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(54) **POLISHING PAD, PAD DRESSING EVALUATION METHOD, AND POLISHING APPARATUS**

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(57) **ABSTRACT**

The present invention provides: a polishing apparatus for polishing a workpiece, comprising a polishing pad whose surface or surface layer part is colored with a color different from a color inside the polishing pad, a pad dresser which performs dressing of the polishing pad, and an observing device which observes the surface of the polishing pad; and a method for simply and accurately monitoring the uniformity of dressing state of a polishing pad in dressing the polishing pad of a polishing apparatus such as a CMP device, in order to prolong the life of the polishing pad, and to reduce the number of dummy wafers used in the pad dressing.

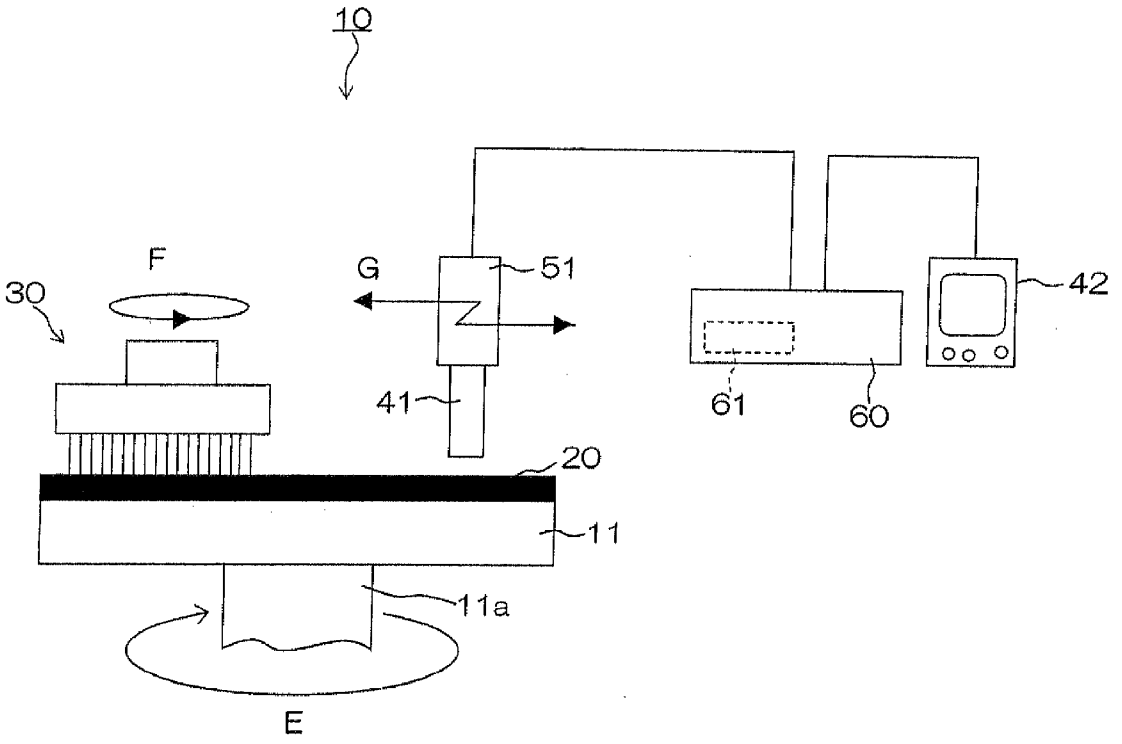


FIG.1

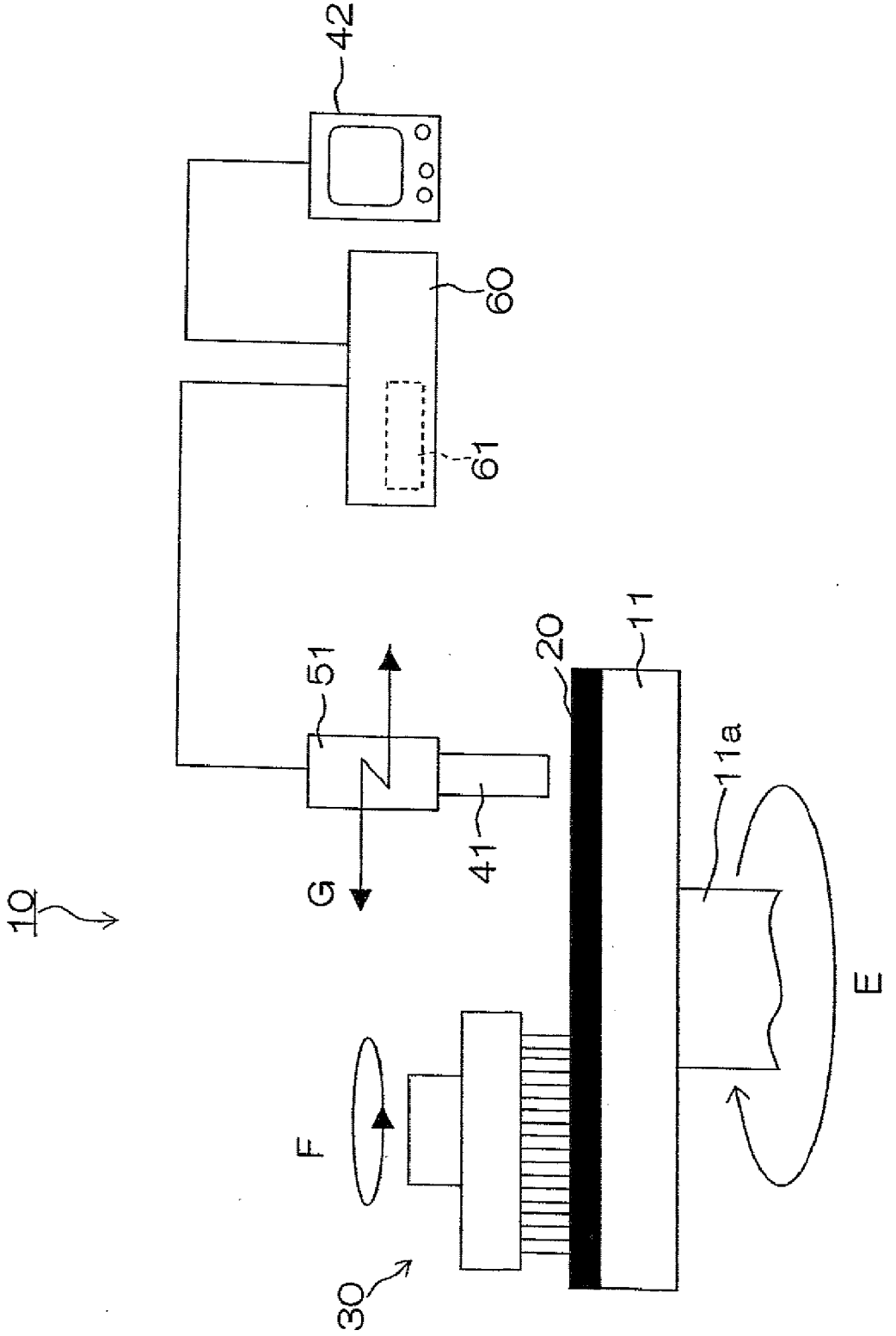


FIG.2

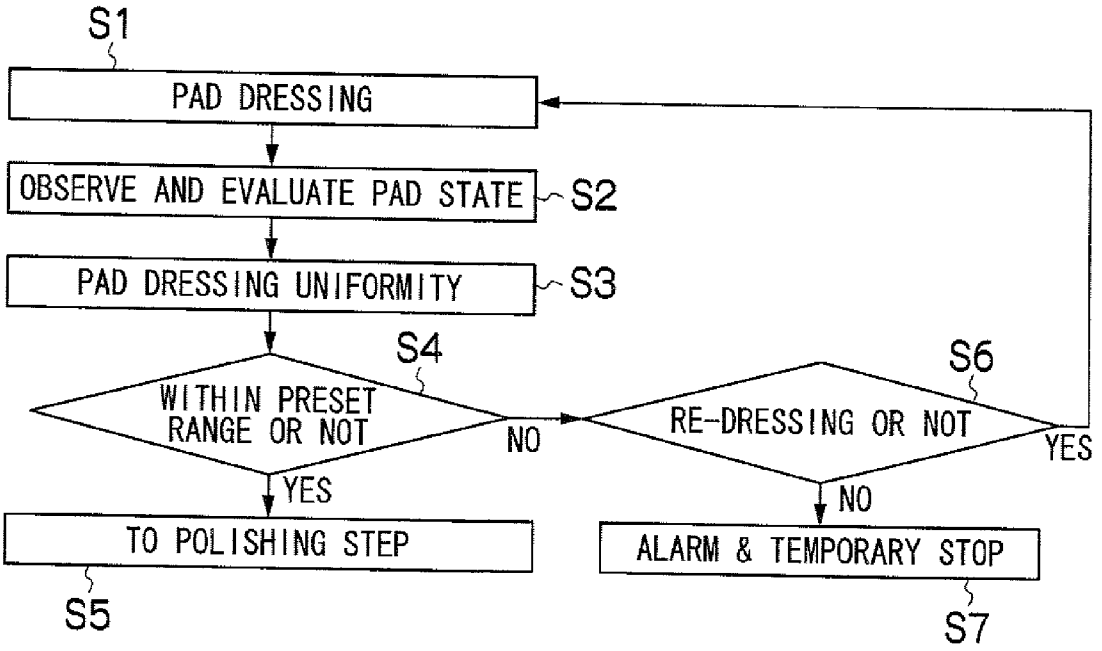

S1
PAD DRESSING
OBSERVE AND EVALUATE PAD STATE
S2
PAD DRESSING UNIFORMITY
S3
S4
WITHIN PRESET RANGE OR NOT
NO
YES
S6
RE-DRESSING OR NOT
YES
NO
TO POLISHING STEP
S5
ALARM & TEMPORARY STOP
S7

