

DESCRIPTION

Title of Invention: COMPUTER PROGRAM, INFORMATION PROCESSING METHOD,
AND INFORMATION PROCESSING DEVICE

Technical Field

[0001]

The present disclosure relates to a computer program, an information processing method, and an information processing device.

Background Art

[0002]

Substrate processing such as etching or film formation on a substrate such as a semiconductor wafer or a glass substrate is performed according to a process recipe defining processing contents. In the related art, a shape simulation has been performed using a computer to calculate a predicted shape that is a shape obtained by predicting a shape of a substrate after substrate processing. In the shape simulation, substrate processing is simulated using a plurality of processing parameters related to the substrate processing according to process recipes. Further, a process recipe for obtaining a desired substrate shape is searched for by adjusting processing parameters such that a specific predicted shape can be obtained through the shape simulation. PTL 1 discloses a technique for performing a shape simulation.

Citation List

Patent Literature

[0003]

PTL 1: JP6890632B

Summary of Invention

Technical Problem

[0004]

As a method of the shape simulation, there is a method of predicting a post-processing shape by using a machine learning model, and a method of predicting a post-processing shape by CAE analysis (non-machine learning). The former method has a higher processing speed than the latter method. However, since the former method has many processing parameters, there is a problem that it takes time to predict a shape of the substrate even when a machine

learning model is used.

This problem is not limited to the shape simulation, and is a technical problem of the simulation for predicting any states of the substrate after substrate processing, such as a state of the film after the processing (film quality, composition), and shape distribution such as in-plane uniformity of a processed shape.

[0005]

An object of the present disclosure is to provide a computer program, an information processing method, and an information processing device capable of efficiently calculating various parameters related to a substrate processing process from a pre-processing state of a substrate and an assumed post-processing state when a process recipe necessary for substrate processing is created.

Solution to Problem

[0006]

A computer program according to an aspect of the present disclosure is a computer program that causes a computer to perform processing of optimizing a parameter related to a condition of substrate processing using a prediction model that calculates a predicted state after the substrate processing based on the parameter related to the condition of the substrate processing and an initial state of a substrate, the processing including: acquiring optimization information obtained when the parameter for processing the substrate from a first pre-processing state to a first post-processing state is optimized, where substrate processing contents are similar; and optimizing the parameter for processing the substrate from a second pre-processing state to a second post-processing state using the acquired optimization information and the prediction model.

[0007]

An information processing method according to an aspect of the present disclosure is an information processing method for optimizing a parameter related to a condition of substrate processing using a prediction model that calculates a predicted state after the substrate processing based on the parameter related to the condition of the substrate processing and an initial state of a substrate, the information processing method including: acquiring optimization information obtained when the parameter for processing the substrate from a first pre-processing state to a first post-processing state is optimized, where substrate processing contents are similar; and optimizing the parameter for processing the substrate from a second pre-processing state to a second post-processing state using the acquired optimization information and the prediction model.

[0008]

An information processing device according to an aspect of the present disclosure is

an information processing device including a processor configured to optimize a parameter related to a condition of substrate processing using a prediction model that calculates a predicted state after the substrate processing based on the parameter related to the condition of the substrate processing and an initial state of a substrate, in which the processor acquires optimization information obtained when the parameter for processing the substrate from a first pre-processing state to a first post-processing state is optimized, where substrate processing contents are similar, and optimizes the parameter for processing the substrate from a second pre-processing state to a second post-processing state using the acquired optimization information and the prediction model.

Advantageous Effects of Invention

[0009]

According to the present disclosure, it is possible to provide a computer program, an information processing method, and an information processing device capable of efficiently calculating various parameters related to a substrate processing process from the pre-processing state of the substrate and the assumed post-processing state when a process recipe necessary for substrate processing is created.

Brief Description of Drawings

[0010]

[FIG.1] FIG.1 is a block diagram illustrating a configuration example of an information processing device according to a first embodiment.

[FIG.2] FIG.2 is a conceptual diagram illustrating an information processing method according to the first embodiment.

[FIG.3] FIG.3 is a conceptual diagram illustrating an optimization method of plasma parameters according to the first embodiment.

[FIG.4] FIG.4 is a flowchart illustrating a processing procedure of creating optimization information according to the first embodiment.

[FIG.5] FIG.5 is a conceptual diagram illustrating an example of the optimization information.

[FIG.6] FIG.6 is a flowchart illustrating an optimization processing procedure of the plasma parameters according to the first embodiment.

[FIG.7] FIG.7 is a block diagram illustrating a configuration example of an information processing device according to a second embodiment.

[FIG.8] FIG.8 is a conceptual diagram illustrating a data configuration of an optimization information DB according to the second embodiment.

[FIG.9] FIG.9 is a conceptual diagram illustrating an information processing method

according to the second embodiment.

