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TSURU

(54) GRINDING APPARATUS

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(57) **ABSTRACT**

To make an improvement in the shape accuracy of a wafer shaped in the grinding operation after pretreatment and make an improvement in the efficiency of grinding operation of a wafer. A grinding apparatus includes at least one plasma generator configured to irradiate, before an outer circumferential edge of a wafer is ground, at least part of the outer circumferential edge with plasma.

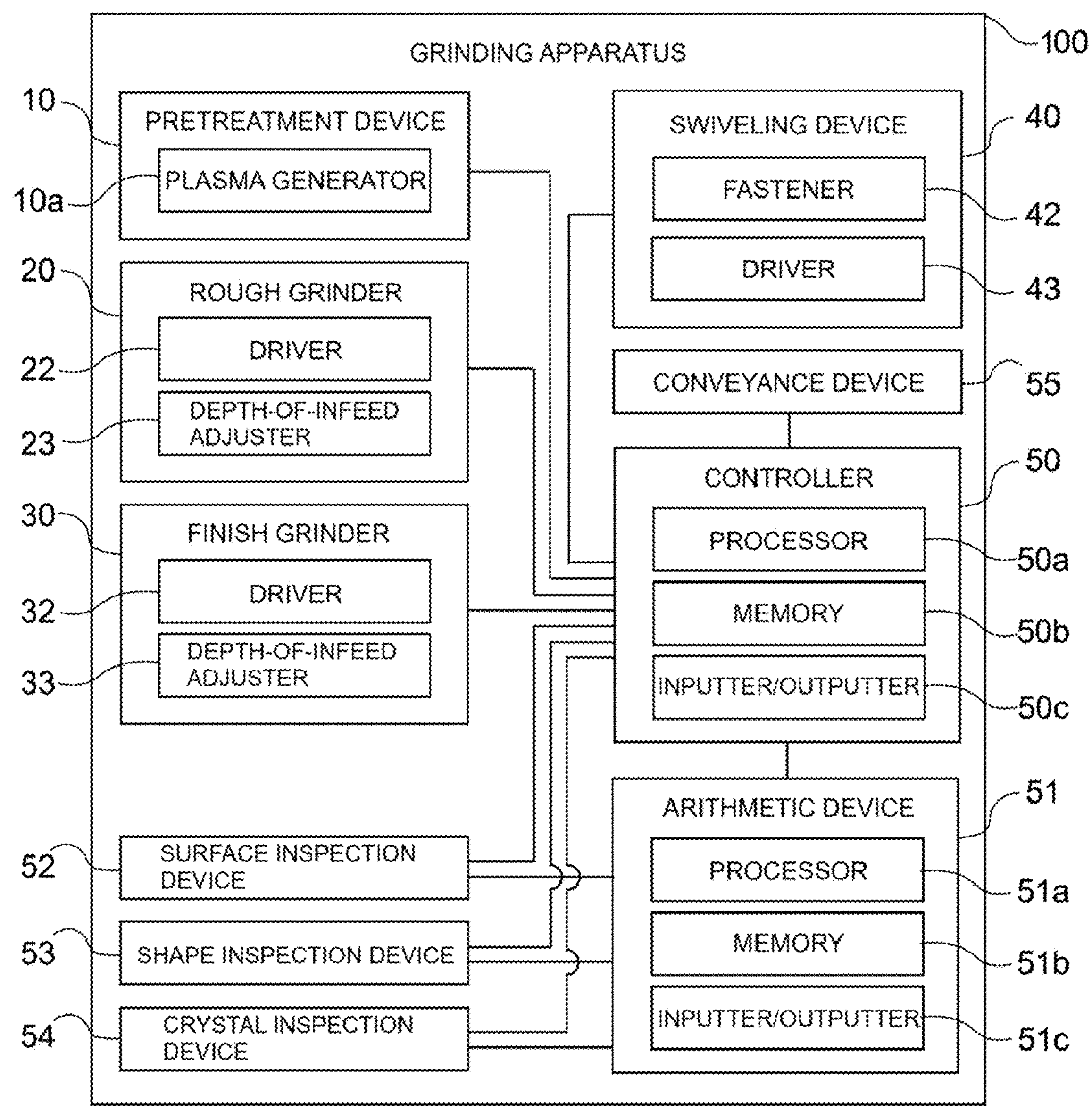


FIG.1

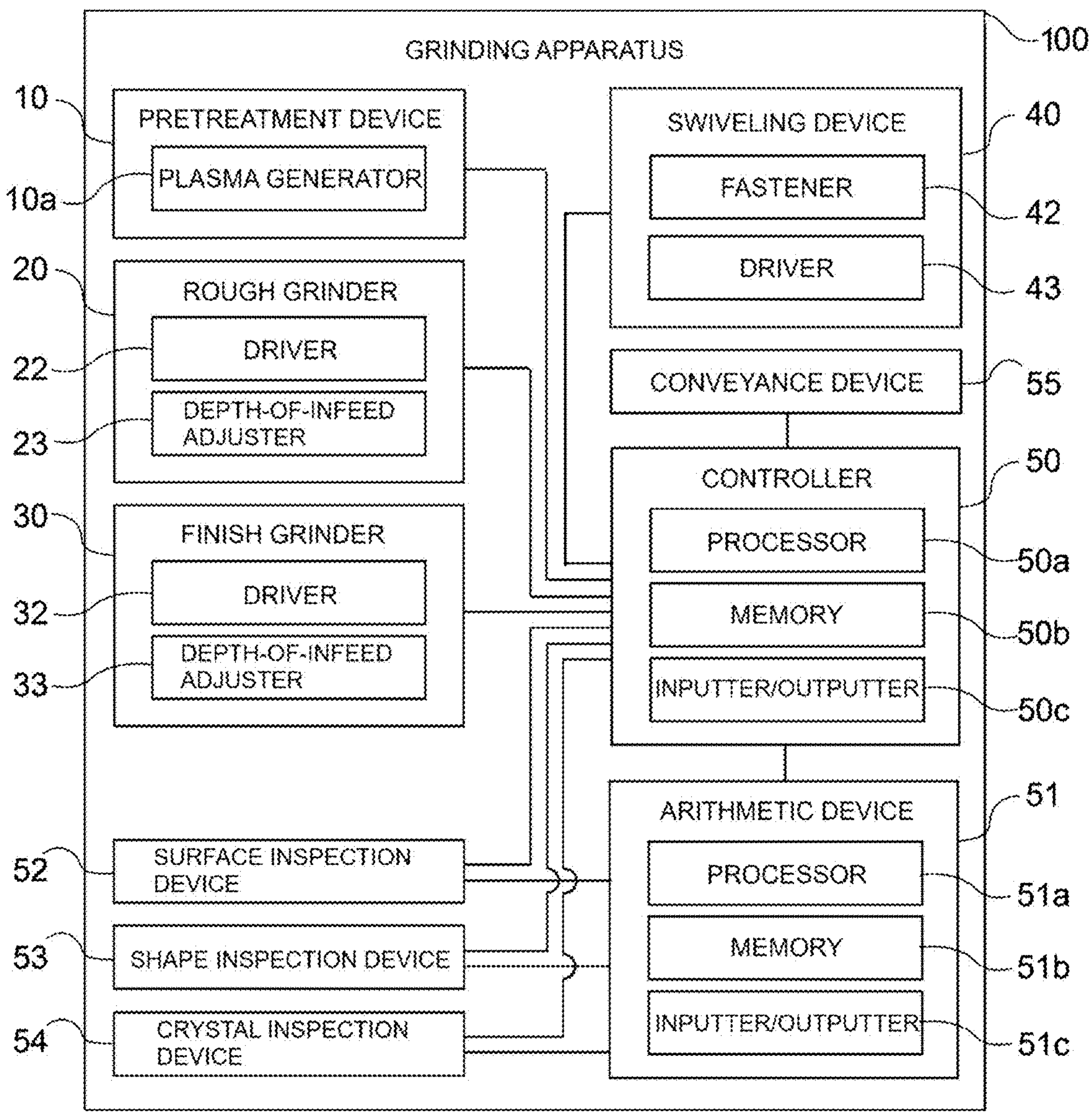

GRINDING APPARATUS
100
10
PRETREATMENT DEVICE
10a
PLASMA GENERATOR
20
ROUGH GRINDER
22
DRIVER
23
DEPTH-OF-INFEED ADJUSTER
30
FINISH GRINDER
32
DRIVER
33
DEPTH-OF-INFEED ADJUSTER
40
SWIVELING DEVICE
42
FASTENER
43
DRIVER
55
CONVEYANCE DEVICE
50
CONTROLLER
50a
PROCESSOR
50b
MEMORY
50c
INPUTTER/OUTPUTTER
51
ARITHMETIC DEVICE
51a
PROCESSOR
51b
MEMORY
51c
INPUTTER/OUTPUTTER
52
SURFACE INSPECTION DEVICE
53
SHAPE INSPECTION DEVICE
54
CRYSTAL INSPECTION DEVICE