FIG.3

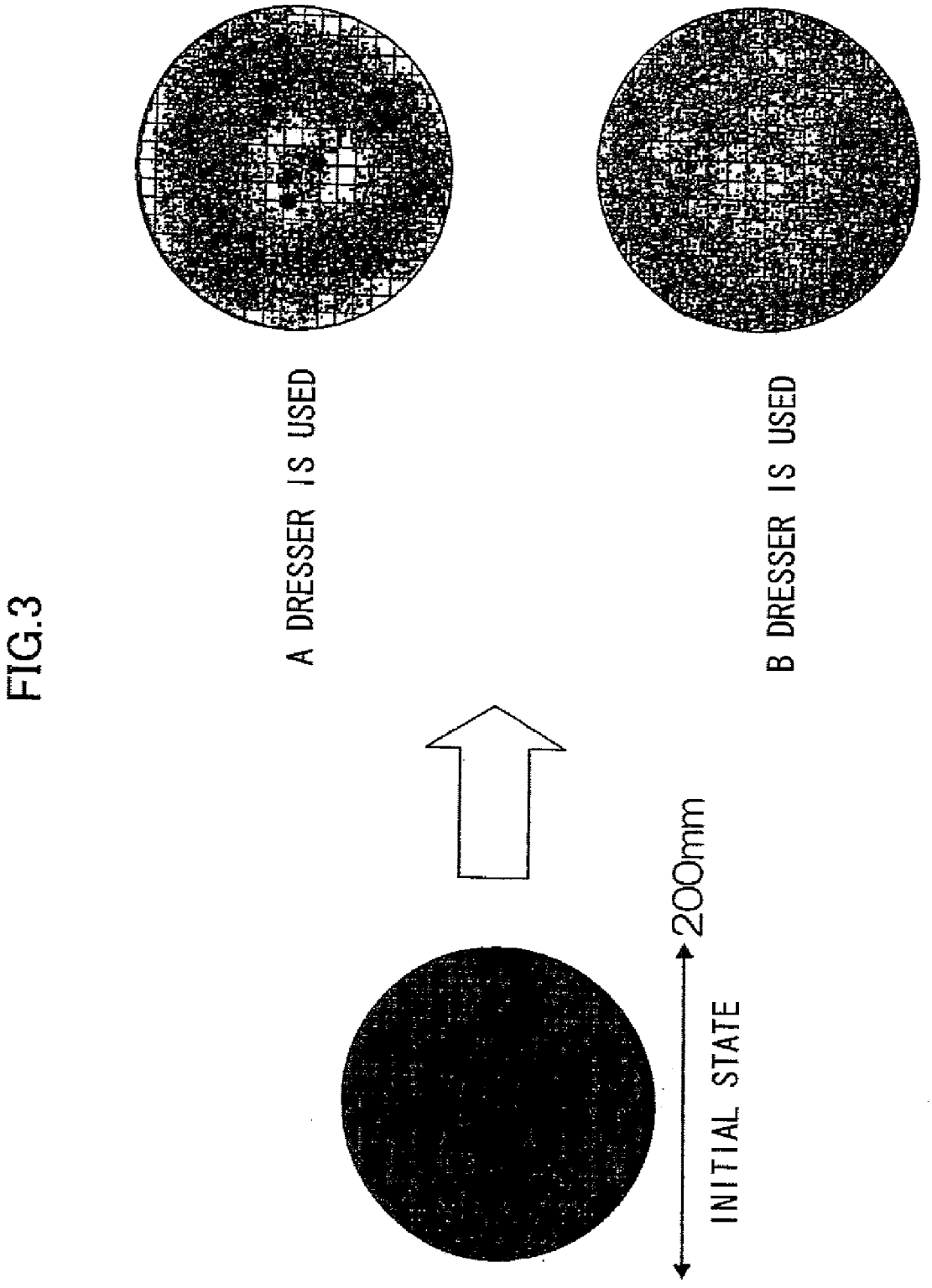


FIG.4