[FIG.10] FIG.10 is a flowchart illustrating an optimization processing procedure of plasma parameters according to the second embodiment.

[FIG.11] FIG.11 is a block diagram illustrating a configuration example of an information processing device according to a third embodiment.

[FIG.12] FIG.12 is a conceptual diagram illustrating an optimization method of plasma parameters according to the third embodiment.

[FIG.13] FIG.13 is a flowchart illustrating an optimization processing procedure of the plasma parameters according to the third embodiment.

[FIG.14] FIG.14 is a flowchart illustrating the optimization processing procedure of the plasma parameters according to the third embodiment.

Description of Embodiments

[0011]

Hereinafter, a computer program, an information processing method, and an information processing device according to embodiments of the present disclosure will be described with reference to the drawings. The present disclosure is not limited to these examples, and is defined by the claims, and is intended to include all modifications within the meaning and scope equivalent to the claims. Further, at least some of the embodiments described below may be freely combined.

[0012]

First Embodiment

Overview of Information Processing Method

An information processing method according to the present embodiment enables efficient calculation of various plasma parameters related to a substrate processing process from a pre-processing state of a substrate and an assumed post-processing state when a process recipe necessary for substrate processing using plasma is created. The pre-processing state and a post-processing shape include a shape of the substrate before and after the processing, the state (film quality, composition) of a film, and the like. The post-processing shape includes a shape of a single structure such as a hole or a wiring, and an average shape of a plurality of structures. Further, the post-processing shape includes a shape distribution of the substrate after processing, for example, in-plane uniformity.

In particular, the information processing method according to the first embodiment utilizes optimization information (for example, a history of an optimization process of the plasma parameters) with similar substrate states performed in the past to find an optimal plasma parameter more quickly and efficiently optimize the plasma parameter.

[0013]

The substrate processing is processing such as etching or film formation performed on a substrate such as a semiconductor wafer, a glass substrate, or a flat panel substrate.

The process recipe is information defining contents of substrate processing. A substrate processing device such as a semiconductor manufacturing device that performs the substrate processing includes a process chamber, and performs the substrate processing on a substrate disposed in the process chamber based on the process recipe. The process recipe includes set values (hereinafter referred to as recipe set values) for controlling an operation of the substrate processing device. The recipe set value is a numerical value that can be input by an operator operating the substrate processing device, and includes a gas flow rate, a gas type, an RF application voltage, a frequency, an internal chamber pressure, a temperature, a processing time, and the like.

[0014]

The plasma parameters are a plurality of parameters necessary for a simulation for predicting a post-processing state of a substrate processed from a pre-processing state of the substrate. The plasma parameters include flux-related information and reaction-related information. The flux-related information includes information such as the type, a flow rate, energy, and angle dependence of particles incident on a wafer. The reaction-related information includes information such as a scraping rate, an adhesion rate, a modification rate, and a sputtering rate of a target medium corresponding to flux information.

A plasma state inside the chamber can be predicted by the plasma parameters, and a relationship between knob information of the substrate processing device and the plasma state can be indirectly evaluated. Interaction reaction information between the particles and the medium included in the plasma parameters is a uniquely determined parameter, and serves as an index for other process prediction and development.

[0015]

Information Processing Device 1

FIG. 1 is a block diagram illustrating a configuration example of an information processing device 1 according to a first embodiment. The information processing device 1 is a computer that implements an information processing method according to the first embodiment, and includes a processor 11, a display unit 12, an operation unit 13, and a storage 14. The respective components are connected to each other by a bus.

[0016]

The information processing device 1 may be a stand-alone computer or a server connected to a network. Further, the information processing device 1 may be a computer in an on-premises environment, or a computer such as a server in a cloud environment. The

information processing device 1 may be configured with a plurality of computers and perform distributed processing, or may be realized by a plurality of virtual machines provided in one server, or may be realized by using a cloud server.

[0017]

The processor 11 includes arithmetic circuits such as a central processing unit (CPU), a multi-core CPU, a graphics processing unit (GPU), a general-purpose computing on graphics processing unit (GPGPU), a tensor processing unit (TPU), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), and a neural processing unit (NPU), internal storage devices such as a read only memory (ROM), and a random access memory (RAM), an I/O terminal, a clock unit, and the like. The processor 11 implements the information processing method according to the first embodiment by executing a computer program (program product) 141 stored in the storage 14 to be described later. Each functional unit of the information processing device 1 may be realized by software, or some or all of the functional units may be realized by hardware.

[0018]

The display unit 12 is, for example, a display device such as a liquid crystal panel or an organic electro luminescence (EL) display.

[0019]

The operation unit 13 is, for example, an input device such as a hardware keyboard, a pointing device, or a touch panel. A user of the information processing device 1 can input information such as text into the information processing device 1 using the operation unit 13. The operation unit 13 may be integrated with the display unit 12.