FIG.2

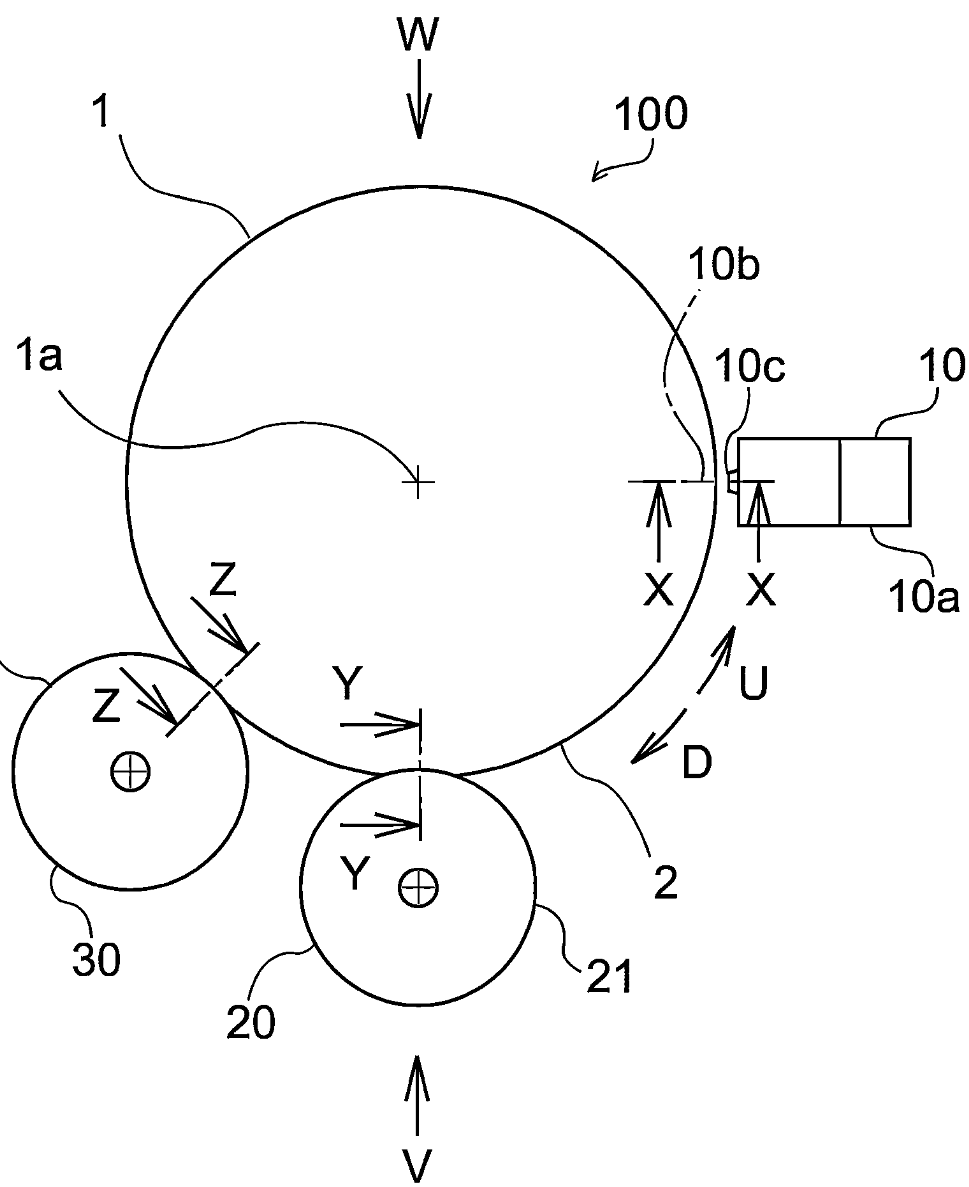


FIG.3

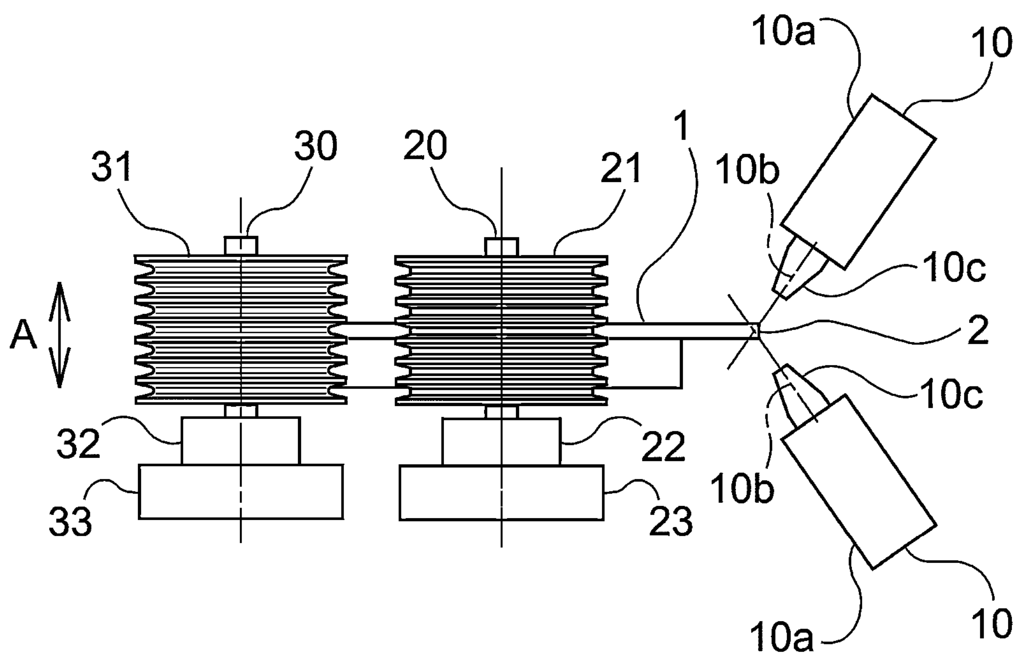


FIG.4

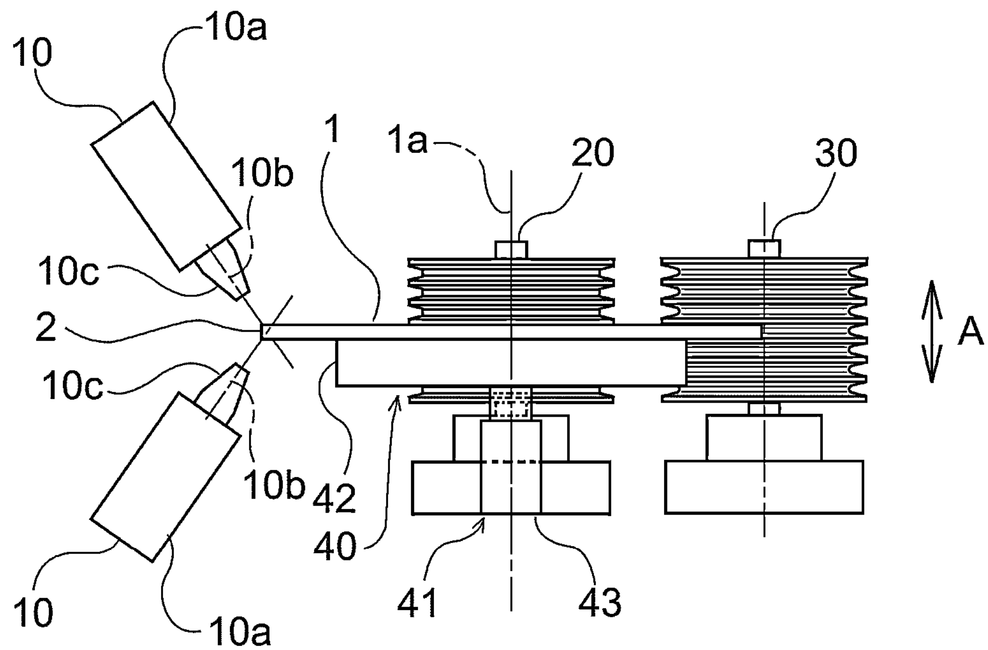


FIG.5

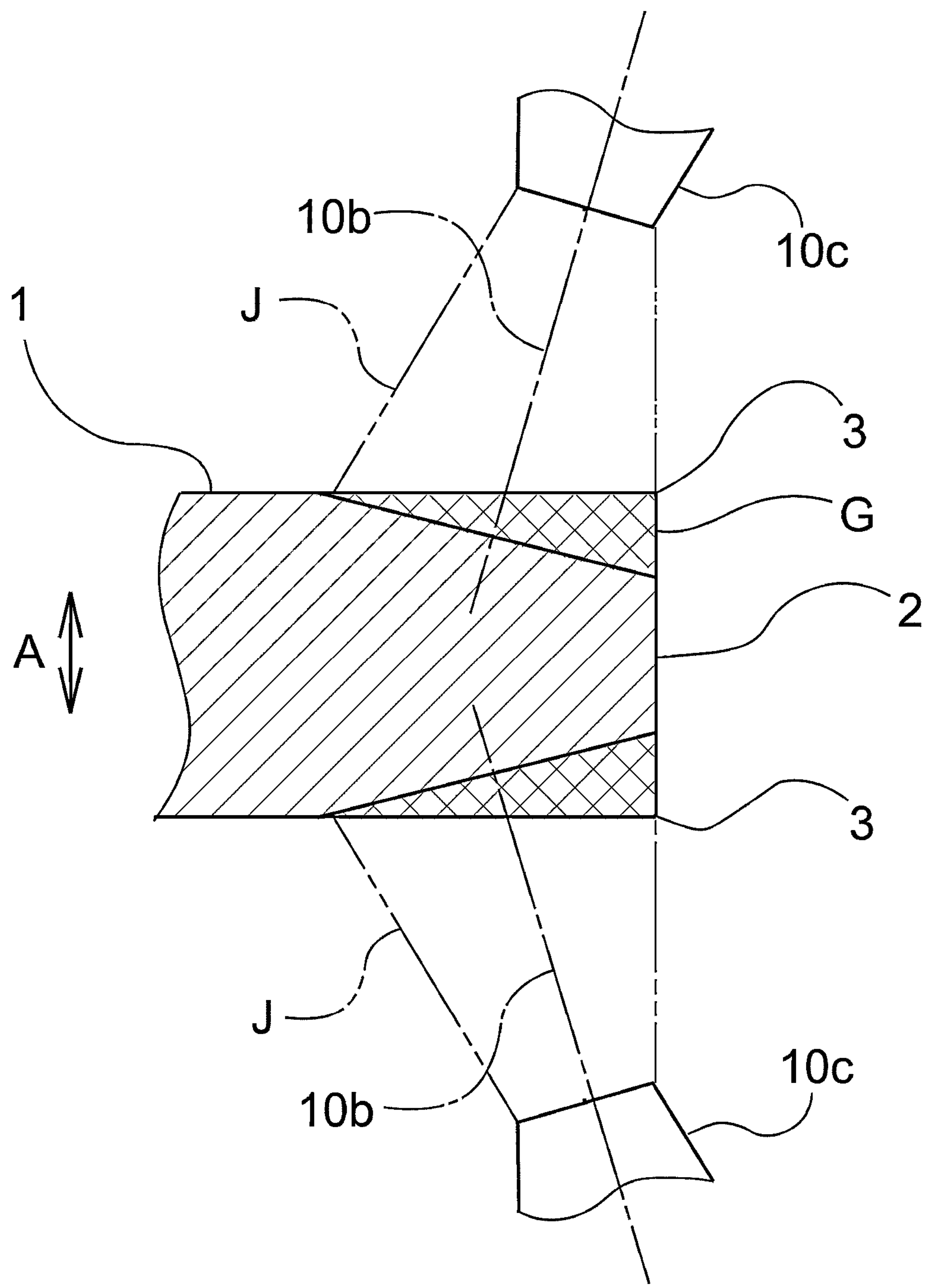


FIG.6

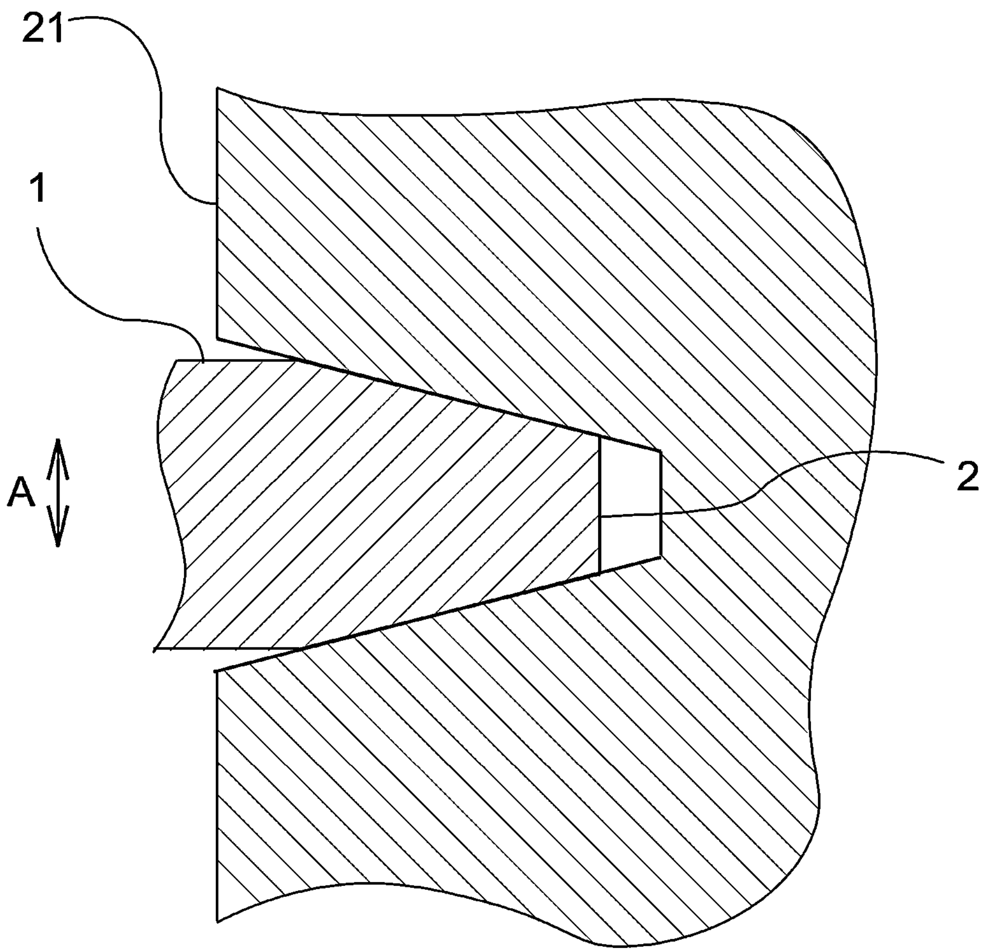


FIG.7

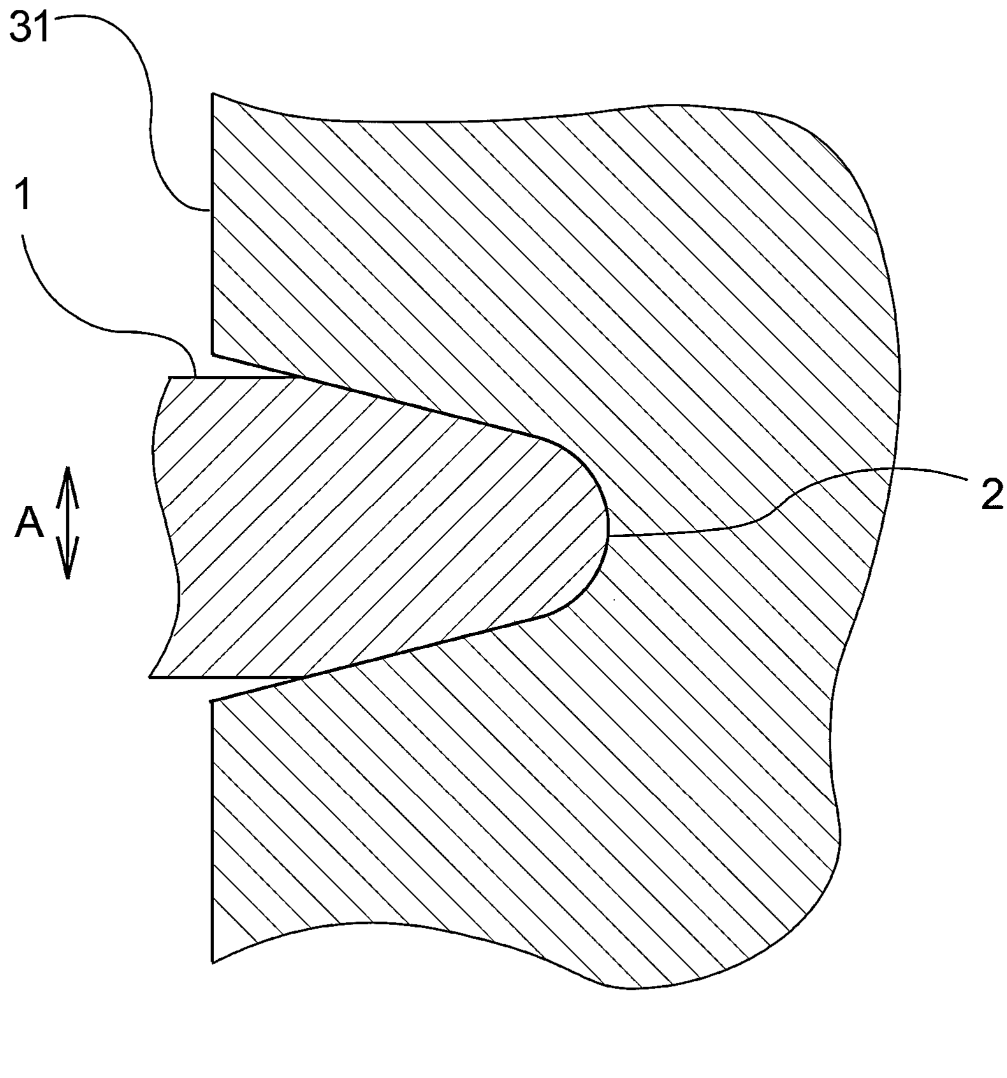


FIG.8

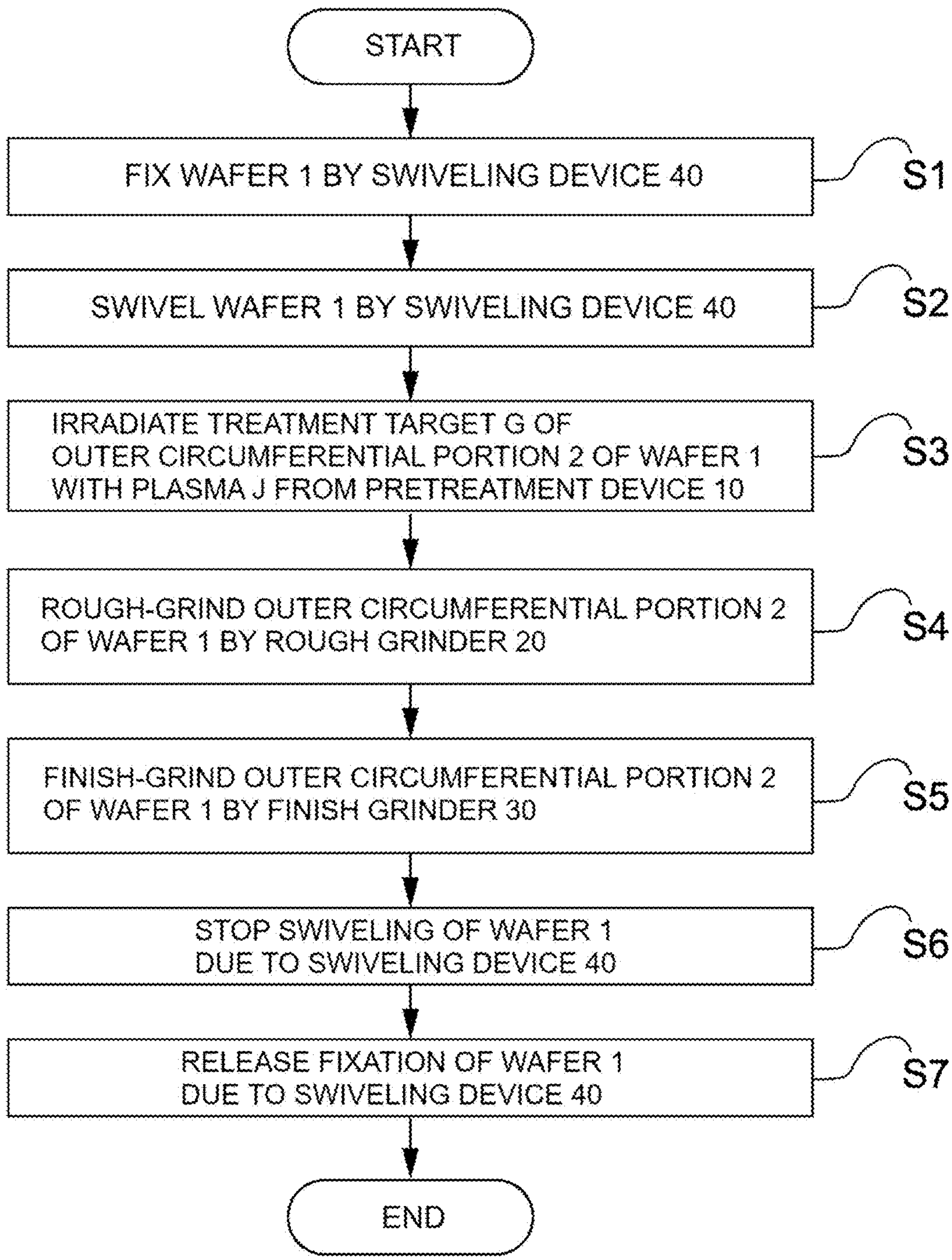

START
FIX WAFER 1 BY SWIVELING DEVICE 40
S1
SWIVEL WAFER 1 BY SWIVELING DEVICE 40
S2
IRRADIATE TREATMENT TARGET G OF OUTER CIRCUMFERENTIAL PORTION 2 OF WAFER 1 WITH PLASMA J FROM PRETREATMENT DEVICE 10
S3
ROUGH-GRIND OUTER CIRCUMFERENTIAL PORTION 2 OF WAFER 1 BY ROUGH GRINDER 20
S4
FINISH-GRIND OUTER CIRCUMFERENTIAL PORTION 2 OF WAFER 1 BY FINISH GRINDER 30
S5
STOP SWIVELING OF WAFER 1 DUE TO SWIVELING DEVICE 40
S6
RELEASE FIXATION OF WAFER 1 DUE TO SWIVELING DEVICE 40
S7
END

FIG.9

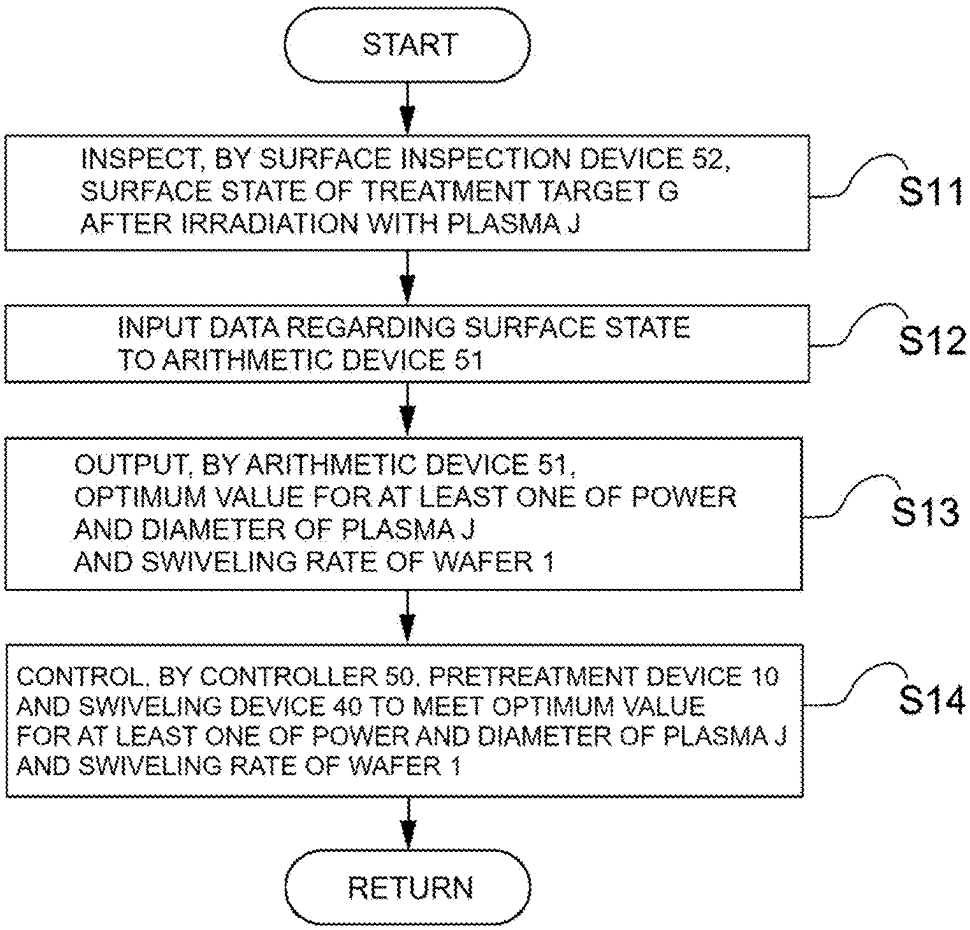

START
INSPECT, BY SURFACE INSPECTION DEVICE 52, SURFACE STATE OF TREATMENT TARGET G AFTER IRRADIATION WITH PLASMA J
S11
INPUT DATA REGARDING SURFACE STATE TO ARITHMETIC DEVICE 51
