semiconductor equipment.

Additionally, the present invention provides a method of providing a quality assurance check. New installations/refurbishments can be checked against acceptance criteria and past component or tool performance.

Although the present invention has been described in detail, it should be understood that various changes, substitutions and alterations can be made here-to without departing from the scope of the invention as described by the appended claims.

1. A system to diagnose potential malfunctions of semiconductor manufacturing equipment components, comprising: a transducer (24) to monitor present component vibration signatures of the semiconductor manufacturing equipment components (20) and provide at least one output signal (27) representative of present component vibration signatures; an electrical circuit (28) to read said at least one output signal (27) generated by said transducer (24) and transmit at least one data signal (29) representative of said present component vibration signatures to a computer system (36) which contains a software application to analyze said at least one data signal, wherein said software application comprises: a set of instructions operable to direct said computer to collect said at least one data signal, store data representative of said present component vibration signatures in a memory location, and compare said data to a database of historical component vibration signatures wherein an alert is supplied to a user noting differences between said present component vibration signatures and the historical component vibration signatures, characterized in that said computer system (36) is adapted to utilize a set of statistical process control rules, in particular the Western Electric rules, to compare present component vibration signatures and historical component vibration signatures.

2. The system of Claim 1, wherein said transducer (24) comprises an accelerometer along an axis of concern.

3. The system of Claim 1, wherein said electrical circuit (28) further comprises a radio transmitter (30) to transmit said at least one data signal (29) to said computer (36), and wherein said computer system (36) further comprises a radio receiver (34) to receive said at least one data signal (29).

4. The system of Claim 1, wherein the semiconductor manufacturing equipment component (20) is a vacuum pump or vacuum system.

5. The system of Claim 1, wherein said transducer is removably mountable to the semiconductor manufacturing equipment components (20) external to any pressure boundaries of the semiconductor manufacturing equipment components (20).

6. The system of Claim 1, wherein said database of
A method for diagnosing potential malfunctions of semiconductor manufacturing equipment components (20).

The system of Claim 1, wherein said electrical circuit (28) is adapted to transmit said at least one data signal (29) to said computer (36); filtering said at least one data signal (29) said at least one output signal (27) to improve signal-to-noise ratio and provide a data signal (29) representative of present component vibration signatures; transmitting on an electromagnetic carrier signal (32) of any kind said data signal (29) representative of said present component vibration signatures to a computer system (36); receiving said data signal (29) at said computer system (36); storing said data signal (29) in a memory location in said computer system (36); transforming said data signal (29) to spectrums of frequency and amplitude over time with a plurality of transformation techniques comprising: fast Fourier transforms; wavelet transforms; and Gabor transforms.

The system of Claim 1, wherein said transducer (24) wherein said transducer (24) is an accelerometer removably mounted external to semiconductor manufacturing equipment components (20).

The system of Claim 1, wherein said transducer (24) with said electrical circuit (28); reading said at least one output signal (27) generated by said transducer (24) with said electrical circuit (28); filtering with said electrical circuit (28) said at least one output signal (27) to improve signal-to-noise ratio and provide a data signal (29) representative of present component vibration signatures; transmitting on an electromagnetic carrier signal (32) of any kind said data signal (29) representative of said present component vibration signatures to a computer system (36); receiving said data signal (29) at said computer system (36); storing said data signal (29) in a memory location in said computer system (36); transforming said data signal (29) to spectrums of frequency and amplitude over time with a plurality of transformation techniques comprising: fast Fourier transforms; wavelet transforms; and Gabor transforms; comparing said spectrums to a historical spectrum of the semiconductor equipment component (20) by utilizing a set of statistical process control rules, in particular the Western Electric rules; and alerting a user to potential malfunctions of the semiconductor equipment component (20) based on differences between said spectrums and said historical spectrum.

The method of Claim 14, wherein the step of comparing said spectrums further comprises the steps of: selecting said historical spectrum from a historical database of spectrums for the semiconductor equipment component (20), and wherein said historical spectrum selected was recorded under similar operating conditions; and comparing said spectrum and said historical spectrum with a plurality of statistical techniques comprising Euclidean distances between corresponding values of present and historical component vibration signatures.

The method of Claim 14, wherein said computer system (36) receives a plurality of data signals representing vibration signatures from a plurality of semiconductor equipment components.