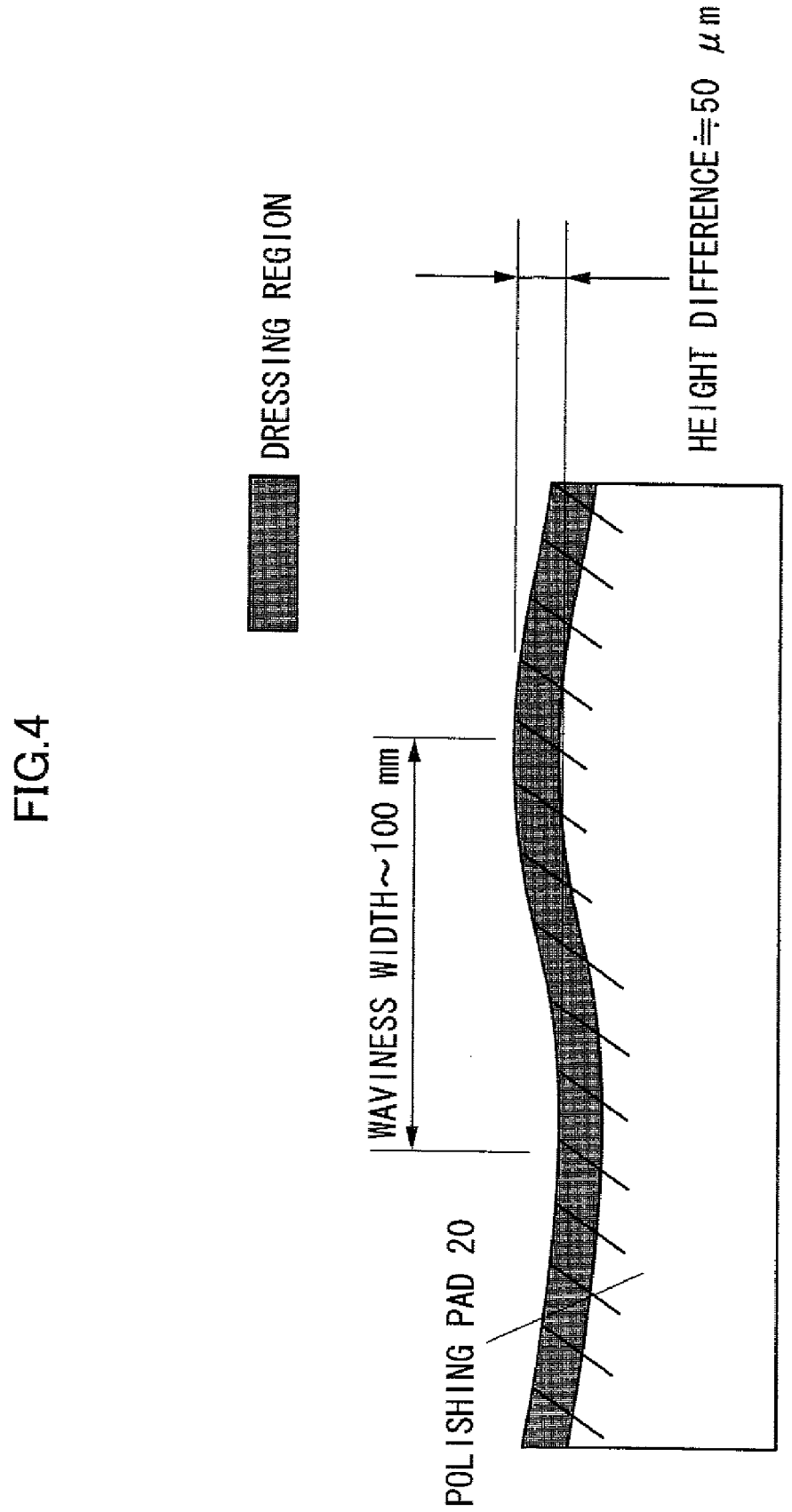
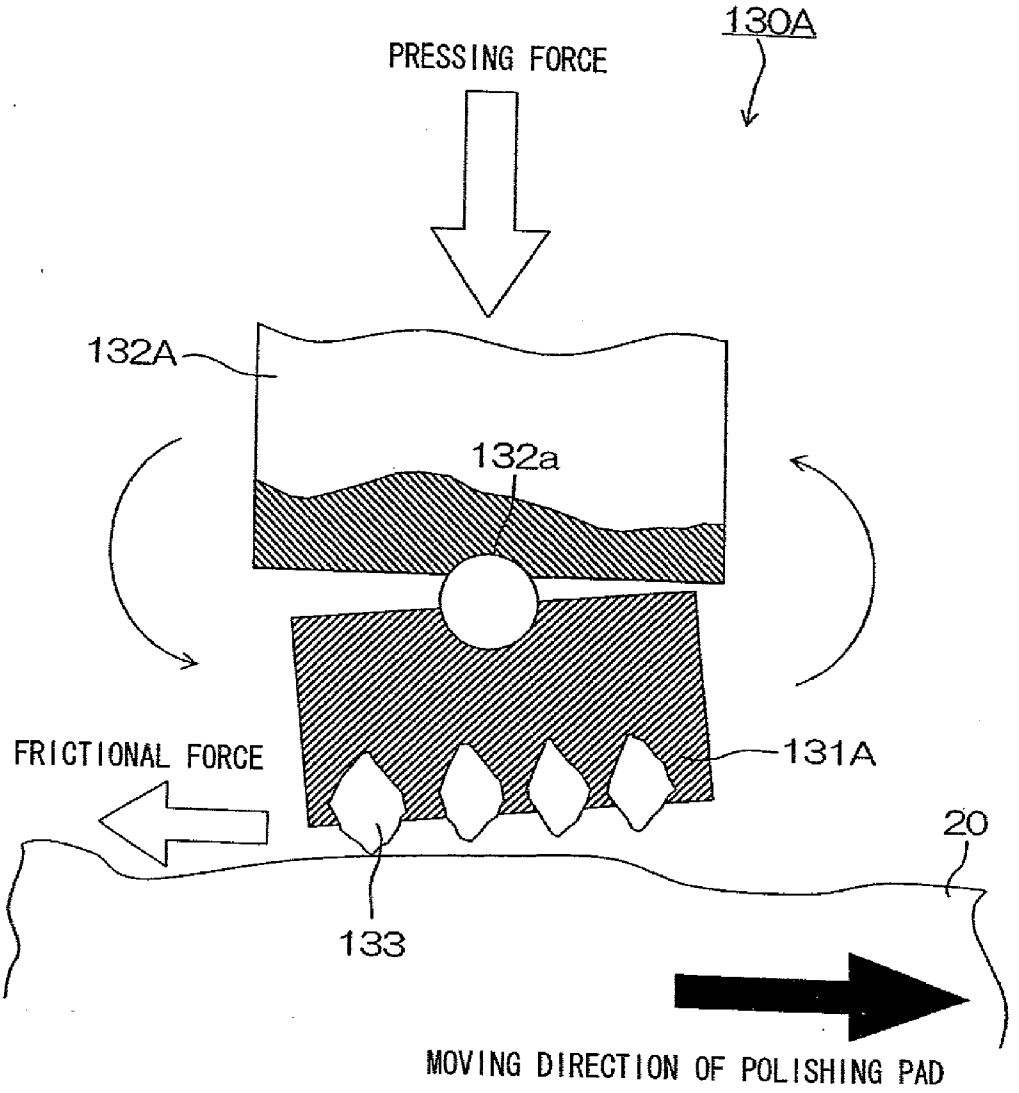