S12
OUTPUT, BY ARITHMETIC DEVICE 51, OPTIMUM VALUE FOR AT LEAST ONE OF POWER AND DIAMETER OF PLASMA J AND SWIVELING RATE OF WAFER 1
S13
CONTROL, BY CONTROLLER 50, PRETREATMENT DEVICE 10 AND SWIVELING DEVICE 40 TO MEET OPTIMUM VALUE FOR AT LEAST ONE OF POWER AND DIAMETER OF PLASMA J AND SWIVELING RATE OF WAFER 1
S14
RETURN

FIG.10

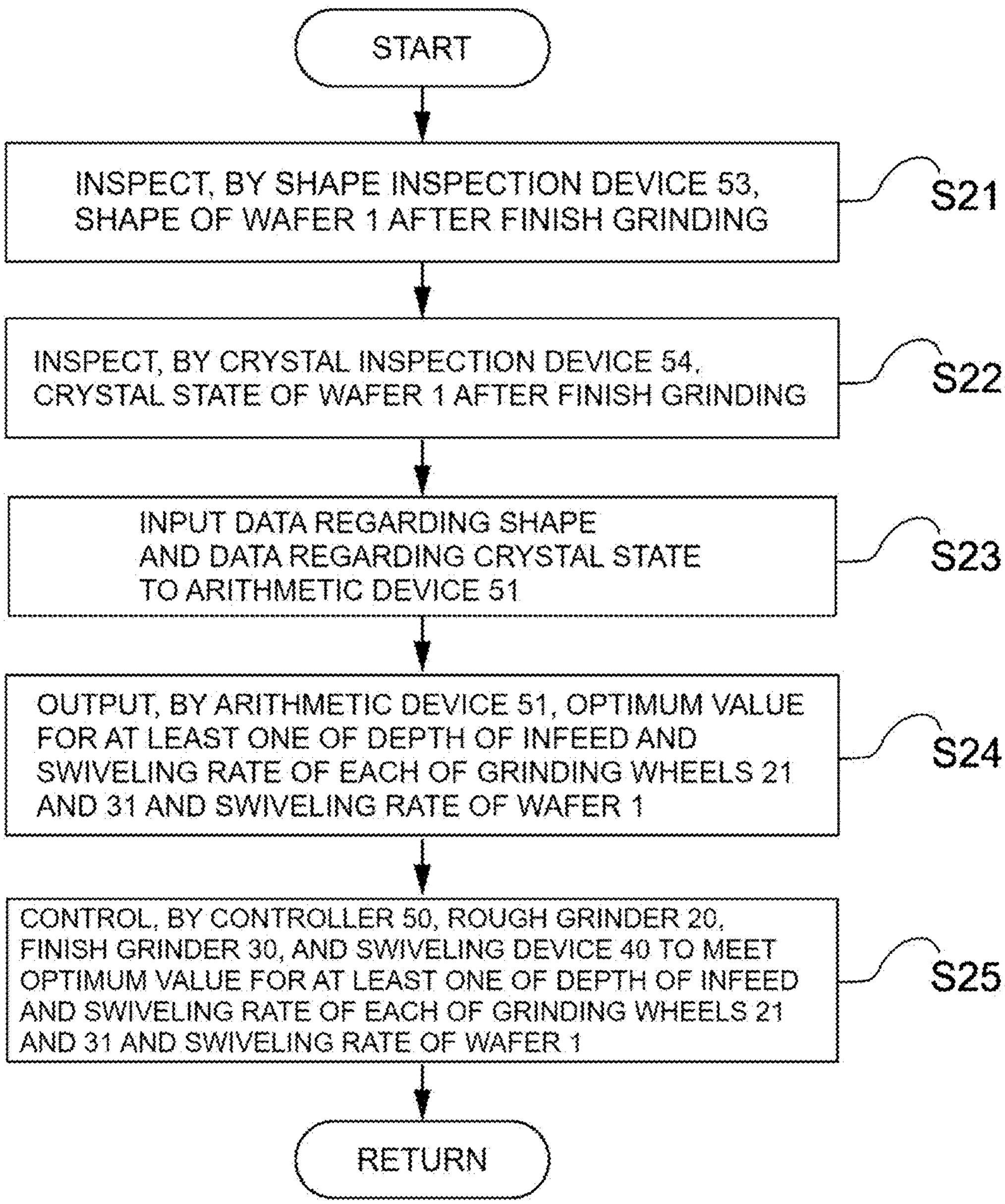

START
INSPECT, BY SHAPE INSPECTION DEVICE 53, SHAPE OF WAFER 1 AFTER FINISH GRINDING
S21
INSPECT, BY CRYSTAL INSPECTION DEVICE 54, CRYSTAL STATE OF WAFER 1 AFTER FINISH GRINDING
S22
INPUT DATA REGARDING SHAPE AND DATA REGARDING CRYSTAL STATE TO ARITHMETIC DEVICE 51
S23
OUTPUT, BY ARITHMETIC DEVICE 51, OPTIMUM VALUE FOR AT LEAST ONE OF DEPTH OF INFEED AND SWIVELING RATE OF EACH OF GRINDING WHEELS 21 AND 31 AND SWIVELING RATE OF WAFER 1
S24
CONTROL, BY CONTROLLER 50, ROUGH GRINDER 20, FINISH GRINDER 30, AND SWIVELING DEVICE 40 TO MEET OPTIMUM VALUE FOR AT LEAST ONE OF DEPTH OF INFEED AND SWIVELING RATE OF EACH OF GRINDING WHEELS 21 AND 31 AND SWIVELING RATE OF WAFER 1
S25
RETURN