A method for diagnosing potential malfunctions of semiconductor manufacturing equipment components (20), comprising the steps of: monitoring component vibration signatures of the semiconductor manufacturing equipment components (20) with a transducer (24) wherein said transducer (24) is an accelerometer removably mounted external to semiconductor manufacturing equipment components pressure boundaries along an axis of concern; providing at least one output signal (27) representative of present component vibration signatures from said transducer (24) to an electrical circuit (28); reading said at least one output signal (27) generated by said transducer (24) with said electrical circuit (28); filtering with said electrical circuit (28) said at least one output signal (27) to improve signal-to-noise ratio and provide a data signal (29) representative of present component vibration signatures; transmitting on an electromagnetic carrier signal (32) of any kind said data signal (29) representative of said present component vibration signatures to a computer system (36); receiving said data signal (29) at said computer system (36); storing said data signal (29) in a memory location in said computer system (36); transforming said data signal (29) to spectrums of frequency and amplitude over time with a plurality of transformation techniques comprising: fast Fourier transforms; wavelet transforms; and Gabor transforms; comparing said spectrums to a historical spectrum of the semiconductor equipment component (20) by utilizing a set of statistical process control rules, in particular the Western Electric rules; and alerting a user to potential malfunctions of the semiconductor equipment component (20) based on differences between said spectrums and said historical spectrum.

The method of Claim 14, wherein said computer system (36) receives a plurality of data signals representing vibration signatures from a plurality of semiconductor equipment components.
und um wenigstens ein Ausgangssignal (27), das momentane Komponentenvibrationssignaturen repräsentiert, bereitzustellen; eine elektrische Schaltung (28), um das wenigstens eine Ausgangssignal (27), das durch den Wandler (24) erzeugt wird, zu lesen und um wenigstens ein Datensignal (29), das die momentanen Komponentenvibrationssignaturen repräsentiert, an ein Computersystem (36) zu senden, das eine Software-Anwendung enthält, um das wenigstens eine Datensignal zu analysieren, wobei die Software-Anwendung enthält: eine Gruppe von Befehlen, die den Computer anweisen können, Daten, die die momentanen Komponentenvibrationssignaturen repräsentieren, an einem Speicherort zu speichern und die Daten mit einer Datenbank historischer Komponentenvibrationssignaturen zu vergleichen, wobei an einen Anwender eine Warnung ausgegeben wird, die Differenzen zwischen den momentanen Komponentenvibrationssignaturen und den historischen Komponentenvibrationssignaturen meldet, dadurch gekennzeichnet, dass das Computersystem (36) dazu ausgelegt ist, eine Gruppe statistischer Prozesssteuerregeln, insbesondere die Western-Electric-Regeln, zu verwenden, um momentane Komponentenvibrationssignaturen und historische Komponentenvibrationssignaturen zu vergleichen.

