CLAIMS

[Claim 1] An information processing apparatus comprising:

an information acquisition section configured to acquire polishing conditions including top-ring state information indicating a state of a top ring, polishing-table state information indicating a state of a polishing table, and polishing-fluid-supply-nozzle state information indicating a state of a polishing-fluid supply nozzle in chemical mechanical polishing of a substrate performed by a substrate processing apparatus including the polishing table configured to rotatably support a polishing pad, the top ring configured to press the substrate against the polishing pad, and the polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad; and

a state prediction section configured to predict substrate state information for the substrate on which the chemical mechanical polishing is performed under the polishing conditions by inputting the polishing conditions acquired by the information acquisition section to a learning model having been generated by machine learning that causes the learning model to learn a correlation between the polishing conditions and the substrate state information indicating a state of the substrate on which the chemical mechanical polishing is performed under the polishing conditions,

wherein the learning model comprises:

a learning model for stress analysis having been generated by machine learning that causes the learning model for stress analysis to learn a correlation between the polishing conditions and stress information indicating stress applied to the substrate on which the chemical mechanical polishing is performed under the polishing conditions; and

a learning model for polishing-quality analysis having been generated by machine learning that causes the learning model for polishing-quality analysis to learn a correlation between the stress information and polishing quality information indicating a polishing quality of the substrate to which the stress indicated by the stress information is applied, and

the state prediction section is configured to:

predict the stress information for the substrate on which the chemical mechanical polishing under the polishing conditions is performed by inputting the polishing conditions acquired by the information acquisition section to the learning model for the stress analysis; and

predict the polishing quality information for the substrate to which the stress indicated by the stress information is applied by inputting the predicted stress information to the learning model for the polishing-quality analysis.

[Claim 2] The information processing apparatus according to claim 1, wherein the top ring includes:

a top ring body which is moved by a rotating mechanism, a vertical movement mechanism, and an oscillation mechanism;

a membrane housed in the top ring body and configured to press the substrate against the polishing pad according to pressurized fluid supplied to a membrane pressure chamber; and

a retainer ring disposed at a periphery of the membrane and configured to press the polishing pad according to pressurized fluid supplied to a retainer-ring pressure chamber, and

the top-ring state information included in the polishing conditions includes at least one of:

a rotation speed of the top ring;

a rotation torque of the top ring;

an oscillation position of the top ring;

an oscillation torque of the top ring;

a height of the top ring;

an elevating torque of the top ring;

a pressure in the membrane pressure chamber;

a flow rate of the pressurized fluid supplied to the membrane pressure chamber;

a condition of the membrane;

a pressure in the retainer-ring pressure chamber;

a flow rate of the pressurized fluid supplied to the retainer-ring pressure chamber; and

a condition of the retainer ring.

[Claim 3] The information processing apparatus according to claim 1 or 2, wherein the polishing-table state information included in the polishing conditions includes at least one of:

a rotation speed of the polishing table;

a rotation torque of the polishing table;

a surface temperature of the polishing pad; and

a condition of the polishing pad.

[Claim 4] The information processing apparatus according to any one of claims 1 to 3, wherein the polishing-fluid-supply-nozzle state information included in the polishing conditions includes at least one of:

a flow rate of the polishing fluid;

a dropping position of the polishing fluid; and

a temperature of the polishing fluid.

[Claim 5] The information processing apparatus according to any one of claims 1 to 4, wherein the polishing conditions further includes:

device internal-environment information indicating environment of a space in which the chemical mechanical polishing is performed, and

the device internal-environment information included in the polishing conditions

includes at least one of:

temperature of the space;

humidity of the space; and

atmospheric pressure of the space.

[Claim 6] The information processing apparatus according to any one of claims 1 to 5, wherein the polishing conditions further include:

unprocessed substrate information indicating a state of an unprocessed substrate which is the substrate before the chemical mechanical polishing is performed.

[Claim 7] The information processing apparatus according to claim 6, wherein the unprocessed substrate information included in the polishing conditions includes at least one of:

a shape of the unprocessed substrate;

a weight of the unprocessed substrate; and

a condition of a substrate surface of the unprocessed substrate.