FIG.11

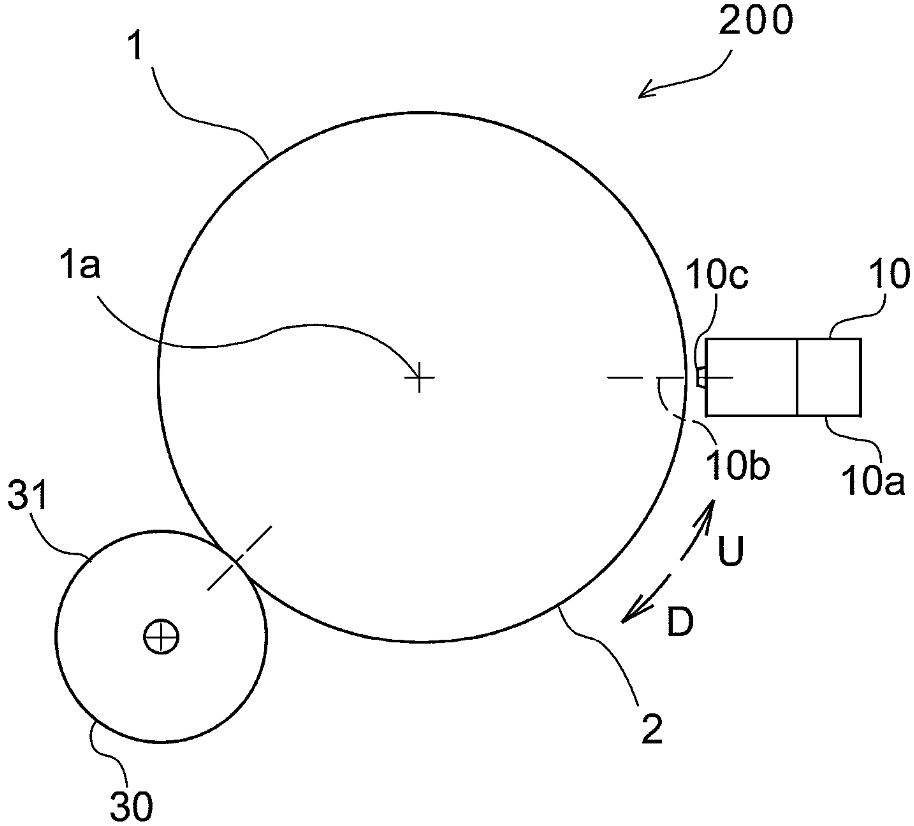


FIG.12

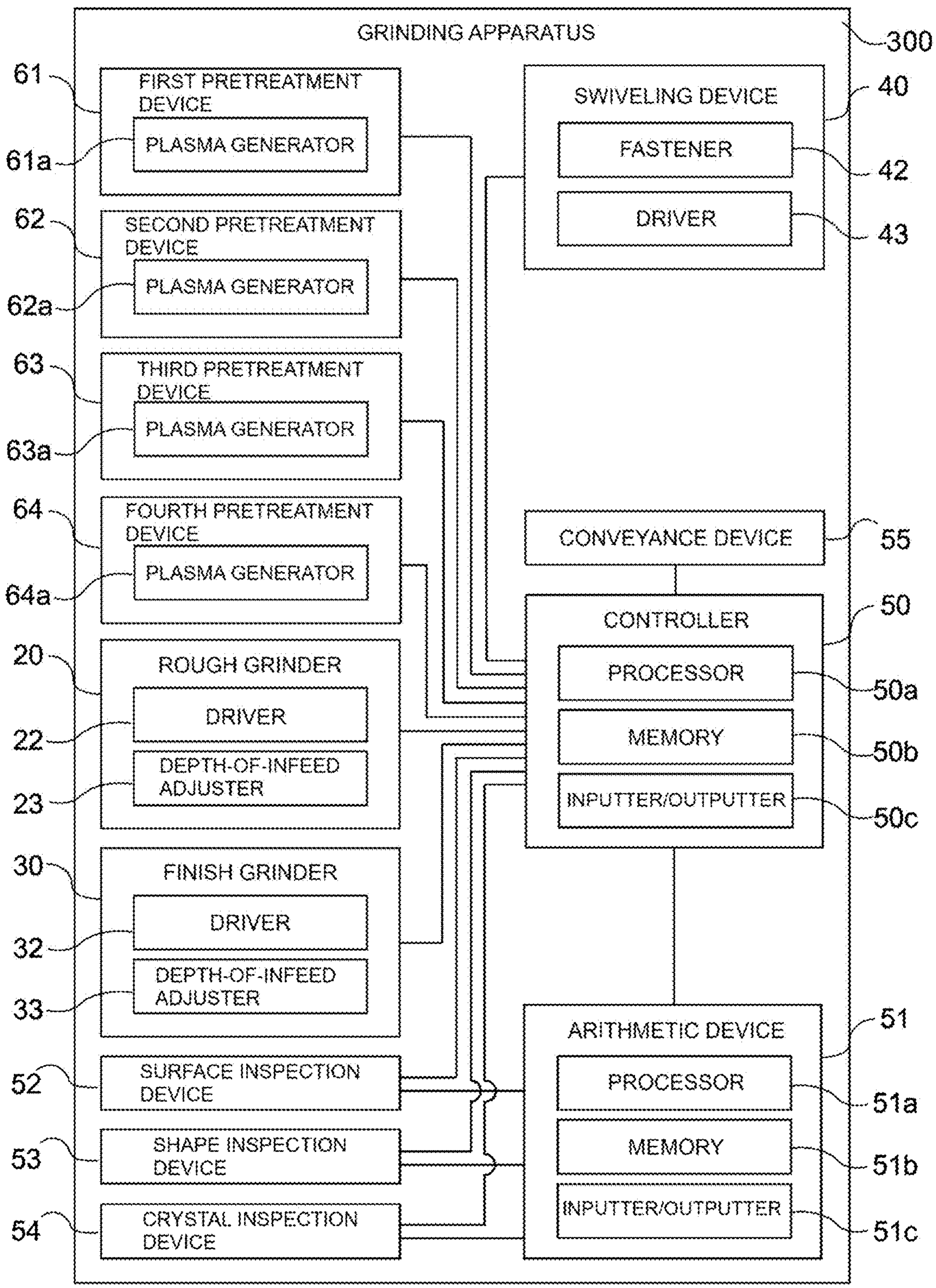

GRINDING APPARATUS
300
61
FIRST PRETREATMENT DEVICE
61a
PLASMA GENERATOR
62
SECOND PRETREATMENT DEVICE
62a
PLASMA GENERATOR
63
THIRD PRETREATMENT DEVICE
63a
PLASMA GENERATOR
64
FOURTH PRETREATMENT DEVICE
64a
PLASMA GENERATOR
20
ROUGH GRINDER
22
DRIVER
23
DEPTH-OF-INFEED ADJUSTER
30
FINISH GRINDER
32
DRIVER
33
DEPTH-OF-INFEED ADJUSTER
52
SURFACE INSPECTION DEVICE
53
SHAPE INSPECTION DEVICE
54
CRYSTAL INSPECTION DEVICE
40
SWIVELING DEVICE
42
FASTENER
43
DRIVER
55
CONVEYANCE DEVICE
50
CONTROLLER
50a
PROCESSOR
50b
MEMORY
50c
INPUTTER/OUTPUTTER
51
ARITHMETIC DEVICE
51a
PROCESSOR
51b
MEMORY
51c
INPUTTER/OUTPUTTER

FIG.13

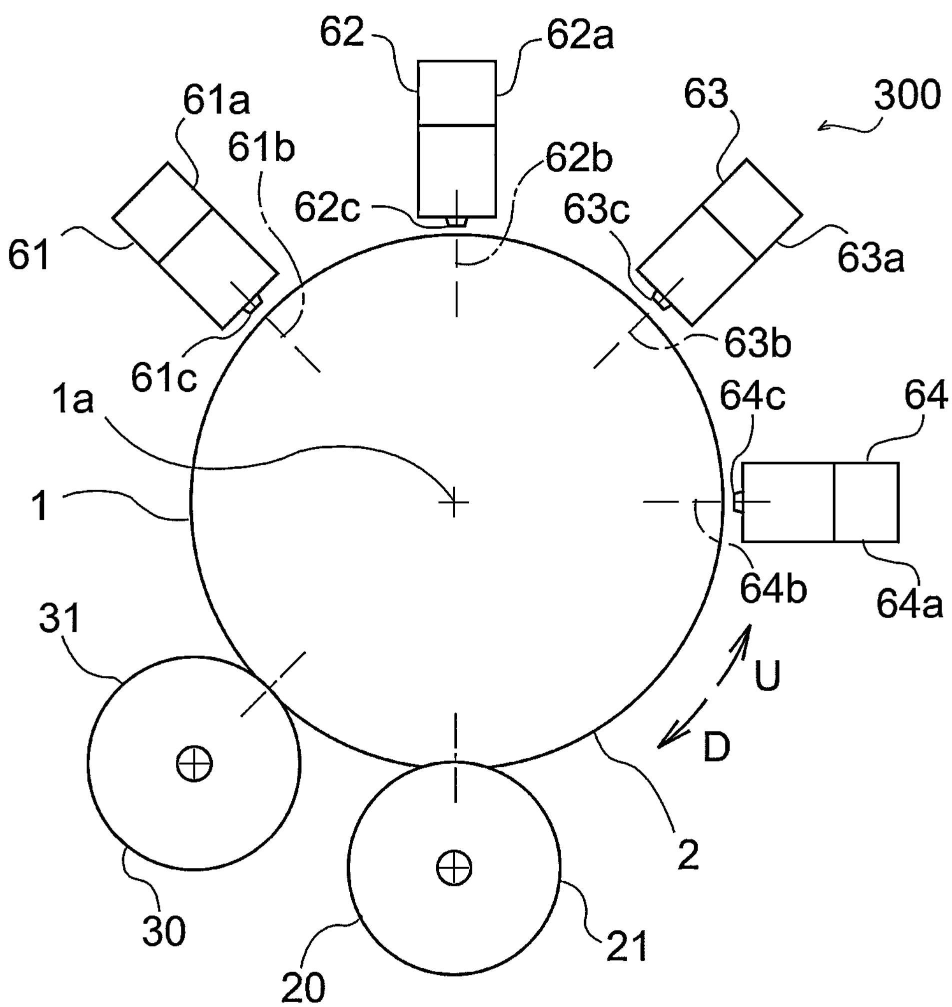

62
62a
61a
61b
300
63
62b
62c
63c
61
63a
61c
63b
1a
64c
64
1
64b
64a
31
U
D
2
30
20
21