[0020]

The storage 14 includes, for example, a main storage and an auxiliary storage. The main storage is a temporary storage area such as a static random access memory (SRAM), a dynamic random access memory (DRAM), or a flash memory, and temporarily stores data necessary for the processor 11 to perform arithmetic processing. The auxiliary storage is a storage device such as a hard disk or an electrically erasable programmable ROM (EEPROM). The storage 14 stores the computer program 141 and a prediction model 142 to be executed by the processor 11. Further, the storage 14 stores a recipe table (not illustrated) in which a pre-processing state before and after a typical or standard substrate processing, a post-processing state, and the recipe set values are associated with each other.

[0021]

The auxiliary storage may be an external storage device connected to the information processing device 1. The computer program 141 and the prediction model 142 may be written into the storage 14 during a manufacturing stage of the information processing device 1, or may

be stored in the storage 14 after the information processing device 1 acquires information delivered by an external server through communication. The computer program 141 and the prediction model 142 may be in a form readable and recorded on a recording medium 10 such as a magnetic disk, an optical disk, or a semiconductor memory, and a reader may read the computer program from the recording medium 10 and store the computer program in the storage 14.

[0022]

The prediction model 142 is a numerical calculation model that predicts the post-processing state based on image data of the pre-processing state of the substrate and the plurality of plasma parameters related to the substrate processing. As the prediction model 142, either a machine learning model or a state simulator (CAE analysis simulator using a non-machine learning model) that analytically predicts the post-processing state may be used. The state simulator includes a shape simulator that predicts a shape of the substrate after processing. Further, the prediction model 142 may be implemented in whole or in part by hardware. In the first embodiment, the prediction model 142 is a machine learning model, and will be described as being implemented by software through arithmetic processing by the processor 11.

[0023]

The prediction model 142 includes, for example, a convolutional neural network (CNN) that has been trained through deep learning. The prediction model 142 includes an input layer that receives image data in the pre-processing state of the substrate and the plurality of plasma parameters, an intermediate layer that extracts image data in the pre-processing state and feature of the plasma parameter, and an output layer that outputs image data in a predicted post-processing state.

[0024]

The pre-processing state is data representing the state of the substrate before the substrate processing is performed, and the post-processing state is data representing the state of the substrate after the substrate processing. The pre-processing state and the post-processing state are, for example, image data representing the state of the substrate, such as a cross-sectional view of the substrate. The pre-processing state and the post-processing state may be data that includes feature indicating a size or physical structure of the substrate. The size of the substrate is, for example, a vertical, horizontal, or height size of the substrate, or a size of a specific portion of the substrate. The feature indicating a physical structure is, for example, a critical dimension (CD) value of a pattern formed on a substrate or an aspect ratio of a groove formed on a substrate.

[0025]

The prediction model 142 is generated by performing machine learning using the

training data in a learning device using a computer. In the training data, the pre-processing state of the substrate, the values of the plasma parameters, and the post-processing state of the substrate are recorded in association with each other. The training data includes a large number of data sets in which the pre-processing state, the values of the plasma parameters, and the post-processing state are associated with each other. The learning device inputs the pre-processing state and the plasma parameters recorded in the training data to the model (for example, the prediction model 142 before learning) that is the basis of the prediction model 142, and the model performs calculations according to the inputs of the pre-processing state and the plasma parameters, thereby outputting the post-processing state that is a predicted state of the substrate. The learning device adjusts the parameters of the calculation of the model such that an error between the post-processing state output by the model and the post-processing state associated with the input pre-processing state and plasma parameters is small. For example, the adjustment of the parameters is performed by an error back propagation method.

[0026]

The learning device performs machine learning by repeating the processing using a plurality of data sets included in the training data and adjusting the parameters of the model. The prediction model 142 is generated by adjusting the parameters of the calculation in this way. The data indicating the configuration and parameters of the model (for example, the prediction model 142 before training) that is the basis of the prediction model 142 is stored as the prediction model 142 in the storage 14 of the information processing device 1.

[0027]

Information Processing Method

FIG. 2 is a conceptual diagram illustrating the information processing method according to the first embodiment, FIG. 3 is a conceptual diagram illustrating an optimization method of the plasma parameters according to the first embodiment, and FIG. 4 is a flowchart illustrating a processing procedure of creating optimization information according to the first embodiment.

[0028]

First, the information processing device 1 performs optimization of the plasma parameters by a method of the related art, and performs processing of creating the optimization information. Specifically, the processor 11 of the information processing device 1 acquires the pre-processing state and the post-processing state of the substrate through the substrate processing (step S111). For example, as illustrated in FIG. 2, the processor 11 acquires a pre-processing state A1 and a post-processing state A2.

[0029]

Subsequently, the processor 11 acquires the recipe set values corresponding to the

acquired pre-processing state and post-processing state (step S112). Specifically, the processor 11 refers to the recipe table stored in the storage 14, and acquires the recipe set values corresponding to the acquired pre-processing state and post-processing state. When no recipe set values corresponding to the acquired pre-processing state and post-processing state exist, the processing in step S112 ends without acquiring the recipe set values.