DRESSING REGION
HEIGHT DIFFERENCE≒50 μm
WAVINESS WIDTH~100 mm
POLISHING PAD 20

FIG.5



RELATED ART

FIG.6

DRESSER	4-INCH DISK TYPE
	4-INCH ELASTIC BRUSH TYPE
LOAD	4Kgf
DRESSING TIME	15 MINUTES (4-INCH DISK TYPE) 21 MINUTES (4-INCH ELASTIC BRUSH TYPE)
PAD	FORMED POLYURETHANE PAD IC1400 (MADE BY NITTA HAAS INCORPORATED)
PAD DIAMETER	760nm
COLORING AGENT	MADE BY TERANISHI CHEMICAL INDUSTRY CO. LTD. MAGIC INK BLACK
STAYING PERIOD RATIO FOR EACH PAD RADIUS	SEE Fig. 7

FIG.7

DRESSER OSCILLATING CONDITION						
No.	1	2	3	4	5	6
STARTING RADIUS	75	105	135	165	195	225
ENDING RADIUS	105	135	165	195	225	255
STAYING PERIOD RATIO	1.7%	3.4%	5.1%	6.8%	8.5%	10.3%
No.	7	8	9	10	11	
STARTING RADIUS	255	285	315	345	375	
ENDING RADIUS	285	315	345	375	380	
STAYING PERIOD RATIO	12.0	13.7%	15.4%	17.1%	6.0%	