FIG.14

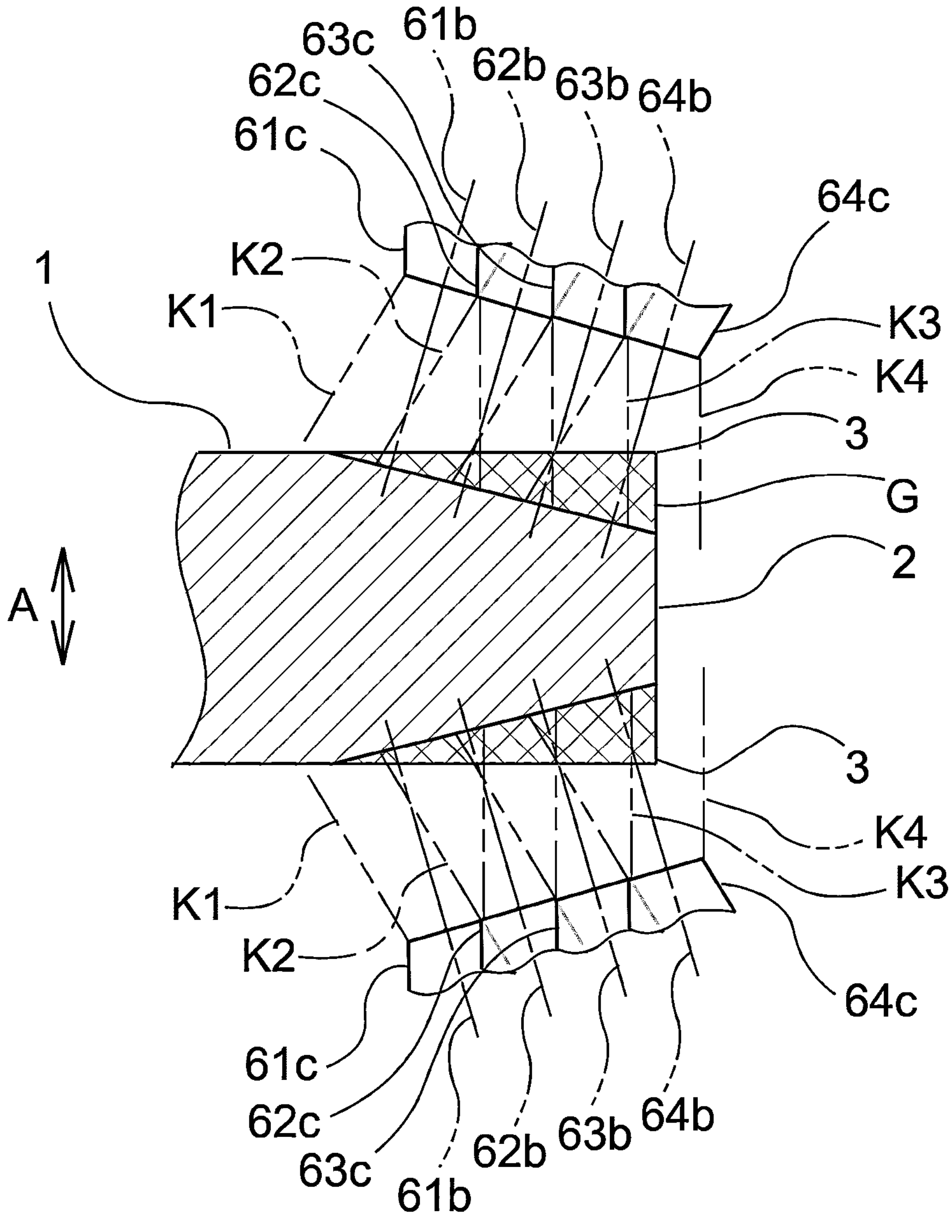
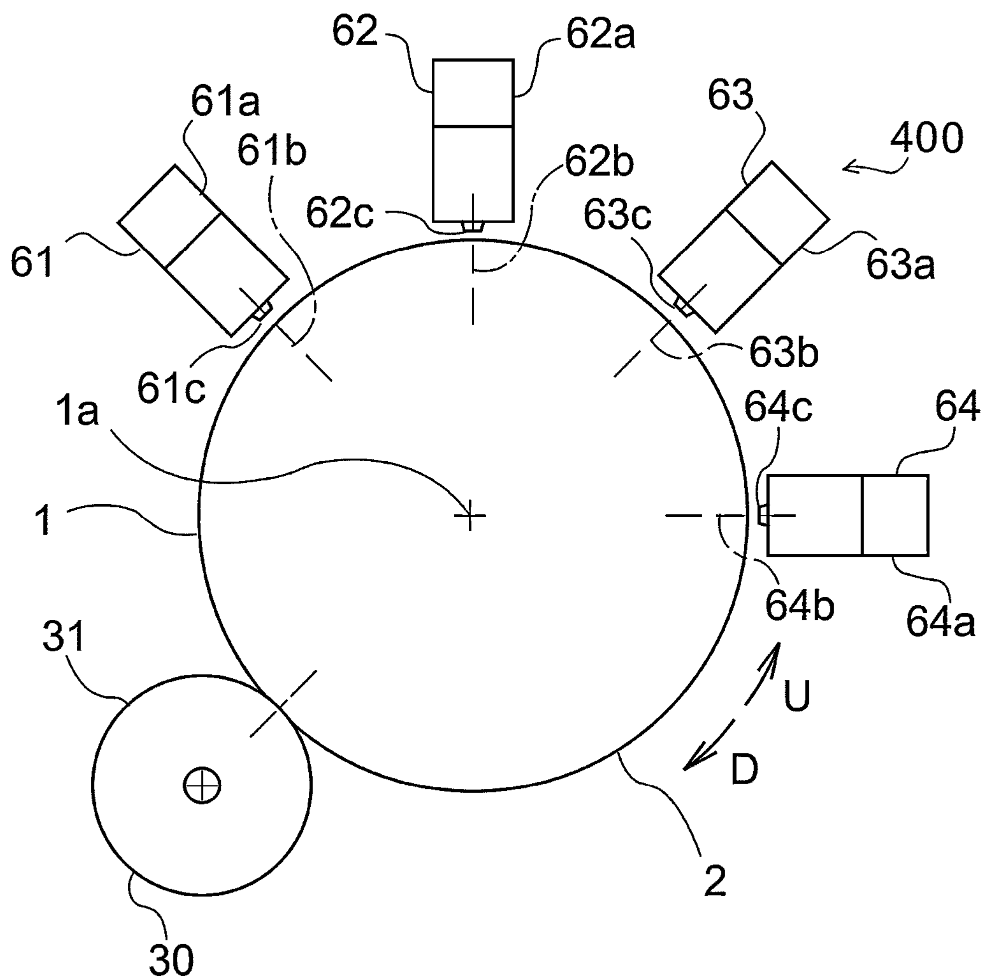

63c
61b
62b
63b
64b
62c
61c
64c
K2
1
K1
K3
K4
3
G
A
2
3
K4
K3
K1
K2
64c
61c
62c
63c
61b
62b
63b
64b

FIG.15


62
62a
61a
61b
63
400
62b
62c
63c
61
63a
63b
61c
1a
64c
64
1
64b
64a
31
U
D
2
30

GRINDING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Japanese Application No. 2024-024704, filed Feb. 21, 2024, the disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a grinding apparatus.

2. Description of the Related Art

[0003] A wafer produced from a monocrystalline raw material is used to produce a semiconductor. In particular, a silicon carbide (SiC) wafer produced from monocrystalline SiC is used to produce a SiC semiconductor. In a process of producing such a SiC semiconductor, a step of growing an epitaxial thin film on a SiC wafer (epitaxial growth step) is performed, so that a SiC epitaxial wafer is produced.

[0004] However, a defect occurs easily at the outer circumferential portion of such a SiC epitaxial wafer, and thus a grinding technique is used to grind the outer circumferential portion of a SiC wafer in a step before the epitaxial growth step. An example of such a grinding technique is a technique as disclosed in Japanese Patent Application Laid-open No. 2016-032002, in which the outer circumferential end of a SiC wafer is rough-polished by a grindstone such as a metal bonded grindstone and then the outer circumferential end of the SiC wafer is finish-polished by a grindstone such as a resin bonded grindstone.

SUMMARY OF THE INVENTION

[0005] However, in the above exemplary grinding technique, a SiC wafer to be subjected to rough polishing is a hard-to-cut material and has a sharp edge. A grindstone used to rough-polish such a SiC wafer abrades easily and further repetition of rough polishing is likely to cause a change in the shape of the grindstone.

[0006] Due to such a change in the shape of the grindstone for rough polishing, the shape accuracy of the SiC wafer is likely to deteriorate after rough polishing shaped by the grindstone. Furthermore, the shape accuracy of the SiC wafer is likely to deteriorate after finish polishing. In addition, due to a change in the shape of the grindstone for rough polishing, the operation of maintenance, such as replacement of the grindstone, is required to be frequently performed. This causes a deterioration in operation efficiency of grinding a SiC wafer.

[0007] In consideration of such a situation, embodiments of the present invention provide a grinding apparatus enabling an improvement in the shape accuracy of a wafer shaped due to the grinding operation and an improvement in operation efficiency of grinding a wafer.

[0008] Embodiments of the present invention to address the above-described problems are as follows.

[0009] [1] A grinding apparatus including at least one plasma generator configured to irradiate, before an outer circumferential edge of a wafer is ground, at least part of the outer circumferential edge with plasma.

[0010] [2] The grinding apparatus according to [1], in which the plasma generator includes a plurality of plasma generators, the plasma generators each include a nozzle configured to emit the plasma, and the nozzles of the plasma generators face two edge portions in a thickness direction of the outer circumferential edge of the wafer in one-to-one correspondence to irradiate the two edge portions with the plasma.

[0011] [3] The grinding apparatus according to [2], in which the nozzles of the plasma generators are each provided inclinably.

[0012] [4] The grinding apparatus according to [1], further including: a swiveling device for swiveling the wafer around a central axis of the wafer; and a grinder including a grinding wheel configured to grind an outer circumferential portion of the wafer, and a driver configured to swivel the grinding wheel, in which the plasma generator is capable of irradiating, with the plasma, a pretreatment target that moves in a circumferential direction of the wafer due to swiveling of the wafer around the central axis.

[0013] [5] The grinding apparatus according to [4], further including: a controller; and an arithmetic device capable of calculating at least either an optimum condition for irradiation with the plasma by the plasma generator or an optimum condition for grinding by the grinder, in which the controller is capable of controlling at least one of the plasma generator and the grinder to meet at least either the optimum condition for irradiation with the plasma or the optimum condition for grinding, calculated by the arithmetic device.

[0014] [6] The grinding apparatus according to [5], further including a surface inspection device capable of inspecting a surface state of the wafer, in which the arithmetic device is capable of calculating, as the optimum condition for irradiation with the plasma, an optimum value for at least one of a diameter and power of the plasma and a swiveling rate of the wafer, based on data regarding the surface state, and the controller is capable of controlling the plasma generator and the swiveling device to meet the optimum value.

[0015] [7] The grinding apparatus according to [5], further including at least either a shape inspection device capable of inspecting a shape of the wafer or a crystal inspection device capable of inspecting a crystal state of the wafer, in which the arithmetic device is capable of calculating, as the optimum condition for grinding, an optimum value for at least one of a depth of infeed and a swiveling rate of the grinding wheel and a swiveling rate of the wafer, based on at least either the shape or the crystal state, and the controller is capable of controlling the grinder and the swiveling device to meet the optimum value.

[0016] [8] The grinding apparatus according to [4], including the plasma generators mutually spaced in a circumferential direction of the wafer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a block diagram of a grinding apparatus according to a first embodiment;

[0018] FIG. **2** is a schematic plan view of main parts of the grinding apparatus according to the first embodiment;

[0019] FIG. **3** is a view in the direction of an arrow V of FIG. **2**;

[0020] FIG. **4** is a view in the direction of an arrow W of FIG. **2**;

[0021] FIG. **5** is a sectional view taken along line X-X of FIG. **2**;

[0022] FIG. **6** is a sectional view taken along line Y-Y of FIG. **2**;

[0023] FIG. **7** is a sectional view taken along line Z-Z of FIG. **2**;

[0024] FIG. **8** is a flowchart for describing a grinding method using the grinding apparatus according to the first embodiment;

[0025] FIG. **9** is a flowchart for describing a method for optimizing the condition for irradiation with plasma by a pretreatment device in the grinding apparatus according to the first embodiment;

[0026] FIG. **10** is a flowchart for describing a method for optimizing the condition for grinding in the grinding apparatus according to the first embodiment;

[0027] FIG. **11** is a schematic plan view of main parts of a grinding apparatus according to a second embodiment;

[0028] FIG. **12** is a block diagram of a grinding apparatus according to a third embodiment;

[0029] FIG. **13** is a schematic plan view of main parts of the grinding apparatus according to the third embodiment;

[0030] FIG. **14** is a sectional view schematically illustrating a state where two edge portions in the outer circumferential portion of a wafer are each irradiated with plasma in the third embodiment; and

[0031] FIG. **15** is a schematic plan view of a grinding apparatus according to a fourth embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

[0032] Respective grinding apparatuses according to first to fourth embodiments will be described below.

[0033] The grinding apparatus according to the first embodiment will be described below with reference to FIGS. **1** to **9**. Referring to FIGS. **1** to **7**, the grinding apparatus according to the present embodiment is roughly configured as follows.

[0034] Referring to FIGS. **1** to **5**, for grinding an outer circumferential portion **2** of a disk-shaped wafer **1**, a grinding apparatus **100** according to the present embodiment enables plasma irradiation, as a treatment before grinding with a grindstone, to a treatment target G (indicated with shading in a lattice pattern in FIG. **5**) that is at least part of the outer circumferential portion **2** of the wafer **1**. In other words, the grinding apparatus **100** enables plasma-assisted grinding. The grinding apparatus **100** includes a pretreatment device **10** including a plasma generator **10***a* capable of irradiating the treatment target G with plasma J to modify the treatment target G.