[Claim 8] The information processing apparatus according to any one of claims 1 to 7, wherein the substrate state information comprises stress information indicating stress applied to the substrate, and

the stress information indicates at least one of mechanical stress and thermal stress applied to the substrate.

[Claim 9] The information processing apparatus according to claim 8, wherein the stress information indicates:

an instantaneous value of the stress at a target point-in-time included in a polishing-process period from start to end of the chemical mechanical polishing; or

an accumulated value of the stress in a target period from the start of the

chemical mechanical polishing to the target point-in-time.

[Claim 10] The information processing apparatus according to claim 8 or 9, wherein the stress information indicates an in-plane distribution state of the stress applied to a substrate surface of the substrate.

[Claim 11] The information processing apparatus according to any one of claims 1 to 7, wherein the substrate state information comprises polishing quality information indicating a polishing quality of the substrate.

[Claim 12] An inference apparatus comprising:

a memory; and

a processor configured to perform:

an information acquisition process of acquiring polishing conditions including top-ring state information indicating a state of a top ring, polishing-table state information indicating a state of a polishing table, and polishing-fluid-supply-nozzle state information indicating a state of a polishing-fluid supply nozzle in chemical mechanical polishing of a substrate performed by a substrate processing apparatus including the polishing table configured to rotatably support a polishing pad, the top ring configured to press the substrate against the polishing pad, and the polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad; and

an inference process of inferring substrate state information indicating a state of the substrate on which the chemical mechanical polishing is performed under the polishing conditions when the polishing conditions are acquired in the information acquisition process.

[Claim 13] An inference apparatus comprising:

a memory; and

a processor configured to perform:

an information acquisition process of acquiring stress information indicating stress applied to a substrate on which chemical mechanical polishing is performed by a substrate processing apparatus including a polishing table configured to rotatably support a polishing pad, a top ring configured to press the substrate against the polishing pad, and a polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad; and

an inference process of inferring polishing quality information indicating a polishing quality of the substrate to which the stress indicated by the stress information is applied when the stress information is acquired in the information acquisition process.

[Claim 14] A machine-learning apparatus comprising:

a learning-data storage section storing multiple sets of learning data including polishing conditions and substrate state information, the polishing conditions including top-ring state information indicating a state of a top ring, polishing-table state information indicating a state of a polishing table, and polishing-fluid-supply-nozzle state information indicating a state of a polishing-fluid supply nozzle in chemical mechanical polishing of a substrate performed by a substrate processing apparatus including the polishing table configured to rotatably support a polishing pad, the top ring configured to press the substrate against the polishing pad, and the polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad, the substrate state information indicating a state of the substrate on which the chemical mechanical polishing is performed under the polishing conditions;

a machine-learning section configured to cause a learning model to learn a correlation between the polishing conditions and the substrate state information by inputting the multiple sets of learning data to the learning model; and

a learned-model storage section configured to store the learning model that has

learned the correlation by the machine-learning section.

[Claim 15] A machine-learning apparatus comprising:

a learning-data storage section storing multiple sets of learning data including stress information and polishing quality information, the stress information indicating stress applied to a substrate on which chemical mechanical polishing is performed by a substrate processing apparatus including a polishing table configured to rotatably support a polishing pad, a top ring configured to press the substrate against the polishing pad, and a polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad, the polishing quality information indicating a polishing quality of the substrate to which the stress indicated by the stress information is applied;

a machine-learning section configured to cause a learning model to learn a correlation between the stress information and the polishing quality information by inputting the multiple sets of learning data to the learning model; and

a learned-model storage section configured to store the learning model that has learned the correlation by the machine-learning section.