FIG.8

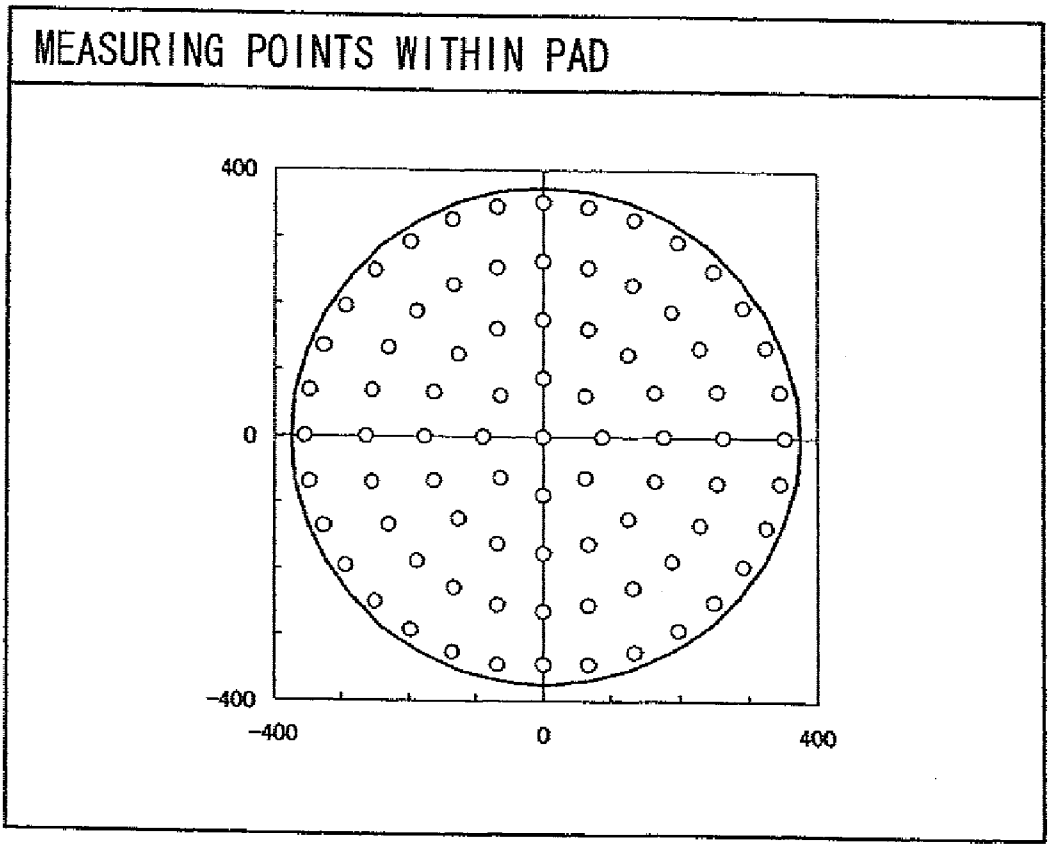


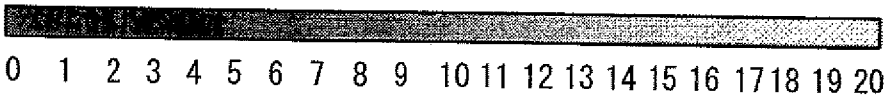
FIG.9

No.	XPos	YPos	No.	XPos	YPos
1	0	0	41	-187.0992	-187.1016
2	0	88.2	42	-229.1496	-132.3
3	62.3664	62.3664	43	-255.5832	-68.484
4	88.2	0	44	-264.6	0
5	62.3664	-62.3664	45	-255.5832	68.4816
6	0	-88.2	46	-229.152	132.3
7	-62.3664	-62.3664	47	-187.1016	187.0992
8	-88.2	0	48	-132.3	229.1496
9	-62.3664	62.3664	49	-68.484	255.5832
10	0	176.4	50	0	352.8
11	67.5048	162.972	51	68.8272	349.02
12	124.7328	124.7328	52	135.0096	325.944
13	162.972	67.5048	53	196.0056	293.3424
14	176.4	0	54	249.468	249.468
15	162.972	-67.5048	55	293.3424	196.0056
16	124.7328	-124.7328	56	325.944	135.012
17	67.5048	-162.972	57	346.02	68.8272
18	0	-176.4	58	352.8	0
19	-67.5048	-162.972	59	346.02	-68.8272
20	-124.7328	-124.7352	60	325.944	-135.0096
21	-162.972	-67.5048	61	293.3424	-196.0056
22	-176.4	0	62	249.468	-249.4656
23	-162.972	67.5048	63	196.0056	-293.6424
24	-124.7352	124.7328	64	135.012	-325.944
25	-67.5072	162.972	65	68.8296	-346.02
26	0	264.6	66	0	-352.8
27	68.484	255.5832	67	-68.8272	-346.0224
28	132.3	229.1496	68	-135.0096	-325.944
29	187.0992	187.1016	69	-196.0032	-293.3424
30	229.1496	132.3	70	-249.4656	-249.468
31	255.5832	68.484	71	-293.3424	-196.0056
32	264.6	0	72	-325.944	-135.012
33	255.5832	-68.484	73	-346.02	-68.8296
34	229.1496	-132.3	74	-352.8	-0.0024
35	187.1016	-187.0992	75	-346.0224	68.8272
36	132.3	-229.1496	76	-325.9464	135.0096
37	68.484	-255.5832	77	-293.3424	196.0032
38	0	-264.6	78	-249.468	249.4656
39	-68.4816	-255.5832	79	-196.0056	293.3424
40	-132.3	-229.1496	80	-135.012	325.944
			81	-68.8296	346.02

FIG.10

MEASURING DEVICE: MADE BY KONICA MINOLTA CO. LTD.
COLOR AND COLOR DIFFERENCE METER CR-400

DEFINITION OF COLOR



COMPLETELY COLORED PART: 0 (LOWER LIMIT),
NON-COLORED PART (COLOR INSIDE PAD): 20 (UPPER LIMIT),
CONTINUOUS NUMERICAL VALUES ARE ASSIGNED BETWEEN THE UPPER AND LOWER LIMITS.

FIG.11

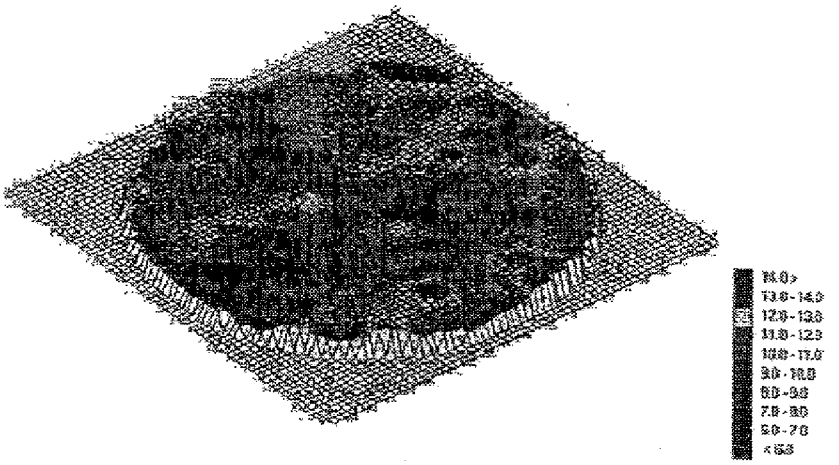
NUMERICAL DATA OF PAD COLOR AT RESPECTIVE POINTS

No.	X	Y	Case1	Case2
1	0	0	11.28	8.57
2	0	88.2	11.32	6.98
3	62.3664	62.3664	10.87	13.26
4	88.2	0	11.1	10.82
5	62.3664	-62.3664	11.17	7.33
6	0	-88.2	11.08	13
7	-62.3664	-62.3664	11.48	10.03
8	-88.2	0	11.69	9.15
9	-62.3664	62.3664	11.17	13.56
10	0	176.4	10.55	10.07
11	67.5048	162.972	10.39	12.21
12	124.7328	124.7328	10.41	9.18
13	162.972	67.5048	9.72	12.77
14	176.4	0	9.16	13.51
15	162.972	-67.5048	11.56	7.11
16	124.7328	-124.7328	11.7	9.18
17	67.5048	-162.972	11.75	9.85
18	0	-176.4	11.44	8.31
19	-67.5048	-162.972	10.77	11.05
20	-124.7328	-124.7352	10.26	9.91
21	-162.972	-67.5048	10.02	6.53
22	-176.4	0	9.86	6.78
23	-162.972	67.5048	9.83	12.99
24	-124.7352	124.7328	11.76	10.96
25	-67.5072	162.972	11.84	7.87
26	0	264.6	11.01	7.35
27	68.484	255.5832	11.21	11.32
28	132.3	229.1496	10.74	12.13
29	187.0992	187.1016	10.12	12.21
30	229.1496	132.3	10.06	10.84
31	255.5832	68.484	10.17	13.08
32	264.6	0	10.15	6.91
33	255.5832	-68.484	12.06	14.47
34	229.1496	-132.3	11.86	11.98
35	187.1016	-187.0992	11.6	9.32
36	132.3	-229.1496	10.77	11.96
37	68.484	-255.5832	11.36	13.22
38	0	-264.6	10.91	10.8
39	-68.4816	-255.5832	10.66	14.08
40	-132.3	-229.1496	10.38	12.37