[0035] As illustrated in FIGS. **2** to **5**, the grinding apparatus **100** includes two plasma generators **10***a*. Each plasma generator **10***a* includes a nozzle **10***c* capable of emitting plasma J outward along its irradiation axis **10***b*. However, the grinding apparatus **100** can include a single plasma generator or three or more plasma generators.

[0036] The wafer **1** serves as a silicon carbide (SiC) wafer **1**. As illustrated in FIG. **5**, the outer circumferential portion **2** of the wafer **1** includes, as the treatment target G, two edge portions **3** located one-to-one at both ends in the direction of the central axis of the wafer **1** (indicated with a double-headed arrow A). The respective nozzles **10***c* of the two plasma generators **10***a* are disposed facing one-to-one the two edge portions **3** such that the two edge portions **3** can be irradiated one-to-one with the plasma J from one of the two plasma generators **10***a* and with the plasma J from the other.

[0037] In the wafer **1**, each edge portion **3** has a shape identical to a shape to be removed by chamfering. The two plasma generators **10***a* are mutually spaced in the direction of the central axis of the wafer **1**. The nozzle **10***c* of each plasma generator **10***a* is disposed with its irradiation axis **10***b* at an angle such that the facing edge portion **3** can be irradiated with the plasma J corresponding to the shape of the facing edge portion **3**.

[0038] Next, referring to FIGS. **1** to **7**, the grinding apparatus **100** according to the present embodiment is roughly configured as follows. As illustrated in FIGS. **1** to **5**, the grinding apparatus **100** includes the above-described pretreatment device **10**. The plasma generator **10***a* of the pretreatment device **10** is capable of irradiating, with the plasma J, the treatment target G that moves in the circumferential direction of the wafer **1** (indicated with two single-headed arrows U and D) due to swiveling of the wafer **1** around its central axis **1***a*.

[0039] As illustrated in FIGS. **1** to **4** and FIGS. **6** and **7**, the grinding apparatus **100** includes two grinders (rough grinder **20** and finish grinder **30**) capable of grinding the outer circumferential portion **2** of the wafer **1**. One of the two grinders and the other include, respectively, a grinding wheel **21** and a grinding wheel **31** capable of grinding the outer circumferential portion **2** of the wafer **1** that moves from one side (indicated with the single-headed arrow U in FIG. **2**) to the other side (indicated with the single-headed arrow D in FIG. **2**) in the circumferential direction of the wafer **1** due to swiveling of the wafer **1**. The one of the two grinders and the other include, respectively, a driver **22** and a driver **32** capable of swiveling, respectively, the grinding wheel **21** and the grinding wheel **31** counter to the movement of the wafer **1**.

[0040] As illustrated in FIGS. **1** and **4**, the grinding apparatus **100** includes a swiveling device **40** for swiveling the wafer **1** around the central axis **1***a* at the time of pretreatment of the wafer **1** by the pretreatment device **10** or at the time of grinding of the wafer **1** by the grinders. As illustrated in FIG. **1**, the grinding apparatus **100** includes a controller **50** capable of controlling the pretreatment device **10**, the grinders, and the swiveling device **40**.

[0041] The grinding apparatus **100** includes an arithmetic device **51** capable of calculating at least either an optimum condition for irradiation with the plasma J by the pretreatment device **10** or an optimum condition for grinding by the grinders. The controller **50** is capable of controlling at least one of the pretreatment device **10** (plasma generator), the grinders, and the swiveling device **40** to meet at least either the optimum condition for irradiation with the plasma J or the optimum condition for grinding, calculated by the arithmetic device **51**.

[0042] The grinding apparatus **100** includes a surface inspection device **52** capable of inspecting the surface state of the treatment target G modified by the pretreatment device **10**. On the basis of data regarding the surface state of the treatment target G obtained by the surface inspection device **52**, the arithmetic device **51** is capable of calculating, as the optimum condition for irradiation with the plasma J, an optimum value for at least one of the power and diameter of the plasma J and the swiveling rate of the wafer **1**. The controller **50** is capable of controlling the pretreatment device **10** (plasma generator) and the swiveling device **40** to meet the optimum value for at least one of the power and diameter of the plasma J and the swiveling rate of the wafer **1**, calculated by the arithmetic device **51**.

[0043] The grinding apparatus **100** includes at least either a shape inspection device **53** capable of inspecting the shape of the wafer **1** ground by the grinders or a crystal inspection device **54** capable of inspecting the crystal state of the wafer **1** ground by the grinders.

[0044] On the basis of at least either data regarding the shape of the wafer **1** obtained by the shape inspection device **53** or data regarding the crystal state of the wafer **1** obtained by the crystal inspection device **54**, the arithmetic device **51** is capable of calculating, as the optimum condition for grinding, an optimum value for at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** and the swiveling rate of the wafer **1**. The controller **50** is capable of controlling the grinders and the swiveling device **40** to meet the optimum value for at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** and the swiveling rate of the wafer **1**, calculated by the arithmetic device **51**.

[0045] As illustrated in FIG. **4**, the swiveling device **40** includes a swiveling mechanism **41** that swivels the wafer **1** around the central axis **1***a* at a certain position at the time of pretreatment of the wafer **1** by the pretreatment device **10** or at the time of grinding of the wafer **1** by the grinders. The pretreatment device **10** is disposed on one side in the circumferential direction of the wafer **1** with respect to the grinders.

[0046] However, the swiveling device is not limited to this. For example, the swiveling device can separately include a swiveling mechanism for pretreatment that swivels the wafer around its central axis at the time of pretreatment of the wafer by the pretreatment device and a swiveling mechanism for grinding that swivels the wafer around its central axis at the time of grinding of the wafer by the grinders. In this case, the swiveling mechanism for pretreatment and the swiveling mechanism for grinding are disposed away from each other. In addition, the wafer can be conveyed between the swiveling mechanism for pretreatment and the swiveling mechanism for grinding by a conveyance device described later.

[0047] Specifically, the wafer **1** as a target to be processed can be provided as follows. The type of the wafer **1** will be described. First, as described above, a SiC wafer **1** can be used as the wafer **1**. That is, SiC can be used as the raw material of the wafer **1**. In particular, as the raw material of the SiC wafer, 4H-SiC, 6H-SiC, 3C-SiC, or the like can be used. However, as the raw material of the wafer, silicon (Si), gallium arsenide (GaAs), or the like can be used.

[0048] As illustrated in FIG. **5**, the treatment target G of the wafer **1** includes two edge portions **3** in the outer circumferential portion **2** of the wafer **1**. In a case where a section of the outer circumferential portion **2** of the wafer **1** taken along the central axis **1***a* of the wafer **1** is viewed, the range of each edge portion **3** can be regarded as a substantially triangular range. The range of each edge portion **3** can be defined as a range surrounded by a first side along one face in the direction of the central axis of the wafer **1**, a second side along the outer circumferential face of the wafer **1**, and a third side that extends inside the wafer **1** and connects the one face and the outer circumferential face.

[0049] Referring to FIGS. **1** to **5**, specifically, the grinding apparatus **100** according to the present embodiment can be provided as follows. In the grinding apparatus **100**, the plasma generators **10***a* each serve as a plasma jet generator. The plasma generators **10***a* as above are capable of irradiation with a water vapor plasma jet under atmospheric pressure. However, the plasma generators are not limited to such a plasma jet generator. For example, the plasma generators may be each a plasma torch.

[0050] The treatment target G irradiated with the plasma J by each plasma generator **10***a* is modified as follows. In a case where the raw material of the wafer **1** is SiO, particularly, 4H-SiO, OH radicals are generated as reactive species in response to plasma irradiation to the treatment target G of the wafer **1** by each plasma generator **10***a*. Due to such hydroxyl (OH) radicals, the treatment target G is modified to SiO2. In this case, the treatment target G softens as a result.

[0051] The plasma generators **10***a* can be each configured to perform raster scanning such that scanning with the plasma J along the radial direction of the wafer **1** is performed all over the edge portion **3** facing its nozzle **10***c*. In this case, the position of arrangement of each nozzle **10***c*, the power and diameter of the plasma J from each nozzle **10***c*, and the swiveling rate of the wafer **1** can be adjusted as appropriate to accurately modify the entirety of the edge portion **3** facing the corresponding nozzle **10***c*.

[0052] The plasma J for irradiation from the nozzle **10***c* of each plasma generator **10***a* is emitted along the irradiation axis **10***b*. The irradiation axis **10***b* is substantially identical to the central axis of the plasma J. Furthermore, the pretreatment device **10** is configured to allow simultaneous emission of plasma J from two plasma generators **10***a*. Due to the two plasma generators **10***a*, two edge portions **3** can be simultaneously irradiated with the plasma J. As an example, the maximum output of each plasma generator **10***a* can be set to approximately 1.5 kW.

[0053] Next, referring to FIGS. **1** to **7**, specifically, the grinding apparatus **100** according to the present embodiment can be configured as follows. The grinding apparatus **100** includes two grinders.

[0054] As illustrated in FIGS. **1** to **4** and FIG. **6**, one of the two grinders serves as the rough grinder **20** capable of rough-grinding the outer circumferential portion **2** of the wafer **1** pretreated by the pretreatment device **10**. As illustrated in FIGS. **1** to **4** and FIG. **7**, the other of the two grinders serves as the finish grinder **30** (precision grinder) capable of finish-grinding the outer circumferential portion **2** of the wafer **1** rough-ground by the rough grinder **20**. As illustrated in FIG. **2**, the rough grinder **20** is located on one side (indicated with the single-headed arrow U) in the rotational direction of the wafer **1** with respect to the finish grinder **30**.

[0055] As illustrated in FIGS. **2** to **4** and FIG. **6**, the rough grinder **20** includes the grinding wheel **21** capable of rough-grinding the outer circumferential portion **2** of the wafer **1** after pretreatment by the pretreatment device **10**. The grinding wheel **21** is formed such that at least the two edge portions **3** in the outer circumferential portion **2** of the wafer **1** can be ground. At the time of rough grinding by the rough grinder **20**, the outer circumferential portion **2** of the wafer **1** moves from one side to the other side in the circumferential direction of the wafer **1** due to swiveling of the wafer **1**.

[0056] As illustrated in FIGS. **1** to **4** and FIG. **6**, the rough grinder **20** includes the driver **22** capable of swiveling the grinding wheel **21** counter to the movement of the wafer **1**. The rough grinder **20** can include a depth-of-infeed adjuster **23** capable of adjusting the depth of infeed of the grinding wheel **21** to the outer circumferential portion **2** of the wafer **1**. The depth-of-infeed adjuster **23** is configured such that the grinding wheel **21** is movable in a direction closer to the wafer **1** and in a direction away from the wafer **1**.

[0057] For example, the depth-of-infeed adjuster **23** as above can operate the grinding wheel **21** to move away from the outer circumferential portion **2** of the wafer **1** before the treatment target G of the outer circumferential portion **2** of the wafer **1** is irradiated with the plasma J by the pretreatment device **10** and operate the grinding wheel **21** to rough-grind the outer circumferential portion **2** of the wafer **1** after the treatment target G of the outer circumferential portion **2** of the wafer **1** is irradiated with the plasma J by the pretreatment device **10**.

[0058] As illustrated in FIGS. **2** to **4** and FIG. **7**, the finish grinder **30** includes the grinding wheel **31** capable of finish-grinding the outer circumferential portion **2** of the wafer **1** after rough grinding by the rough grinder **20**. The grinding wheel **31** is formed corresponding to a finished shape for the outer circumferential portion **2** of the wafer **1**. At the time of finish grinding by the finish grinder **30**, the outer circumferential portion **2** of the wafer **1** moves from one side to the other side in the circumferential direction of the wafer **1** due to swiveling of the wafer **1**. Note that the finish grinder **30** may be a helical grinder that performs grinding with the grinding wheel **31** having a rotation axis at an angle to the rotation axis of the wafer **1**.

[0059] As illustrated in FIGS. **1** to **4** and FIG. **7**, the finish grinder **30** includes the driver **32** capable of swiveling the grinding wheel **31** counter to the movement of the wafer **1**. The finish grinder **30** can include a depth-of-infeed adjuster **33** capable of adjusting the depth of infeed of the grinding wheel **31** to the outer circumferential portion **2** of the wafer **1**. The depth-of-infeed adjuster **33** is configured such that the grinding wheel **31** is movable in a direction closer to the wafer **1** and in a direction away from the wafer **1**.

[0060] For example, the depth-of-infeed adjuster **33** as above can operate the grinding wheel **31** to move away from the outer circumferential portion **2** of the wafer **1** before the outer circumferential portion **2** of the wafer **1** is rough-ground by the rough grinder **20** and operate the grinding wheel **31** to finish-grind the outer circumferential portion **2** of the wafer **1** after the outer circumferential portion **2** of the wafer **1** is rough-ground by the rough grinder **20**.