2. System nach Anspruch 1, wobei der Wandler (24) einen Beschleunigungsmesser längs einer betrachteten Achse umfasst.
3. System nach Anspruch 1, wobei die elektrische Schaltung (28) ferner einen Funksender (30) umfasst, um das wenigstens eine Datensignal (29) an den Computer (36) zu senden, und wobei das Computersystem (36) ferner einen Funkempfänger (34) umfasst, um das wenigstens eine Datensignal (29) zu empfangen.
4. System nach Anspruch 1, wobei die Halbleiterfertigungsanlagen-Komponente (20) eine Vakuumpumpe oder ein Vakuumsystem ist.
5. System nach Anspruch 1, wobei der Wandler an den Halbleiterfertigungsanlagen-Komponenten (20) außerhalb irgendwelcher Druckgrenzen der Halbleiterfertigungsanlagen-Komponenten (20) abnehmbar montiert werden kann.
6. System nach Anspruch 1, wobei die Datenbank historischer Komponentenvibrationssignaturen mehrere historische Komponentenvibrationssignaturen enthält, die verschiedene Betriebsbedingungen der Halbleiterfertigungsanlagen-Komponente (17) repräsentieren.
7. System nach Anspruch 1, wobei die Software-Anwendung dazu ausgelegt ist, die Daten, die die momentanen Komponentenvibrationssignaturen und die historischen Komponentenvibrationssignaturen repräsentieren, mittels mehrerer Transformationsmethoden, die die schnellen Fourier-Transformationsmethoden, die Wavelet-Transformationen und die Gabor-Transformationen umfassen, in Frequenz- und Amplitudenspektren als Funktion der Zeit zu transformieren.
8. System nach Anspruch 1, wobei die Software-Anwendung dazu ausgelegt ist, euklidische Abstände zwischen entsprechenden Werten momentaner und historischer Komponentenvibrationssignaturen zu verwenden, um momentane Komponentenvibrationssignaturen und historische Komponentenvibrationssignaturen zu vergleichen.
9. System nach Anspruch 1, wobei der Wandler (24) dazu ausgelegt ist, Vibrationsum in Bereich von 0 bis 20000 Hertz zu überwachen.
10. System nach Anspruch 1, wobei die elektrische Schaltung (28) ferner einen Filter (42') umfasst, um an dem wenigstens einen Datensignal (29), das die momentanen Komponentenvibrationssignaturen repräsentiert, eine Anti-Alias-Verarbeitung auszuführen, wobei das wenigstens eine Datensignal (29) ein analoges Signal ist.
11. System nach Anspruch 1, wobei jede momentane und jede historische mechanische Komponentenvibrationssignatur einen eindeutigen Komponentenidentifizierer enthält und wobei der Computer (36) dazu ausgelegt ist, die momentanen Komponentenvibrationssignaturen von mehreren Halbleiterfertigungskomponenten (20) für die Analyse zu sammeln.
12. System nach Anspruch 1, wobei von einem lokalen Netz auf den Computer (36) zugegriffen werden kann.
13. System nach Anspruch 1, wobei die elektrische Schaltung (28) dazu ausgelegt ist, das wenigstens eine Datensignal (29) mittels eines elektromagnetischen Trägersignals (32) beliebiger Art zum Computer (36) zu senden.
14. Verfahren für die Diagnose potentieller Fehlfunktionen von Halbleiterfertigungsanlagen-Komponenten (20), das die folgenden Schritte umfasst: Überwachen von Komponentenvibrationssignaturen der Halbleiterfertigungsanlagen-Komponenten (20) mit einem Wandler (24), wobei der Wandler (24) ein Beschleunigungsmesser längs einer betrachteten Achse ist, der außerhalb von Druckgrenzen von Halb-
Revendications

1. Système de diagnostic de défauts de fonctionnement potentiels de composants d’équipements de fabrication de semi-conducteurs, comprenant : un transducteur (24) servant à surveiller les signatures vibrationnelles actuelles des composants d’équipements de fabrication de semi-conducteurs (20) et à délivrer au moins un signal de sortie (27) représentatif des signatures vibrationnelles actuelles des composants ; un circuit électrique (28) servant à lire au moins un signal de sortie (27) généré par ledit transducteur (24) et à transmettre au moins un signal de données (29) représentatif des signatures vibrationnelles actuelles des composants dans un emplacement mémoire et comparer lesdites données à une base de données représentatives des signatures vibrationnelles historiques des composants, une alerte étant fournie à un utilisateur lorsque des différences sont observées entre lesdites signatures vibrationnelles actuelles des composants et les signatures vibrationnelles historiques des composants, caractérisé en ce que ledit système informatique (36) est adapté pour utiliser un ensemble de règles statistiques de contrôle de traitement, en particulier les règles Western Electric, pour comparer les signatures vibrationnelles actuelles des composants et les signatures vibrationnelles historiques des composants.

2. Système selon la revendication 1, dans lequel ledit transducteur (24) comprend un accéléromètre le long d’un axe à surveiller.

3. Système selon la revendication 1, dans lequel ledit circuit électrique (28) comprend en plus un émetteur radio (30) pour transmettre au moins un signal de données (29) audit système informatique (36) et dans lequel ledit système informatique (36) comprend en plus un récepteur radio (34) pour recevoir au moins un signal de données (29).

4. Système selon la revendication 1, dans lequel le composant d’équipement de fabrication de semi-conducteurs (20) est une pompe à vide ou un système de vide.

5. Système selon la revendication 1, dans lequel ledit transducteur se fixe de manière démontable sur les composants d’équipements de fabrication de semi-conducteurs (20) à l’extérieur des éventuelles envê-
Système selon la revendication 1, dans lequel ledit base de données de signatures vibrationnelles historiques des composants comprend une pluralité de signatures vibrationnelles historiques des composants représentant différentes conditions opérationnelles du composant d’équipement de fabrication de semi-conducteurs (20).

6. Système selon la revendication 1, dans lequel ladite application logicielle est adaptée pour transformer lesdites données représentatives desdites signatures vibrationnelles actuelles et lesdites signatures vibrationnelles historiques des composants en spectres de fréquence et d’amplitude dans le temps en utilisant une pluralité de techniques de transformation comprenant : les transformées rapides de Fourier ; les transformées en ondelettes ; et les transformées de Gabor.