No.	X	Y	Case1	Case2
41	-187.0992	-187.1016	10.11	11.77
42	-229.1496	-132.3	12.01	7.97
43	-255.5832	-68.484	11.79	9.19
44	-264.6	0	11.74	6.74
45	-255.5832	68.4816	11.08	12.54
46	-229.152	132.3	11.03	12.09
47	-187.1016	187.0992	10.14	9.44
48	-132.3	229.1496	11.52	12.47
49	-68.484	255.5832	9.96	10.92
50	0	352.8	10.45	12.86
51	68.8272	349.02	11.62	7.05
52	135.0096	325.944	11.3	10.81
53	196.0056	293.3424	11.21	8.35
54	249.468	249.468	10.96	13.84
55	293.3424	196.0056	10.55	14.32
56	325.944	135.012	10.04	12.98
57	346.02	68.8272	10.35	7.46
58	352.8	0	10.32	9.24
59	346.02	-68.8272	10.63	13.44
60	325.944	-135.0096	12.13	7.61
61	293.3424	-196.0056	11.21	8.77
62	249.468	-249.4656	10.96	11.48
63	196.0056	-293.6424	10.69	7.06
64	135.012	-325.944	10.89	13.56
65	68.8296	-346.02	10.96	14.12
66	0	-352.8	10.12	9.8
67	-68.8272	-346.0224	9.82	8.2
68	-135.0096	-325.944	11.32	9.74
69	-196.0032	-293.3424	12.03	13.96
70	-249.4656	-249.468	11.32	8.8
71	-293.3424	-196.0056	11.27	12.48
72	-325.944	-135.012	10.89	7.28
73	-346.02	-68.8296	11.19	10.22
74	-352.8	-0.0024	10.73	9.33
75	-346.0224	68.8272	10.14	10.63
76	-325.9464	135.0096	11.73	8.53
77	-293.3424	196.0032	11.61	9.26
78	-249.468	249.4656	11.28	13.79
79	-196.0056	293.3424	11.33	7.17
80	-135.012	325.944	10.97	6.81
81	-68.8296	346.02	11.17	12.82

FIG.12

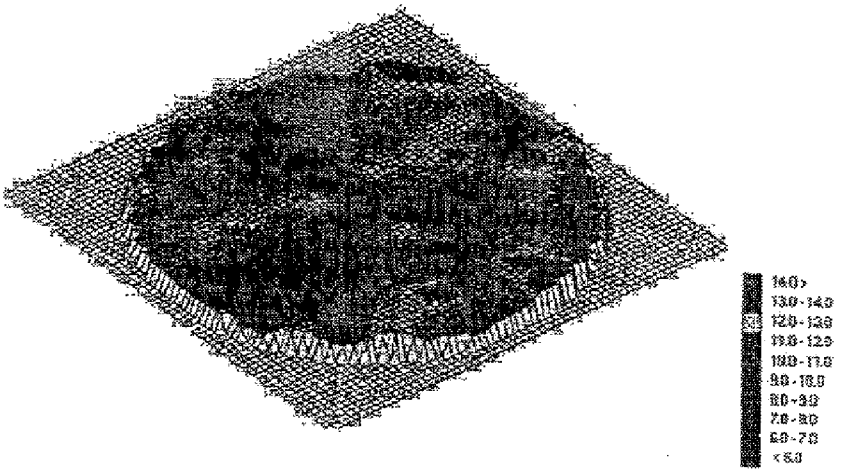
Case1: 4-INCH DISK TYPE



Average:10.46
1σ:2.379
DRESSING UNIFORMITY(※):22.73%
※DRESSING UNIFORMITY IS DEFINED BY DIVIDING STANDARD DEVIATION OF ALL POINTS BY AVERAGE VALUE THEREOF

FIG.13

Case2: 4-INCH ELASTIC RBUSH TYPE



Average:10.93
1σ:0.65
DRESSING UNIFORMITY(※):6.03%
※DRESSING UNIFORMITY IS DEFINED BY DIVIDING STANDARD DEVIATION OF ALL POINTS BY AVERAGE VALUE THEREOF

POLISHING PAD, PAD DRESSING EVALUATION METHOD, AND POLISHING APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a polishing pad, a pad dressing evaluation method, and a polishing apparatus, and more particularly to a polishing pad used in a polishing apparatus for polishing a workpiece such as a semiconductor wafer, a pad dressing valuation method for evaluating a dressing state of the polishing pad, and the polishing apparatus.

[0003] 2. Description of the Related Art

[0004] As the microminiaturization and multilayering of a semiconductor device progress, the CMP (Chemical Mechanical Polishing) technique has become a technique indispensable to the process of manufacturing a semiconductor device. The CMP technique is used not only for flattening an interlayer insulating film but also for various processes such as Cu wiring and element isolation.

[0005] One of important specifications of the CMP for flattening is the work in-plane uniformity of the polishing rate (polishing uniformity). In order to improve the polishing uniformity, it is important to uniformly distribute factors influencing the polishing rate in the work surface.

[0006] The important factors include a polishing pressure, a relative polishing speed, and the like, but the important factor which has not been conventionally well quantified is a surface state of a polishing pad (hereinafter, which may simply referred to as pad). A preferable surface state of a polishing pad is formed by pad dressing (hereinafter, which may simply be referred to as dressing). In this respect, it is apparent also from the fact that the polishing rate is reduced suddenly when the pad dressing is stopped in the so-called in-situ dressing in which the pad dressing can be performed simultaneously during polishing, that the strict control of the surface state of the polishing pad is important.

[0007] The pad dressing means a process in which a pad dresser (hereinafter, which may simply be referred to as dresser), to which a grinding wheel such as diamond is attached, is brought into contact with a polishing pad such as to shave off or roughen the surface of the polishing pad, with the result that slurry holding characteristics are made excellent so as to initialize the polishing pad to a state where it is capable of polishing, and that the polishing pad in use is made to recover the slurry holding characteristics to maintain its polishing capability.