[0030]

Next, the processor 11 functioning as a parameter setting unit 22 sets initial values of provisional plasma parameters (step S113). The provisional plasma parameters are plasma parameters that are provisionally set and input into the prediction model 142 when the plasma parameters are optimized using the prediction model 142. A method of selecting the initial value is not particularly limited, and the initial value may be a predetermined value set in advance, or may be any value.

[0031]

Then, the processor 11 inputs the pre-processing state acquired in step S111 and the provisional plasma parameters into the prediction model 142, thereby estimating the post-processing state (step S114). The processor 11 calculates an evaluation value of the post-processing state calculated by the prediction model 142 (step S115). The evaluation value is calculated using an evaluation function 21. The evaluation function 21 is a function that evaluates a difference between the target post-processing state acquired in step S111 and the post-processing state predicted by the prediction model 142. The evaluation function 21 is a function that returns, for example, a pixel error between an image in the post-processing state acquired in step S111 and an image in the post-processing state output by the prediction model 142.

[0032]

Then, the processor 11 determines whether the evaluation value is less than a predetermined threshold value (step S116). When it is determined that the evaluation value is less than the predetermined threshold value (step S116: YES), the processor 11 functioning as the parameter setting unit 22 changes the provisional plasma parameters (step S117), and returns the processing to step S114. The search for the provisional plasma parameters is performed until the evaluation value becomes equal to or more than the predetermined threshold value. When it is determined that the evaluation value is equal to or more than the predetermined threshold value (step S116: NO), the processor 11 stores, as the optimization information, a history of a plasma parameter searching process performed in step S113 to step S117 in the storage 14 (step S118), and ends the processing. As illustrated in FIG. 2, a plasma parameter A for which the evaluation value is equal to or more than the predetermined threshold value is obtained by searching for the plasma parameters. That is, the plasma parameter A when the substrate is

processed from the pre-processing state A1 to the post-processing state A2 is obtained.

[0033]

FIG. 5 is a conceptual diagram illustrating an example of the optimization information. The optimization information is information that associates numbers indicating steps of a plasma parameter optimization process, plasma parameters tried at the time of optimization, and evaluation values of post-processing states estimated using the plasma parameters.

[0034]

Next, processing of optimizing the plasma parameters for processing the substrate from the pre-processing state to the post-processing state, where substrate processing contents are similar, using the created optimization information will be described.

[0035]

FIG. 6 is a flowchart illustrating an optimization processing procedure of the plasma parameters according to the first embodiment. The processor 11 of the information processing device 1 acquires the pre-processing state and the post-processing state of the substrate through the substrate processing (step S131). For example, as illustrated in FIG. 2, the processor 11 acquires a pre-processing state B1 and a post-processing state B2. Here, it is assumed that the pre-processing state A1 used when the optimization information is created and the pre-processing state B1 acquired in step S131 are the same or similar. Then, similar to step S111, the processor 11 acquires the recipe set values corresponding to the acquired pre-processing state and post-processing state (step S132).

[0036]

Subsequently, the processor 11 acquires the optimization information created in the preceding processing (step S133). In other words, the processor 11 reads the optimization information from the storage 14.

[0037]

Then, the processor 11 sets the initial values of the provisional plasma parameters (step S134). Then, the processor 11 inputs the pre-processing state acquired in step S131 and the provisional plasma parameters into the prediction model 142, thereby estimating the post-processing state (step S135). The processor 11 calculates the evaluation value of the post-processing state calculated by the prediction model 142 (step S136).

[0038]

Then, the processor 11 determines whether the evaluation value is less than the predetermined threshold value (step S137). When it is determined that the evaluation value is less than the predetermined threshold value (step S137: YES), the processor 11 functioning as the parameter setting unit 22 changes the provisional plasma parameters based on the optimization information acquired in step S133 and the evaluation value acquired in step S136

(step S138), and returns the processing to step S135. For example, the processor 11 refers to the optimization information, and specifies a method of changing the provisional plasma parameters when the provisional plasma parameters and the evaluation value are similar, and the evaluation value is next improved. Then, the provisional plasma parameters are changed by using a specified changing method.

[0039]

The search for the provisional plasma parameters is performed until the evaluation value becomes equal to or more than the predetermined threshold value. When it is determined that the evaluation value is equal to or more than the predetermined threshold value (step S137: NO), the processor 11 stores, as the optimization information, the history of the plasma parameter searching process performed in step S134 to step S138 in the storage 14 (step S139). As illustrated in FIG. 2, a plasma parameter B for which the evaluation value is equal to or more than the predetermined threshold value is obtained by searching for the plasma parameters. That is, the plasma parameter B when the substrate is processed from the pre-processing state B1 to the post-processing state B2 is obtained. The optimization information stored in step S139 can be used for optimization processing of the plasma parameters in other substrate processing.