[0061] As illustrated in FIGS. **1** and **4**, in the grinding apparatus, the swiveling mechanism **41** of the swiveling device **40** includes a fastener **42** capable of fixing the wafer **1**. The fastener **42** is configured such that a switch can be made between a state where the wafer **1** is fixed and a state where the fixation of the wafer **1** is released. The swiveling mechanism **41** includes a driver **43** capable of swiveling the fastener **42** together with the wafer **1** around the central axis **1***a* of the wafer **1**.

[0062] As illustrated in FIG. **5**, the treatment target G of the outer circumferential portion **2** of the wafer **1** that swivels due to the swiveling mechanism **41** as above is irradiated with the plasma J from the pretreatment device **10**. Due to such irradiation, the treatment target G extending over the entire circumference of the outer circumferential portion **2** of the wafer **1** is modified. Furthermore, as illustrated in FIGS. **6** and **7**, the entirety of the outer circumferential portion **2** of the wafer **1** that swivels due to the swiveling mechanism **41** is ground by the two grinders.

[0063] As illustrated in FIG. **1**, the controller **50** includes a processor **50***a*, a memory **50***b*, and an inputter/outputter **50***c*. The processor **50***a* is an integrated circuit for control. For example, as the processor **50***a*, a central processing unit (CPU) or a microcontroller can be used. The processor **50***a* can include a random access memory (RAM) for working, not illustrated.

[0064] The memory **50***b* is a general information storage medium. As the memory **50***b*, a nonvolatile memory can be used. For example, as the memory **50***b*, a read only memory (ROM), an electrically erasable programmable read only memory (EEPROM), a flash memory, or a hard disk can be used. The memory **50***b* can store programs, various types of data, and the like.

[0065] The inputter/outputter **50***c* serves as an interface for electrically connecting the controller **50** to the pretreatment device **10**, the two grinders, the swiveling device **40**, and the arithmetic device **51**. The inputter/outputter **50***c* also serves as an interface for electrically connecting the controller **50** to the surface inspection device **52**. Furthermore, the inputter/outputter **50***c* serves as an interface for electrically connecting the controller **50** to at least either the shape inspection device **53** or the crystal inspection device **54**.

[0066] The arithmetic device **51** can include a processor **51***a*, a memory **51***b*, and an inputter/outputter **51***c*, similarly to the controller **50**. The arithmetic device **51** can include a machine learning model for pretreatment inspection that is capable of calculating an optimum value for at least one of the power and diameter of the plasma J and the swiveling rate of the wafer **1**, on the basis of data regarding the surface state of the treatment target G obtained by the surface inspection device **52**.

[0067] Note that the above machine learning model can be generated on the basis of a data set (training data set) including a plurality of entries each including the pretreatment condition for the wafer (the power and diameter of the plasma J and the swiveling rate of the wafer **1**) and the resultant surface state in association.

[0068] However, the arithmetic device is not limited to including such a machine learning model for pretreatment inspection. For example, the arithmetic device can perform statistical analysis for pretreatment inspection to calculate an optimum value for at least one of the power and diameter of the plasma and the swiveling rate of the wafer **1**, on the basis of data regarding the surface state of the pretreatment target obtained by the surface inspection device.

[0069] The arithmetic device **51** includes a machine learning model for grinding evaluation that is capable of calculating an optimum value for at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** and the swiveling rate of the wafer **1**, on the basis of at least either data regarding the shape of wafer **1** obtained by the shape inspection device **53** (e.g., shape dimensions and surface roughness) or data regarding the crystal state of the wafer **1** obtained by the crystal inspection device **54**.

[0070] However, the arithmetic device **51** is not limited to including such a machine learning model for grinding evaluation. For example, the arithmetic device **51** can perform statistical analysis for pretreatment inspection to calculate an optimum value for at least one of the power and diameter of the plasma and the swiveling rate of the wafer **1**, on the basis of data regarding the surface state of the pretreatment target obtained by the surface inspection device **52**.

[0071] The surface inspection device **52** can be configured to perform, for example, X-ray photoelectron spectroscopy (XPS) analysis or transmission electron microscope (TEMS)/scanning transmission electron microscope (STEM) analysis to the treatment target G after irradiation with the plasma J. Due to the surface inspection device **52** as above, the elementary composition and chemical bond state of the treatment target G after irradiation with the plasma J can be measured. That is, the surface state obtained by the surface inspection device **52** can be regarded as the elementary composition and chemical bond state.

[0072] The shape inspection device **53** can be configured to measure, for example, the shape dimensions and surface roughness of the wafer **1**, particularly, the shape dimensions and surface roughness of the outer circumferential portion **2** of the wafer **1**. Preferably, the shape inspection device **53** is of a noncontact type. For example, as the shape inspection device **53**, any shape inspection device can be used, such as LEP series (registered trademark) manufactured by KOBELCO research institute, LJ-X series (registered trademark) manufactured by KEYENCE CORPORATION, and Opt-scope (registered trademark) manufactured by TOKYO SEIMITSU CO., LTD.

[0073] The crystal inspection device **54** can be configured to inspect the crystal structure of the wafer **1**, particularly, the crystal structure of the outer circumferential portion **2** of the wafer **1**, for example, by Raman spectroscopic observation, X-ray 3D topography, or X-ray diffraction (XRD).

[0074] Furthermore, the grinding apparatus **100** can include a conveyance device **55** capable of conveying the wafer **1**. The conveyance device **55** can convey the wafer **1** between the swiveling device **40**, the surface inspection device **52**, and the shape inspection device **53** and/or the crystal inspection device **54**. For example, the conveyance device **55** as above can be configured to convey the wafer **1** using an arm (not illustrated) capable of grasping the wafer **1**.

[0075] A grinding method using the grinding apparatus **100** according to the present embodiment will be described with reference to FIG. **8**. First, a wafer **1** is fixed to the fastener **42** of the swiveling mechanism **41** of the swiveling device **40** (step S**1**). At this time, the controller **50** can control the fastener **42** such that the wafer **1** is kept fixed. The wafer **1** is swiveled by the driver **43** of the swiveling mechanism **41** and is kept swiveled (step S**2**).

[0076] The treatment target G of the outer circumferential portion **2** of the wafer **1**, which is kept swiveled, is irradiated with the plasma J from each plasma generator **10***a* of the pretreatment device **10** (step S**3**). The outer circumferential portion **2** of the wafer **1**, which is kept swiveled, after irradiation with the plasma J is rough-ground by the grinding wheel **21** of the rough grinder **20** swiveling counter to the swiveling of the wafer **1** (step S**4**).

[0077] The outer circumferential portion **2** of the wafer **1**, which is kept swiveled, after rough grinding is finish-ground by the grinding wheel **31** of the finish grinder **30** swiveling counter to the swiveling of the wafer **1** (step S**5**). The swiveling of the wafer **1** due to the driver **43** is stopped (step S**6**). The fastener **42** releases the fixation of the wafer **1** after finish grinding (step S**7**). At this time, the controller **50** can control the fastener **42** such that the fixation of the wafer **1** is released.

[0078] A method for optimizing the condition for irradiation with the plasma J by the pretreatment device **10** in the grinding apparatus **100** according to the present embodiment will be described with reference to FIG. **9**. The surface inspection device **52** inspects a plurality of surface states of the treatment target G of the wafer **1** after irradiation with plasma J (step S**11**). Data regarding the surface states obtained by this inspection is input to the arithmetic device **51** (step S**12**).

[0079] On the basis of the input data regarding the surface states, the arithmetic device **51** calculates and outputs an optimum value for at least one of the power and diameter of the plasma J and the swiveling rate of the wafer **1** (step S**13**). The controller **50** controls the pretreatment device **10** and the swiveling device **40** to meet the output optimum value for at least one of the power and diameter of the plasma J and the swiveling rate of the wafer **1** (step S**14**).

[0080] A method for optimizing the condition for grinding by the grinders in the grinding apparatus **100** according to the present embodiment will be described with reference to FIG. **10**. The shape inspection device **53** inspects a plurality of shapes of the wafer **1** after finish grinding (step S**21**). The crystal inspection device **54** inspects a plurality of crystal states of the wafer **1** after finish grinding (step S**22**). Data regarding the shapes and data regarding the crystal states obtained by these inspections are input to the arithmetic device **51** (step S**23**).

[0081] On the basis of the input data regarding the shapes and data regarding the crystal states, the arithmetic device **51** calculates and outputs an optimum value for at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** of the rough grinder **20** and the finish grinder **30** and the swiveling rate of the wafer **1** (step S**24**). The controller **50** controls the rough grinder **20**, the finish grinder **30**, and the swiveling device **40** to meet the output optimum value for at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** of the rough grinder **20** and the finish grinder **30** and the swiveling rate of the wafer **1** (step S**25**).

[0082] According to the above, the pretreatment device **10** according to the present embodiment includes the plasma generators **10***a* each capable of irradiating, before the outer circumferential portion **2** of the disk-shaped wafer **1** is ground, the treatment target G, which is at least part of the outer circumferential portion **2** of the wafer **1**, with the plasma J to modify the treatment target G.

[0083] According to the pretreatment device **10** as above, the treatment target G softens due to irradiation with the plasma J. Thus, the softened outer circumferential portion **2** of the wafer **1** can be efficiently ground in the grinding operation after irradiation with the plasma J.

[0084] Furthermore, in grinding the outer circumferential portion **2** including the softened treatment target G in the wafer **1**, the grinding wheels **21** and **31** can be inhibited from abrading. As a result, an improvement can be made in the shape accuracy of the wafer **1** shaped by the grinding wheels **21** and **31** as above. Therefore, an improvement can be made in the shape accuracy of the wafer **1** shaped by grinding after pretreatment and an improvement can be made in the efficiency of grinding operation of the wafer **1**.

[0085] The pretreatment device **10** according to the present embodiment includes the two plasma generators **10***a*. Each plasma generator **10***a* includes the nozzle **10***c* capable of emitting the plasma J outward along its irradiation axis **10***b*. The wafer **1** is provided as a SiC wafer **1**. The outer circumferential portion **2** of the wafer **1** includes the two edge portions **3** located one-to-one at both ends in the direction of the central axis of the wafer **1** as the treatment target G. The nozzles **10***c* of the two plasma generators **10***a* are disposed facing one-to-one the two edge portions **3** such that the two edge portions **3** can be irradiated one-to-one with the plasma J from one of the two plasma generators **10***a* and with the plasma J from the other.

[0086] According to the pretreatment device **10** (plasma generators) as above, the edge portions **3**, which are sharp in shape, in the outer circumferential portion **2** of the wafer **1** can be each softened due to irradiation with the plasma J. Thus, the softened edge portions **3** of the outer circumferential portion **2** of the wafer **1** can be efficiently ground in the grinding operation after irradiation with the plasma J. Furthermore, in grinding the outer circumferential portion **2** including the softened edge portions **3** in the wafer **1**, the grinding wheels **21** and **31** can be inhibited from abrading. As a result, an improvement can be made in the shape accuracy of the wafer **1** shaped by the grinding wheels **21** and **31** as above.

[0087] In the pretreatment device **10** according to the present embodiment, each edge portion **3** has a shape identical to a shape to be removed by chamfering. The two plasma generators **10***a* are mutually spaced in the direction of the central axis of the wafer **1**. The nozzle **10***c* of each plasma generator **10***a* is disposed with its irradiation axis **10***b* at an angle such that the entirety of the facing edge portion **3** can be irradiated with the plasma J.

[0088] According to the pretreatment device **10** as above, the entirety of each edge portion **3** of the outer circumferential portion **2** of the wafer **1** can be accurately softened due to irradiation of the plasma J. Thus, the outer circumferential portion **2** including the softened edge portions **3** in the wafer **1** can be efficiently ground in the grinding operation of the wafer **1** after irradiation with the plasma J.

[0089] The grinding apparatus **100** according to the present embodiment includes the pretreatment device **10** according to the present embodiment, the two grinders capable of grinding the outer circumferential portion **2** of the wafer **1**, and the swiveling device **40** for swiveling the wafer **1** around the central axis **1***a* at the time of pretreatment of the wafer **1** by the pretreatment device **10** or at the time of grinding of the wafer **1** by the grinders. The plasma generators **10***a* of the pretreatment device **10** are each capable of irradiating, with the plasma J, the treatment target G that moves in the circumferential direction of the wafer **1** due to swiveling of the wafer **1** around the central axis **1***a*. One of the grinders and the other include, respectively, the grinding wheel **21** and the grinding wheel **31** capable of grinding the outer circumferential portion **2** of the wafer **1** that moves from one side to the other side in the circumferential direction of the wafer **1** due to swiveling of the wafer **1**, and the driver **22** and the driver **32** capable of swiveling, respectively, the grinding wheel **21** and the grinding wheel **31** counter to the movement of the wafer **1**.

[0090] According to the grinding apparatus as above, an improvement can be made in the shape accuracy of the wafer **1** shaped due to grinding by the two grinders after pretreatment by the above-described pretreatment device **10**, and an improvement can be made in the efficiency of grinding operation of the wafer **1**.