[0008] There is known a technique in which in performing pad dressing, the surface shape of the pad is measured by scanning the pad surface by a laser displacement sensor, and in which the dressing time period of worn area and the dressing time period of little worn area are changed so as to achieve the in-plane uniformization in the pad dressing (for example, Japanese Patent Application Laid-Open No. 2001-129754).

SUMMARY OF THE INVENTION

[0009] However, the technique described in Japanese Patent Application Laid-Open No. 2001-129754 is a technique which takes a long time to measure the entire surface of a polishing pad and is too unrealistic to be applied during polishing. Further, the technique is to control the manner of dressing by measuring the surface shape of the pad before the pad dressing is performed. Thus, the technique is not to evaluate whether or not the dressing is uniformly performed after the pad dressing is performed, and hence, cannot make it possible to grasp the dressing state of the entire surface of the polishing pad.

[0010] Further, a polishing pad used in a CMP device has thickness irregularity in itself, and irregularity due to attachment to the polishing surface plate, as a result of which the polishing pad surface after the attachment is not flat. The polishing pad surface after the attachment usually has a height difference of about 30 μm to 50 μm.

[0011] However, in the CMP, in order to uniformly polish the wafer surface, even the polishing pad surface having such waviness is required to be uniformly dressed along the polishing pad surface.

[0012] FIG. **4** shows a concept of the specification of pad dressing required for the CMP. As shown in FIG. **4**, in the case of dressing a polishing pad **20** in which waviness with a height difference of about 50 μm is formed with a width of about 100 mm, it is required to uniformly perform dressing along the waviness. Thus, since the polishing pad is made of an elastic material, the pad dressing in the CMP device can be regarded as the reference surface grinding processing of the elastic material.

[0013] The state of dressing performed along such waviness of the pad surface cannot be judged even by measuring the shape and size of the pad surface.

[0014] Further, in the distribution state of pad dressing, the distribution in the circumferential direction is very important besides the distribution in the radial direction. This is because a dresser is required to be brought into continuous contact with the surface of the polishing pad rotated at high speed with a constant pressure, without being intermittently brought into contact with the surface of the polishing pad.

[0015] Specifically, in the case where a plate type pad dresser is connected to a pressing device by using a flexible joint as shown in a principle figure of FIG. **5**, and used to follow the waviness of the pad surface, a large frictional force is applied to the pad dresser surface in contact with the polishing pad **20** rotated at a high speed, thereby making the pad dresser inclined with respect to the polishing pad **20**.

[0016] When the pad dresser is inclined to reduce the frictional force, it occurs that the pad dresser is made to return to the original attitude. This occurs in a short time, as a result of which the pad dresser is intermittently brought into contact with the polishing pad **20** (stick slips). When the pad dresser is inclined with respect to the polishing pad **20**, the dressing is only partially performed. Thus, it is apparent in principle that the dressing is varied in the circumferential direction of the polishing pad **20**.

[0017] When the dressing is varied in the pad surface, the dressing is continued until the entire pad surface is dressed by a fixed amount, which results in a long dressing time. During this time period, the dressing is made to partially progress, so that the polishing rate (polishing amount per unit time) is gradually increased. When the entire pad surface is dressed by a predetermined amount, the polishing rate is finally stabilized.

[0018] While the polishing rate is gradually raised, it is difficult to subject a product wafer to the polishing processing. The product wafer can be subjected to the polishing processing only after the polishing rate is stabilized. As a result, many dummy wafers need to be used in order to stabilize the polishing rate.

[0019] Further, when the pad dressing pressure is reduced, the difference between the dressed and non-dressed parts in the pad surface becomes remarkable. For this reason, it is necessary to secure a minimum dressing amount even in the parts with small dressing amount. Therefore, it is necessary to set the dressing pressure a little higher so as to enable any part of the pad to be dressed by the minimum dressing amount.

[0020] To this end, the average pad amount removed by the pad dressing is set larger to some extent. As a result, the consumption amount of the pad surface is increased, leading to a problem that the life of the polishing pad is short.

[0021] Such a problem has not become known because there is no effective method to immediately measure the dressing distribution (grinding distribution) in the pad surface. As a result, many dummy wafers are used for setting up the polishing pad, with the result that the pad life after the setting-up is short.

[0022] The present invention has been made in view of the above described circumstances. An object of the present invention is to provide a method for simply and accurately monitoring the uniformity of dressing state of a polishing pad in dressing the polishing pad of a polishing apparatus such as a CMP device, and to provide a polishing pad and a polishing apparatus for use in the method.

[0023] In order to achieve the above described object, according to a first aspect of the present invention, there is provided a polishing pad of a polishing apparatus for polishing a workpiece, the polishing pad characterized in that the surface or the surface layer part of the polishing pad is colored with a color different from a color inside the polishing pad.

[0024] According to the first aspect of the invention, the surface or the surface layer part of the polishing pad is colored with a color different from a color inside the polishing pad. Thus, when the polishing pad is dressed, in the dressed part, the colored parts are removed to enable the base of the polishing pad to be seen, while in the non-dressed part, the colored part is left as it is. This makes it possible to easily grasp the polishing irregularity in the pad dressing on the basis of the distribution state of the color of the polishing pad surface, and to thereby make the uniformity of the dressing easily judged.

[0025] According to a second aspect of the present invention, there is provided a pad dressing evaluation method for evaluating a dressing state of pad dressing by which the surface of a polishing pad of a polishing apparatus is dressed, the pad dressing evaluation method characterized in that the polishing pad whose surface is colored or whose surface or surface layer part is colored beforehand with a color different from a color inside the polishing pad is used, the pad dressing is performed for a predetermined time period, and the dressing state of the pad dressing is evaluated on the basis of color irregularity of the polishing pad surface ground by the pad dressing.

[0026] Further, according to a third aspect of the present invention, in the second aspect, the color of the polishing pad surface ground by the pad dressing is preferably measured and quantified at plural points, thereby enabling the color irregularity of the polishing pad to be obtained.

[0027] Further, according to a fourth aspect of the present invention, in one of the second and third aspects, the evaluation of the dressing state can be performed by evaluating dressing uniformity in the surface of the polishing pad.

[0028] According to the pad dressing valuation method of the present invention, it is possible to qualitatively and quantitatively grasp the in-plane uniformity of the pad dressing. This makes it possible to prevent excessive grinding by the pad dressing, so that the life of the polishing pad can be prolonged.