[0040]

Subsequently, the processor 11 outputs the optimized plasma parameters (step S140). For example, the processor 11 displays the plasma parameters on the display unit 12.

[0041]

The operator of the substrate processing device or the processor 11 adjusts or corrects the recipe set value based on the optimized plasma parameters (step S141). The processor 11 uses the determined recipe set values to control the operation of a substrate processing device (not illustrated) to perform the plasma processing on the substrate (step S142), and ends the processing.

[0042]

According to the information processing device 1 of the first embodiment configured as described above, in order to create the process recipe necessary for the substrate processing, the optimization information is used, so that various plasma parameters related to the substrate processing process can be efficiently calculated from the pre-processing state of the substrate and the assumed post-processing state.

[0043]

Then, an optimal recipe set value is determined using the optimized plasma parameters, and the plasma processing using the substrate processing device can be performed.

[0044]

By using the history of the plasma parameters and the evaluation values tried when optimizing the plasma parameters under similar substrate processing contents, the processor 11 can more flexibly and efficiently optimize the plasma parameters than when only the optimal values of the plasma parameters are used.

[0045]

Use Example

Currently, engineers perform individual analysis on each state feature when modeling the state of a substrate. However, it takes an enormous amount of time for analysis and consideration for an engineer to quantify each state feature and exhaustively search for a corresponding parameter. Further, in the optimization method of the related art, even if the similar state calculation is performed in the past, the optimization calculation from scratch is performed, and a significant amount of optimization time is required for analyzing the factors of specific state feature.

[0046]

Therefore, the information processing device 1 according to the first embodiment calculates the plasma parameters at the time when a desired average state or a post-processing state is obtained from the pre-processing state, and stores the optimization information. Then, the optimization is performed using the optimization information for each post-processing state that includes a state error (deviation) from the average post-processing state. In this way, the plasma parameters corresponding to the state error (deviation) are evaluated.

[0047]

By using the information processing method or the like according to the first embodiment, it is possible to efficiently calculate the plasma parameters for obtaining a similar post-processing state by using the optimization information obtained in a past optimization process. Further, by using the optimization information with respect to the state averaged in measurement data under the same experimental conditions, it is possible to quantify the factor (plasma parameters) of the state error (deviation) from the averaged state. Further, this method reduces the problem of redundancy of a search solution by using any optimization information for optimization of a target. Accordingly, in the optimization under the same process condition, it is also useful for the robustness evaluation to the target post-processing state in which the similarity in the search parameter space is ensured.

[0048]

Second Embodiment

The information processing device 1 according to a second embodiment is different from the first embodiment in that optimization information of similar substrate processing contents is searched for from a plurality of pieces of optimization information accumulated in

the past to optimize the plasma parameters. Since the other components of the information processing device 1 are the same as those of the information processing device 1 according to the first embodiment, the same reference numerals are given to the same portions, and a detailed description thereof will be omitted.

[0049]

FIG. 7 is a block diagram illustrating a configuration example of the information processing device 1 according to the second embodiment. The information processing device 1 according to the second embodiment includes an optimization information DB 243 that accumulates a plurality of pieces of optimization information obtained through the optimization processing of the plasma parameters performed in the past.

[0050]

FIG. 8 is a conceptual diagram illustrating a data configuration of the optimization information DB 243 according to the second embodiment. The optimization information DB 243 stores record numbers, optimized plasma parameters, the recipe set values, the pre-processing states, the post-processing states, and the optimization information, in association with each other. The optimization information is similar to the information illustrated in FIG. 5, and includes histories of a plurality of plasma parameters tried in the optimization process and evaluation values of predicted states obtained by the respective plasma parameters.

[0051]

FIG. 9 is a conceptual diagram illustrating an information processing method according to the second embodiment, and FIG. 10 is a flowchart illustrating an optimization processing procedure of the plasma parameters according to the second embodiment. Similar to the first embodiment, the processor 11 acquires the pre-processing state and the post-processing state of the substrate through the substrate processing (step S131), and acquires the recipe set values corresponding to the acquired pre-processing state and the post-processing state (step S132).

[0052]

The user can freely designate some values of the plasma parameters among the plurality of plasma parameters as necessary, and can input the designated values of the plasma parameters using the operation unit 13. When some values of the plasma parameters are designated by the operation unit 13, the processor 11 acquires the designated values (step S233).

[0053]

Next, the processor 11 searches for and acquires optimization information whose processing contents are similar to the current substrate processing contents, from among the past optimization information recorded in the optimization information DB 243 (step S234).