[0091] The grinding apparatus **100** according to the present embodiment includes the controller **50** capable of controlling the pretreatment device **10**, the grinders, and the swiveling device **40**, and the arithmetic device **51** capable of calculating at least either an optimum condition for irradiation with the plasma J by the pretreatment device **10** or an optimum condition for grinding by the grinders. The controller **50** is capable of controlling at least one of the pretreatment device **10**, the grinders, and the swiveling device **40** to meet at least either the optimum condition for irradiation with the plasma J or the optimum condition for grinding, calculated by the arithmetic device **51**.

[0092] According to the grinding apparatus **100** as above, the condition for irradiating the treatment target G with the plasma J by the pretreatment device **10** can be optimized to accurately soften the entire treatment target G, and the condition for grinding the wafer **1** by the grinders can be optimized to make an improvement in the shape accuracy of the wafer **1** shaped by grinding.

[0093] The grinding apparatus **100** according to the present embodiment includes the surface inspection device **52** capable of inspecting the surface state of the treatment target G modified by the pretreatment device **10**. The arithmetic device **51** is capable of calculating an optimum value for at least one of the power and diameter of the plasma J and the swiveling rate of the wafer **1**, on the basis of data regarding the surface state of the treatment target G obtained by the surface inspection device **52** as the optimum condition for irradiation with the plasma J. The controller **50** is capable of controlling the pretreatment device **10** and the swiveling device **40** to meet the optimum value for at least one of the power and diameter of the plasma J and the swiveling rate of the wafer **1**, calculated by the arithmetic device **51**.

[0094] According to the grinding apparatus **100** as above, at least one of the power and diameter of the plasma J with which the treatment target G is irradiated by the pretreatment device **10** and the swiveling rate of the wafer **1** can be optimized to accurately soften the entire treatment target G.

[0095] The grinding apparatus **100** according to the present embodiment includes at least either the shape inspection device **53** capable of inspecting the shape of the wafer **1** ground by the grinders or the crystal inspection device **54** capable of inspecting the crystal state of the wafer **1** ground by the grinders. The arithmetic device **51** is capable of calculating an optimum value for at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** and the swiveling rate of the wafer **1**, on the basis of at least either data regarding the shape of the wafer **1** obtained by the shape inspection device **53** or data regarding the crystal state of the wafer **1** obtained by the crystal inspection device **54** as the optimum condition for grinding. The controller **50** is capable of controlling the grinders and the swiveling device **40** to meet the optimum value for at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** and the swiveling rate of the wafer **1**, calculated by the arithmetic device **51**.

[0096] According to the grinding apparatus **100** as above, at least one of the depth of infeed and swiveling rate of each of the grinding wheels **21** and **31** in the grinders and the swiveling rate of the wafer **1** can be optimized to make an improvement in the shape accuracy of the wafer **1** shaped due to grinding by the grinders.

[0097] In the grinding apparatus **100** according to the present embodiment, the swiveling device **40** includes the swiveling mechanism **41** that swivels the wafer **1** around the central axis **1***a* at a certain position at the time of pretreatment of the wafer **1** by the pretreatment device **10** or at the time of grinding of the wafer **1** by the grinders. The pretreatment device **10** is disposed on one side in the circumferential direction of the wafer **1** with respect to the grinders.

[0098] The grinding apparatus **100** as above enables smooth and efficient performance of a series of steps in which the treatment target G of the outer circumferential portion **2** of the wafer **1** is softened due to the plasma J from the pretreatment device **10** and then the outer circumferential portion **2** including the softened treatment target G in the wafer **1** is ground by the grinders.

[0099] A grinding apparatus **200** according to a second embodiment will be described below with reference to FIG. **11**. A pretreatment device **10** included in the grinding apparatus **200** is similar to the pretreatment device **10** included in the grinding apparatus **100** according to the first embodiment. The grinding apparatus **200** according to the present embodiment is similar to the grinding apparatus **100** according to the first embodiment except that no rough grinder **20** is provided.

[0100] A grinding method using the grinding apparatus **200** according to the present embodiment is different from the grinding method using the grinding apparatus **100** according to the first embodiment in that no step S**4** regarding rough grinding is included and no rough grinder **20** is used. In such a grinding method, a treatment target G of an outer circumferential portion **2** of a wafer **1** that is kept swiveled is irradiated with plasma J from each plasma generator **10***a* of the pretreatment device **10** and then the outer circumferential portion **2** of the wafer **1**, which is kept swiveled, after irradiation with the plasma J is finish-ground by a grinding wheel **31** of a finish grinder **30** swiveling counter to the swiveling of the wafer **1**. In other aspects, the grinding method according to the present embodiment is similar to the grinding method according to the first embodiment.

[0101] In the grinding apparatus according to the present embodiment, a method for optimizing the condition for irradiation with the plasma J by the pretreatment device **10** can be performed, similarly to the first embodiment, and a method for optimizing the condition for grinding by the finish grinder **30** can be performed, similarly to the first embodiment.

[0102] As described above, the grinding apparatus **200** according to the present embodiment can bring about operations and effects similar to those of the grinding apparatus **100** according to the first embodiment.

[0103] A grinding apparatus **300** according to a third embodiment will be described with reference to FIGS. **12** to **14**. The grinding apparatus **300** includes first to fourth pretreatment devices **61**, **62**, **63**, and **64**. As illustrated in FIG. **12**, the grinding apparatus **300** according to the present embodiment is similar to the grinding apparatus **100** according to the first embodiment except that a plurality of pretreatment devices (first to fourth pretreatment devices **61**, **62**, **63**, and **64**) are mutually spaced in the circumferential direction of a wafer **1**.

[0104] As illustrated in FIGS. **13** and **14**, the pretreatment devices (first to fourth pretreatment devices **61** to **64**) included in the grinding apparatus **300** are roughly configured like the pretreatment device **10** included in the grinding apparatus **100** according to the first embodiment. The pretreatment devices (first to fourth pretreatment devices **61** to **64**) as above include plasma generators **61***a*, **62***a*, **63***a*, and **64***a* capable of irradiating a treatment target G with plasma K1, plasma K2, plasma K3, and plasma K4, respectively, to modify the treatment target G. The plasma generators **61***a* to **64***a* include nozzles **61***c*, **62***c*, **63***c*, and **64***c* capable of emitting the plasma K1, the plasma K2, the plasma K3, and the plasma K4 outward along irradiation axes **61***b*, **62***b*, **63***b*, and **64***b*, respectively.

[0105] As illustrated in FIG. **14**, the nozzles **61***c* to **64***c* of the plasma generators **61***a* to **64***a* in the pretreatment devices (first to fourth pretreatment devices **61** to **64**) are disposed differently from each other in the radial direction of a wafer **1** such that the entirety of a facing edge portion **3** of an outer circumferential portion **2** of the wafer **1** can be irradiated with the respective plasma K1, plasma K2, plasma K3, and plasma K4 emitted from the nozzles **61***c* to **64***c*. The plasma generators **61***a* to **64***a* as above can be configured not to perform such raster scanning as described above.

[0106] A grinding method using the grinding apparatus **300** according to the present embodiment is similar to the grinding method using the grinding apparatus **300** according to the first embodiment except that the pretreatment devices (first to fourth pretreatment devices **61** to **64**) are used. The grinding apparatus **100** according to the present embodiment can perform a method for optimizing the condition for irradiation with the plasma K1, the plasma K2, the plasma K3, and the plasma K4 by the pretreatment devices (first to fourth pretreatment devices **61** to **64**), similarly to the first embodiment, and can perform a method for optimizing the condition for grinding by grinders, similarly to the first embodiment.

[0107] Note that FIG. **13** illustrates, as an example, the grinder including four pretreatment devices (first to fourth pretreatment devices **61** to **64**), namely, the first pretreatment device **61**, the second pretreatment device **62**, the third pretreatment device **63**, and the fourth pretreatment device **64**. However, the grinding apparatus can include two, three, or five or more pretreatment devices.

[0108] As described above, the grinding apparatus **300** according to the present embodiment can bring about operations and effects similar to those of the grinding apparatus **100** according to the first embodiment.

[0109] Furthermore, the grinding apparatus **300** according to the present embodiment includes the pretreatment devices (first to fourth pretreatment devices **61** to **64**) mutually spaced in the circumferential direction of the wafer **1**. Thus, the entirety of the treatment target G can be efficiently softened due to irradiation with the plasma K**1**, the plasma K**2**, the plasma K**3**, and the plasma K**4**.

[0110] Pretreatment devices (first to fourth pretreatment devices **61** to **64**) and a grinding apparatus according to a fourth embodiment will be described below with reference to FIG. **15**. The pretreatment devices (first to fourth pretreatment devices **61** to **64**) included in the grinding apparatus according to the present embodiment are similar to the pretreatment devices (first to fourth pretreatment devices **61** to **64**) included in the grinding apparatus according to the third embodiment. A grinding apparatus **400** according to the present embodiment is similar to the grinding apparatus **300** according to the third embodiment except that no rough grinder **20** is provided.

[0111] Note that the grinding apparatus can include two, three, or five or more pretreatment devices.

[0112] A grinding method using the grinding apparatus **400** according to the present embodiment is different from the grinding method using the grinding apparatus **300** according to the third embodiment in that no step regarding rough grinding is included and no rough grinder **20** is used. In such a grinding method, a treatment target G of an outer circumferential portion **2** of a wafer **1** that is kept swiveled is irradiated with plasma K**1**, plasma K**2**, plasma K**3**, and plasma K**4** from plasma generators **61***a* to **64***a* of the pretreatment devices (first to fourth pretreatment devices **61** to **64**) and then the outer circumferential portion **2** of the wafer **1**, which is kept swiveled, after irradiation with the plasma K**1**, the plasma K**2**, the plasma K**3**, and the plasma K**4** is finish-ground by a grinding wheel **31** of a finish grinder **30** swiveling counter to the swiveling of the wafer **1**. In other aspects, the grinding method according to the present embodiment is similar to the grinding method according to the third embodiment.

[0113] In the grinding apparatus **400** according to the present embodiment, a method for optimizing the condition for irradiation with the plasma K**1**, the plasma K**2**, the plasma K**3**, and the plasma K**4** by the pretreatment devices (first to fourth pretreatment devices **61** to **64**) can be performed, similarly to the third embodiment, and a method for optimizing the condition for grinding by the finish grinder can be performed, similarly to the first embodiment.

[0114] As described above, the grinding apparatus **400** according to the present embodiment can bring about operations and effects similar to those of the grinding apparatus **300** according to the third embodiment.

[0115] Although the embodiments of the present invention have been described above, the present invention is not limited to the embodiments described above. Thus, modifications and alterations can be made on the basis of the technical idea of the present invention.

[0116] A grinding apparatus according to the present invention enables an improvement in the shape accuracy of a wafer shaped due to the grinding operation and an improvement in the efficiency of grinding operation of a wafer.

What is claimed is:

1. A grinding apparatus comprising at least one plasma generator configured to irradiate, before an outer circumferential edge of a wafer is ground, at least part of the outer circumferential edge with plasma.

2. The grinding apparatus according to claim **1**, wherein

the plasma generator includes a plurality of plasma generators,

the plasma generators each includes a nozzle configured to emit the plasma, and

the nozzles of the plasma generators face two edge portions in a thickness direction of the outer circumferential edge of the wafer in one-to-one correspondence to irradiate the two edge portions with the plasma.

3. The grinding apparatus according to claim **2**, wherein the nozzles of the plasma generators are each provided inclinably.

4. The grinding apparatus according to claim **1**, further comprising:

a swiveling device for swiveling the wafer around a central axis of the wafer; and

a grinder including a grinding wheel configured to grind an outer circumferential portion of the wafer, and a driver configured to swivel the grinding wheel, wherein

the plasma generator is capable of irradiating, with the plasma, a pretreatment target that moves in a circumferential direction of the wafer due to swiveling of the wafer around the central axis.

5. The grinding apparatus according to claim **4**, further comprising:

a controller; and

an arithmetic device capable of calculating at least either an optimum condition for irradiation with the plasma by the plasma generator or an optimum condition for grinding by the grinder, wherein

the controller is capable of controlling at least one of the plasma generator and the grinder to meet at least either the optimum condition for irradiation with the plasma or the optimum condition for grinding, calculated by the arithmetic device.

6. The grinding apparatus according to claim **5**, further comprising a surface inspection device capable of inspecting a surface state of the wafer, wherein

the arithmetic device is capable of calculating, as the optimum condition for irradiation with the plasma, an optimum value for at least one of a diameter and power of the plasma and a swiveling rate of the wafer, based on data regarding the surface state, and

the controller is capable of controlling the plasma generator and the swiveling device to meet the optimum value.

7. The grinding apparatus according to claim **5**, further comprising at least either a shape inspection device capable of inspecting a shape of the wafer or a crystal inspection device capable of inspecting a crystal state of the wafer, wherein

the arithmetic device is capable of calculating, as the optimum condition for grinding, an optimum value for at least one of a depth of infeed and a swiveling rate of the grinding wheel and a swiveling rate of the wafer, based on at least either the shape or the crystal state, and

the controller is capable of controlling the grinder and the swiveling device to meet the optimum value.

8. The grinding apparatus according to claim **4**, comprising the plasma generators mutually spaced in a circumferential direction of the wafer.

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