[Claim 16] An information processing method comprising:

an information acquisition process of acquiring polishing conditions including top-ring state information indicating a state of a top ring, polishing-table state information indicating a state of a polishing table, and polishing-fluid-supply-nozzle state information indicating a state of a polishing-fluid supply nozzle in chemical mechanical polishing of a substrate performed by a substrate processing apparatus including the polishing table configured to rotatably support a polishing pad, the top ring configured to press the substrate against the polishing pad, and the polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad; and

a state prediction process of predicting substrate state information for the substrate on which the chemical mechanical polishing is performed under the polishing

conditions by inputting the polishing conditions acquired in the information acquisition process to a learning model having been generated by machine learning that causes the learning model to learn a correlation between the polishing conditions and the substrate state information indicating a state of the substrate on which the chemical mechanical polishing is performed under the polishing conditions,

wherein the learning model comprises:

a learning model for stress analysis having been generated by machine learning that causes the learning model for stress analysis to learn a correlation between the polishing conditions and stress information indicating stress applied to the substrate on which the chemical mechanical polishing is performed under the polishing conditions; and

a learning model for polishing-quality analysis having been generated by machine learning that causes the learning model for polishing-quality analysis to learn a correlation between the stress information and polishing quality information indicating a polishing quality of the substrate to which the stress indicated by the stress information is applied, and

the state prediction process includes:

predicting the stress information for the substrate on which the chemical mechanical polishing under the polishing conditions is performed by inputting the polishing conditions acquired by the information acquisition section to the learning model for the stress analysis; and

predicting the polishing quality information for the substrate to which the stress indicated by the stress information is applied by inputting the predicted stress information to the learning model for the polishing-quality analysis.

[Claim 17] An inference method executed by an inference apparatus including a memory and a processor, the processor performing:

an information acquisition process of acquiring polishing conditions including

top-ring state information indicating a state of a top ring, polishing-table state information indicating a state of a polishing table, and polishing-fluid-supply-nozzle state information indicating a state of a polishing-fluid supply nozzle in chemical mechanical polishing of a substrate performed by a substrate processing apparatus including the polishing table configured to rotatably support a polishing pad, the top ring configured to press the substrate against the polishing pad, and the polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad; and

an inference process of inferring substrate state information indicating a state of the substrate on which the chemical mechanical polishing is performed under the polishing conditions when the polishing conditions are acquired in the information acquisition process.

[Claim 18] An inference method executed by an inference apparatus including a memory and a processor, the processor performing:

an information acquisition process of acquiring stress information indicating stress applied to a substrate on which chemical mechanical polishing is performed by a substrate processing apparatus including a polishing table configured to rotatably support a polishing pad, a top ring configured to press the substrate against the polishing pad, and a polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad; and

an inference process of inferring polishing quality information indicating a polishing quality of the substrate to which the stress indicated by the stress information is applied when the stress information is acquired in the information acquisition process.

[Claim 19] A machine-learning method comprising:

a learning-data storing process of storing multiple sets of learning data including polishing conditions and substrate state information in a learning-data storage section, the polishing conditions including top-ring state information indicating a state of a top ring,

polishing-table state information indicating a state of a polishing table, and polishing-fluid-supply-nozzle state information indicating a state of a polishing-fluid supply nozzle in chemical mechanical polishing of a substrate performed by a substrate processing apparatus including the polishing table configured to rotatably support a polishing pad, the top ring configured to press the substrate against the polishing pad, and the polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad, the substrate state information indicating a state of the substrate on which the chemical mechanical polishing is performed under the polishing conditions;

a machine-learning process of causing a learning model to learn a correlation between the polishing conditions and the substrate state information by inputting the multiple sets of learning data to the learning model; and

a learning-data storing process of storing multiple sets of learning model that has learned the correlation by the machine-learning process in the learning-data storage section.

[Claim 20] A machine-learning method comprising:

a learning-data storing process of storing multiple sets of learning data including stress information and polishing quality information, the stress information indicating stress applied to a substrate on which chemical mechanical polishing is performed by a substrate processing apparatus including a polishing table configured to rotatably support a polishing pad, a top ring configured to press the substrate against the polishing pad, and a polishing-fluid supply nozzle configured to supply a polishing fluid onto the polishing pad, the polishing quality information indicating a polishing quality of the substrate to which the stress indicated by the stress information is applied;

a machine-learning process of causing a learning model to learn a correlation between the stress information and the polishing quality information by inputting the multiple sets of learning data to the learning model; and

a learning-data storing process of storing multiple sets of learning model that has

learned the correlation by the machine-learning process in the learning-data storage section.