[0054]

For example, the processor 11 may search for and acquire, from the optimization

information DB 243, the optimization information having similar recipe set values. Specifically, the processor 11 calculates a similarity between the recipe set value identified in step S132 and the recipe set value associated with each piece of optimization information recorded in the optimization information DB 243, and selects the optimization information associated with the recipe set value having a high similarity.

[0055]

For example, the processor 11 may search for and acquire, from the optimization information DB 243, optimization information whose pre-processing state and post-processing state are similar to those of the the current substrate processing contents. Specifically, the processor 11 calculates the similarity between the pre-processing state and the post-processing state acquired in step S131 and the pre-processing state and the post-processing state associated with each piece of the optimization information recorded in the optimization information DB 243, and selects the optimization information associated with the state having the higher similarity.

[0056]

For example, the processor 11 may search for and acquire, from the optimization information DB 243, optimization information in which a part of the plasma parameters is similar. Specifically, the processor 11 calculates the similarity between the designated values of some of the plasma parameters acquired in step S233 and the corresponding plasma parameters associated with the respective pieces of optimization information recorded in the optimization information DB 243, and selects the optimization information associated with the plasma parameter with the higher similarity.

[0057]

Although three methods for searching for the optimization information have been illustrated, the processor 11 may collectively evaluate the three similarities described above to search for and acquire the optimization information. Further, by performing comprehensive evaluation using any two of the three similarities described above, the optimization information may be searched for and acquired. The overall evaluation method is not particularly limited, and for example, the processor 11 may select the optimization information having the largest sum of similarities.

[0058]

In the following, the processor 11 performs the processing of steps S134 to S142, as in the first embodiment.

[0059]

With the information processing device 1 according to the second embodiment configured as described above, the optimization information with similar substrate processing

contents can be searched for from the optimization information stored in the optimization information DB 243, so that the plasma parameters can be efficiently optimized.

[0060]

Third Embodiment

The information processing device 1 according to a third embodiment is different from the first embodiment in that the plasma parameters are optimized using a plurality of learning models having different prediction processing speeds and state prediction accuracy. Since the other components of the information processing device 1 are the same as those of the information processing device 1 according to the first embodiment, the same reference numerals are given to the same portions, and a detailed description thereof will be omitted.

[0061]

FIG. 11 is a block diagram illustrating a configuration example of the information processing device 1 according to the third embodiment. The information processing device 1 according to the third embodiment stores two different models as the prediction model 142. Specifically, the storage 14 stores a first learning model 342a and a second learning model 342b. The processor 11 according to the third embodiment uses the different first learning model 342a and second learning model 342b to optimize the plasma parameters.

[0062]

The second learning model 342b is a model having higher state prediction accuracy of the substrate and a lower prediction processing speed than the first learning model 342a. For example, the first learning model 342a is a machine learning model, and the second learning model 342b is a machine learning model with the higher state prediction accuracy of the substrate and the lower prediction processing speed than the first learning model 342a. Further, the first learning model 342a may be a machine learning model, and the second learning model 342b may be a state simulator that calculates a predicted state by CAE analysis based on the plasma parameters and an initial state of the substrate. In other words, the first learning model 342a may be the machine learning model, and the second learning model 342b may be the non-machine learning model.

Hereinafter, the third embodiment will be described assuming that the first learning model 342a is a machine learning model and the second learning model 342b is a non-machine learning model.

[0063]

FIG. 12 is a conceptual diagram illustrating an optimization method of the plasma parameters according to the third embodiment, and FIGS. 13 and 14 are flowcharts illustrating an optimization processing procedure of the plasma parameters according to the third embodiment. Here, it is assumed that optimization processing of the plasma parameters is

performed using the first learning model 342a and the second learning model 342b with respect to the similar substrate processing contents, and the storage 14 stores the optimization information obtained in the process of the optimization processing of the plasma parameters using the first learning model 342a, and optimization information obtained in the process of the optimization processing of the plasma parameters using the second learning model 342b.

[0064]

The processor 11 uses the first learning model 342a as the prediction model 142 to perform the same processing as in steps S131 to S138 according to the first embodiment (steps S331 to S338).

[0065]

In step S337, the processor 11 determines whether the evaluation value of the post-processing state estimated using the first learning model 342a is less than a first predetermined threshold value (step S337). When it is determined that the evaluation value of the post-processing state estimated using the first learning model 342a is equal to or more than the first predetermined threshold value (step S337: NO), the processor 11 performs the optimization processing of the plasma parameters using the second learning model 342b.

[0066]

Specifically, the processor 11 acquires the optimization information for the second learning model 342b (step S339). Further, the processor 11 takes over the plasma parameters optimized by using the first learning model 342a as the provisional plasma parameters (step S340).

[0067]

Subsequently, the processor 11 uses the second learning model 342b to estimate the post-processing state based on the pre-processing state acquired in step S331 and the provisional plasma parameters taken over in step S340 (step S341). The processor 11 calculates the evaluation value of the post-processing state calculated by the second learning model 342b (step S342).