7. Système selon la revendication 1, dans lequel ladite application logicielle est adaptée pour transformer lesdites données représentatives desdites signatures vibrationnelles actuelles et lesdites signatures vibrationnelles historiques des composants afin de comparer les signatures vibrationnelles actuelles des composants à partir dudit transducteur (24) à un spectre historique (29) au niveau dudit système informatique (36) ; lire au moins un signal de sortie (27) généré par ledit transducteur (24) au moyen dudit circuit électrique (28) ; filtrer avec ledit circuit électrique (28) au moins un signal de sortie (27) afin d’améliorer le rapport signal/bruit et délivrer un signal de données (29) représentatif des signatures vibrationnelles actuelles des composants ; transmettre sur un signal électromagnétique porteur (32) de type quelconque ledit signal de données (29) représentatif desdites signatures vibrationnelles actuelles des composants à un système informatique (36) ; recevoir ledit signal de données (29) au niveau dudit système informatique (36) ; stocker ledit signal de données (29) à un emplacement mémoire dans ledit système informatique (36) ; transformer ledit signal de données (29) en spectres de fréquence et d’amplitude dans le temps en utilisant une pluralité de techniques de transformation comprenant : les transformées rapides de Fourier ; les transformées en ondelettes ; et les transformées de Gabor ; comparer lesdits spectres à un spectre historique du composant d’équipement de fabrication de semi-conducteurs (20) en utilisant un ensemble de règles statistiques de contrôle de traitement, en particulier les règles Western Electric ; et alerter un utilisateur sur les défauts de fonctionnement potentiels du composant d’équipement de fabrication de semi-conducteurs (20) sur la base des différences entre lesdits spectres et ledit spectre historique.

8. Système selon la revendication 1, dans lequel ladite application logicielle est adaptée pour utiliser des distances euclidiennes entre des valeurs correspondantes de signatures vibrationnelles actuelles et historiques des composants afin de comparer les signatures vibrationnelles actuelles des composants et les signatures vibrationnelles historiques des composants.

9. Système selon la revendication 1, dans lequel ledit transducteur (24) est adapté pour contrôler des vibrations de fréquence allant de 0 à 20 000 hertz.

10. Système selon la revendication 1, dans lequel ledit circuit électrique (28) comprend en plus un filtre (42') pour décréneler au moins un signal de données (29) représentatif desdites signatures vibrationnelles actuelles des composants, au moins un signal de données (29) étant un signal analogique.

11. Système selon la revendication 1, dans lequel chaque signature de vibration mécanique actuelle et historique des composants contient un identifiant de composant unique et ledit système informatique (36) est adapté pour acquérir lesdites signatures vibrationnelles actuelles des composants provenant d’une pluralité de composants de fabrication de semi-conducteurs (20) en vue de les analyser.

12. Système selon la revendication 1, dans lequel ledit système informatique (36) est accessible par le biais d’un réseau local.

13. Système selon la revendication 1, dans lequel ledit circuit électrique (28) est adapté pour transmettre au moins un signal de données (29) audit système informatique (36) en utilisant un signal électromagnétique porteur (32) de type quelconque.

14. Procédé de diagnostic de défauts de fonctionnement potentiels de composants d’équipements de fabrication de semi-conducteurs (20), comprenant les étapes consistant à : contrôler les signatures vibrationnelles des composants à partir dudit transducteur (24), lequel transducteur (24) est un accéléromètre fixé de manière démontable à l’extérieur des enveloppes de pression de composants d’équipements de fabrication de semi-conducteurs le long d’un axe à surveiller ; envoyer au moins un signal de sortie (27) représentatif des signatures vibrationnelles actuelles des composants à un circuit électrique (28) ; lire au moins un signal de sortie (27) génére par ledit transducteur (24) au moyen dudit circuit électrique (28) ; filtrer avec ledit circuit électrique (28) au moins un signal de sortie (27) afin d’améliorer le rapport signal/bruit et délivrer un signal de données (29) représentatif des signatures vibrationnelles actuelles des composants ; transmettre sur un signal électromagnétique porteur (32) de type quelconque ledit signal de données (29) représentatif desdites signatures vibrationnelles actuelles des composants à un système informatique (36) ; recevoir ledit signal de données (29) au niveau dudit système informatique (36) ; stocker ledit signal de données (29) à un emplacement mémoire dans ledit système informatique (36) ; transformer ledit signal de données (29) en spectres de fréquence et d’amplitude dans le temps en utilisant une pluralité de techniques de transformation comprenant : les transformées rapides de Fourier ; les transformées en ondelettes ; et les transformées de Gabor ; comparer lesdits spectres à un spectre historique du composant d’équipement de fabrication de semi-conducteurs (20) en utilisant un ensemble de règles statistiques de contrôle de traitement, en particulier les règles Western Electric et alerter un utilisateur sur les défauts de fonctionnement potentiels du composant d’équipement de fabrication de semi-conducteurs (20) sur la base des différences entre lesdits spectres et ledit spectre historique.