[0068]

Then, the processor 11 determines whether the evaluation value is less than a second predetermined threshold value (step S343). The second predetermined threshold value may be set to a value larger than the first predetermined threshold value. When it is determined that the evaluation value is less than the second predetermined threshold value (step S343: YES), the processor 11 functioning as the parameter setting unit 22 changes the provisional plasma parameters based on the optimization information acquired in step S339 and the evaluation value calculated in step S342 (step S344), and returns the processing to step S341. For example, the processor 11 refers to the optimization information, and specifies a method of changing the

provisional plasma parameters when the provisional plasma parameters and the evaluation value are similar, and the evaluation value is next improved. Then, the provisional plasma parameters are changed by using a specified changing method.

[0069]

The search for the provisional plasma parameters is performed until the evaluation value becomes equal to or more than the second predetermined threshold value. When it is determined that the evaluation value is equal to or more than the second predetermined threshold value (step S343: NO), the processor 11 stores the history of the plasma parameter searching process performed in step S334 to step S338 as the optimization information of the first learning model 342a, and stores the history of the plasma parameter searching process performed in step S340 to step S344 as the optimization information of the second learning model 342b, in the storage 14 (step S345).

[0070]

In the following, similar to the first embodiment, the processor 11 performs the processing of steps S140 to S142 (steps S346 to S348).

[0071]

According to the information processing device 1 of the third embodiment configured as described above, the plasma parameters can be optimized more quickly and with high accuracy than in the related art using a simple machine learning model.

[0072]

Means for solving the problems of the present disclosure will be described.

(Appendix 1)

A computer program that causes a computer to perform processing of optimizing a parameter related to a condition of substrate processing using a prediction model that calculates a predicted state after the substrate processing based on the parameter related to the condition of the substrate processing and an initial state of a substrate, the processing including:

acquiring optimization information obtained when the parameter for processing the substrate from a first pre-processing state to a first post-processing state is optimized, where substrate processing contents are similar; and

optimizing the parameter for processing the substrate from a second pre-processing state to a second post-processing state using the acquired optimization information and the prediction model.

(Appendix 2)

The computer program according to appendix 1, wherein

the optimization information includes histories of a plurality of the parameters obtained in a process of optimizing the plurality of parameters for processing the substrate from the first

pre-processing state to the first post-processing state, and evaluation values for the plurality of parameters.

(Appendix 3)

The computer program according to appendix 1 or 2, wherein
the parameter includes a plasma parameter related to a condition of plasma processing.

(Appendix 4)

The computer program according to any one of appendixes 1 to 3, wherein
the parameter includes a set value of a process recipe.

(Appendix 5)

The computer program according to any one of appendixes 1 to 4, the processing
further including:

searching for the optimization information with similar substrate processing contents,
from a storage that stores the optimization information including information that associates
the first pre-processing state, the first post-processing state, and a plurality of the optimized
parameters for processing the substrate from the first pre-processing state to the first post-
processing state; and

optimizing the parameters for processing the substrate from the second pre-processing
state to the second post-processing state using the plurality of parameters related to the
optimization information obtained by searching.

(Appendix 6)

The computer program according to appendix 5, wherein
the optimization information is searched for based on a similarity between a set value
of a process recipe related to the first pre-processing state and the first post-processing state
and a set value of a process recipe related to the second pre-processing state and the second
post-processing state.

(Appendix 7)

The computer program according to appendix 5, wherein
the optimization information is searched for based on a similarity between the first pre-
processing state and the first post-processing state, and the second pre-processing state and the
second post-processing state.

(Appendix 8)

The computer program according to appendix 5, wherein
the optimization information is searched for based on a similarity to the plurality of
parameters with a part set to a specific value.

(Appendix 9)

The computer program according to appendix 5, wherein

the optimization information is searched for based on a similarity between a set value of a process recipe related to the first pre-processing state and the first post-processing state and a process recipe related to the second pre-processing state and the second post-processing state, a similarity between the first pre-processing state and the first post-processing state, and the second pre-processing state and the second post-processing state, and a similarity to the parameters with a part set to a specific value.

(Appendix 10)

The computer program according to clause 9 of any one of appendixes 1 to 3, wherein the prediction model optimizes the parameters by using different first learning model and second learning model.

(Appendix 11)

The computer program according to appendix 10, wherein the second learning model has higher state prediction accuracy of the substrate and a lower prediction processing speed than the first learning model.

(Appendix 12)

The computer program according to appendix 10 or 11, wherein the first learning model is a machine learning model, and the second learning model includes a machine learning model having higher state prediction accuracy of the substrate and a lower prediction processing speed than the first learning model.

(Appendix 13)

The computer program according to appendix 10 or 11, wherein the first learning model is a machine learning model, and the second learning model includes a state simulator that calculates the predicted state of the substrate by CAE analysis based on the parameter and the initial state of the substrate.