15. Procédé selon la revendication 14, dans lequel l’étape de comparaison desdits spectres comprend en plus les étapes consistant à : sélectionner ledit spectre historique dans une base de données de spectres historiques pour le composant d’équipement de semi-conducteurs (20), ledit spectre historique sélectionné ayant été enregistré dans des conditions opérationnelles similaires ; et comparer ledit spectre et ledit spectre historique en utilisant une pluralité de techniques statistiques, comprenant les distances euclidiennes entre des valeurs correspondantes.
de signatures vibrationnelles actuelles et historiques des composants.

16. Procédé selon la revendication 14, dans lequel l’étape consistant à transmettre sur un signal électromagnétique porteur (32) de type quelconque ledit signal de données (29) comprend en plus l’utilisation d’un émetteur radio (30) pour transmettre ledit signal électromagnétique porteur (32).

17. Procédé selon la revendication 14, dans lequel ledit système informatique reçoit une pluralité de signaux de données représentant les signatures vibrationnelles d’une pluralité de composants d’équipements de semi-conducteurs.
FIG. 8

FIG. 9
<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Detection Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>One point beyond Zone A</td>
<td>detects a shift in the mean, an increase in the standard deviation, or a single aberration in the process. For interpreting Test 1, the R chart can be used to rule out increases in variation.</td>
</tr>
<tr>
<td>Test 2</td>
<td>Nine points in a row in Zone C or beyond</td>
<td>detects a shift in the process mean.</td>
</tr>
<tr>
<td>Test 3</td>
<td>Six points in a row steadily increasing or decreasing</td>
<td>detects a trend or drift in the process mean. Small trends are signaled by this test before Test 1.</td>
</tr>
<tr>
<td>Test 4</td>
<td>Fourteen points in a row alternating up and down</td>
<td>detects systematic effects such as two alternately used machines, vendors, or operators.</td>
</tr>
<tr>
<td>Test 5</td>
<td>Two out of three points in a row in Zone A or beyond</td>
<td>detects a shift in the process average or increase in the standard deviation. Any two out of three points provide a positive test.</td>
</tr>
<tr>
<td>Test 6</td>
<td>Four out of five points in Zone B or beyond</td>
<td>detects a shift in the processing mean. Any four out of five points provide a positive test.</td>
</tr>
<tr>
<td>Test 7</td>
<td>Fifteen points in a row in Zone C, above and below the center line</td>
<td>detects stratification of subgroups when the observations in a single subgroup come from various sources with different means.</td>
</tr>
<tr>
<td>Test 8</td>
<td>Eight points in a row on both sides of the center line with none in Zone C</td>
<td>detects stratification of subgroups when the observations in one subgroup come from a single source, but subgroups come from different sources with different means.</td>
</tr>
</tbody>
</table>
DISCRETE EVENTS

NEXT CYCLE
SEAL DOOR OPEN

LOCK VENTING

CASSETTE MOVEMENT
PRESSURE PLATE FORWARD
TRANSFER PLATE FORWARD

TRANSFER/PRESSURE PLATES BACK
RAMS RELEASE

LOCK PUMPING DOWN

SEAL DOOR CLOSE
LOAD DOOR OPEN
RETRACT/RELEASE
WAFFER INTO CLIPS

CLIP EXTEND/CHUCK EXTEND/WAFFER LOAD
LOAD DOOR CLOSES

ELEVATOR DOWN
ELEVATOR UP WAFER LOAD
CASSETTE MOVEMENT
ELEVATOR DOWN
ELEVATOR UP/DETENT/WAFFER RELEASE
LOAD DOOR OPEN
RETRACT

CLIP EXTEND/CHUCK EXTEND
LOAD DOOR CLOSE

AMPLITUDE

FIG. 12
REFERENCES CITED IN THE DESCRIPTION

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