(Appendix 14)

The computer program according to any one of appendixes 1 to 13, wherein a set value of a process recipe is determined based on the optimized parameter, and the substrate processing is controlled based on the determined set value of the process recipe.

Reference Signs List

[0073]

- 1: information processing device
- 10: recording medium
- 11: processor
- 12: display unit

13: operation unit
14: storage
141: computer program
142: prediction model
342a: first learning model
342b: second learning model
243: optimization information DB

CLAIMS

[Claim 1]

A computer program that causes a computer to perform processing of optimizing a parameter related to a condition of substrate processing using a prediction model that calculates a predicted state after the substrate processing based on the parameter related to the condition of the substrate processing and an initial state of a substrate, the processing comprising:

acquiring optimization information obtained when the parameter for processing the substrate from a first pre-processing state to a first post-processing state is optimized, where substrate processing contents are similar; and

optimizing the parameter for processing the substrate from a second pre-processing state to a second post-processing state using the acquired optimization information and the prediction model.

[Claim 2]

The computer program according to claim 1, wherein

the optimization information includes histories of a plurality of the parameters obtained in a process of optimizing the plurality of parameters for processing the substrate from the first pre-processing state to the first post-processing state, and evaluation values for the plurality of parameters.

[Claim 3]

The computer program according to claim 1, wherein

the parameter includes a plasma parameter related to a condition of plasma processing.

[Claim 4]

The computer program according to claim 1, wherein

the parameter includes a set value of a process recipe.

[Claim 5]

The computer program according to claim 1, the processing further comprising:

searching for the optimization information with similar substrate processing contents, from a storage that stores the optimization information including information that associates the first pre-processing state, the first post-processing state, and a plurality of the optimized parameters for processing the substrate from the first pre-processing state to the first post-processing state; and

optimizing the parameters for processing the substrate from the second pre-processing state to the second post-processing state using the plurality of parameters related to the optimization information obtained by searching.

[Claim 6]

The computer program according to claim 5, wherein
the optimization information is searched for based on a similarity between a set value of a process recipe related to the first pre-processing state and the first post-processing state and a process recipe related to the second pre-processing state and the second post-processing state.

[Claim 7]

The computer program according to claim 5, wherein
the optimization information is searched for based on a similarity between the first pre-processing state and the first post-processing state, and the second pre-processing state and the second post-processing state.

[Claim 8]

The computer program according to claim 5, wherein
the optimization information is searched for based on a similarity to the plurality of parameters with a part set to a specific value.

[Claim 9]

The computer program according to claim 5, wherein
the optimization information is searched for based on a similarity between a set value of a process recipe related to the first pre-processing state and the first post-processing state and a set value of a process recipe related to the second pre-processing state and the second post-processing state, a similarity between the first pre-processing state and the first post-processing state, and the second pre-processing state and the second post-processing state, and a similarity to the parameters with a part set to a specific value.

[Claim 10]

The computer program according to claim 1, wherein
the prediction model optimizes the parameters by using different first learning model and second learning model.

[Claim 11]

The computer program according to claim 10, wherein
the second learning model has higher state prediction accuracy of the substrate and a lower prediction processing speed than the first learning model.

[Claim 12]

The computer program according to claim 10, wherein
the first learning model is a machine learning model, and
the second learning model includes a machine learning model having higher state prediction accuracy of the substrate and a lower prediction processing speed than the first learning model.

[Claim 13]

The computer program according to claim 10, wherein
the first learning model is a machine learning model, and
the second learning model includes a state simulator that calculates the predicted state of the substrate by CAE analysis based on the parameter and the initial state of the substrate.

[Claim 14]

The computer program according to claim 1, wherein
a set value of a process recipe is determined based on the optimized parameter, and
the substrate processing is controlled based on the determined set value of the process recipe.

[Claim 15]

An information processing method for optimizing a parameter related to a condition of substrate processing using a prediction model that calculates a predicted state after the substrate processing based on the parameter related to the condition of the substrate processing and an initial state of a substrate, the information processing method comprising:

acquiring optimization information obtained when the parameter for processing the substrate from a first pre-processing state to a first post-processing state is optimized, where substrate processing contents are similar; and

optimizing the parameter for processing the substrate from a second pre-processing state to a second post-processing state using the acquired optimization information and the prediction model.

[Claim 16]

An information processing device comprising:

a processor configured to optimize a parameter related to a condition of substrate processing using a prediction model that calculates a predicted state after the substrate processing based on the parameter related to the condition of the substrate processing and an initial state of a substrate, wherein

the processor is configured to

acquire optimization information obtained when the parameter for processing the substrate from a first pre-processing state to a first post-processing state is optimized, where substrate processing contents are similar, and

optimize the parameter for processing the substrate from a second pre-processing state to a second post-processing state using the acquired optimization information and the prediction model.