[0029] According to a fifth aspect of the present invention, there is provided a polishing apparatus for polishing a workpiece, characterized by comprising: a polishing pad whose surface or surface layer part is colored with a color different from a color inside the polishing pad; a pad dresser which performs dressing of the polishing pad; and an observing device which observes the surface of the polishing pad.

[0030] Further, according to a sixth aspect of the present invention, there is provided a polishing apparatus for polishing a workpiece, characterized by comprising: a polishing pad whose surface or surface layer part is colored with a color different from a color inside the polishing pad; a pad dresser which performs dressing of the polishing pad; and a measuring device which measures and quantifies color of the polishing pad surface. In the sixth aspect according to the present invention, it is possible to provide a judging device which judges whether or not the quantified values are within a range set beforehand, and thereby judges whether or not polishing of the workpiece is performed.

[0031] According to the polishing apparatus of the present invention, it is possible to easily check the dressing state of the polishing pad. Further, the surface state of the polishing pad can be numerically represented. Thereby, after the pad dressing is performed, whether or not the polishing of a workpiece is to be performed can be judged by determining whether or not the surface state of the pad is normal. As a result, the number of dummy wafers used in the pad dressing can be substantially reduced.

[0032] As described above, according to the polishing pad and the pad dressing evaluation method of the present invention, it is possible to easily grasp the grinding irregularity in the pad dressing, and to thereby easily judge the uniformity of the dressing. Further, according to the polishing apparatus of the present invention, excessive grinding in the pad dressing can be prevented, thereby making it possible to prolong the life of the polishing pad, and to reduce the number of dummy wafers used in the pad dressing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. **1** is a figure showing a constitution of a polishing apparatus according to an embodiment of the present invention;

[0034] FIG. **2** is a flow chart showing a pad dressing valuation method according to the present invention;

[0035] FIG. **3** is an illustration showing results of an example;

[0036] FIG. **4** is an illustration showing a concept of pad dressing required for the CMP;

[0037] FIG. **5** is a conceptual diagram showing a constitution of a conventional pad dresser;

[0038] FIG. **6** is a table representing conditions in the examples;

[0039] FIG. **7** shows a table showing dresser oscillation conditions in the examples;

[0040] FIG. **8** is a figure showing measuring points in the polishing pad in the examples;

[0041] FIG. **9** is a table showing XY coordinates of the measuring points in the polishing pad in the examples;

[0042] FIG. **10** is a figure showing the definition of color digitization in the examples;

[0043] FIG. **11** is a table showing measurement data in the examples;

[0044] FIG. **12** is a bird's eye view **1** showing a measurement result in the example; and

[0045] FIG. **13** is a bird's eye view **2** showing a measurement result in the example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0046] In the following, preferred embodiments of a polishing pad, a pad dressing evaluation method, and a polishing apparatus according to the present invention will be described in detail with reference to the accompanying drawings. Note that in each figure, the same member is designated by the same reference numeral or the same reference character.

[0047] FIG. **1** shows a constitution of a polishing apparatus according to an embodiment of the present invention. A polishing apparatus **10** shown in FIG. **1** is constituted mainly by a polishing surface plate **11**, a polishing pad **20**, a wafer carrier (not shown), a pad dresser **30**, a camera **41** and a monitor television **42** which constitute an observing device for observing the surface of the polishing pad **20**, a measuring device **51** which measures and quantifies color of the polishing pad **20** surface, and a controller **60** which controls the operation of each section of the polishing apparatus **10**.

[0048] The polishing surface plate **11** is rotated in the direction of the arrow E in FIG. **1** by driving a motor (not shown) connected with a rotating shaft **11***a*. A wafer carrier for holding a wafer as a workpiece is driven so as to be rotated by the motor (not shown). Further, the polishing pad **20** is attached to the upper surface of the polishing surface plate **11**, and a slurry is supplied to the surface of the polishing pad **20** from a slurry supply nozzle (not shown).

[0049] The polishing pad **20** is a thin disc-like plate formed by an elastic base material made of foamed polyurethane. On the upper surface of the polishing pad, many shallow grooves are formed in a grid shape in order to improve slurry holding characteristics. Further, the surface or the surface layer part of the upper surface of the polishing pad **20** is colored with a color different from a color inside the polishing pad **20**.

[0050] The polishing pad may be colored by being mixed with and laminating a pigment different from a pigment inside the polishing pad only on the surface layer part, or by forming, on the surface of the polishing pad, a film with a color different from a color inside the polishing pad. There are various paints and dyes for coloring the surface of the polishing pad, which include, for example, Pyrokeep TS made by Otsuka Chemical Co., Ltd., Urban Cera made by Nissin Kasei Co., Ltd., Silvia SP Yogore Guard made by Nihon Tokushu Toryo Co., Ltd., Regi Guard FA Renew and High Clean made by Daido Co., Ltd., Bell Clean made by NOF Co., Ltd., Amix Cone made by Atomix Co., Ltd., Aqua Top F-2 made by Sumitomo Seika Chemicals Co. Ltd., Magic Ink made by Teranishi Chemical Industry Co., Ltd., and the like.

[0051] Besides these materials, various kinds of color materials can be used, if they attach only to the very thin surface layer of the polishing pad **20** without penetrating deeply into the polishing pad **20**.

[0052] The pad dresser **30** is rotated in the direction of the arrow F in FIG. **1** and pressed against the surface of the rotating polishing pad **20** to grind and roughen the surface of the polishing pad **20**. Thereby, the polishing pad **20** is made to have excellent slurry holding characteristics so as to be initialized to a state where it can be polished, and the polishing pad **20** in use is made to recover the slurry holding characteristics so as to maintain the polishing capability.

[0053] The camera **41** constituting the observing device which observes the surface of the polishing pad **20**, is arranged above the polishing pad **20**, and a captured image is displayed on the monitor television **42** which is separately arranged. Further, the measuring device **51** which measures and quantifies color of the surface of the polishing pad **20** is connected to the camera **41**.

[0054] The camera **41** and the measuring device **51** are provided so as to be traversable in the direction of the arrow G in FIG. **1**, so that they are capable of observing from the central part of the polishing pad **20** to the periphery thereof by a driving device (not shown). This makes it possible to observe the entire surface of the polishing pad **20** in combination with the rotation of the polishing pad **20**.

[0055] A color is defined by three elements of hue (corresponding to a wavelength of monochromatic light), saturation (brightness, i.e., a degree of not being whitened), and lightness (luminosity, i.e., the intensity of light). As the measuring device **51** according to the present invention, a spectral color difference meter which measures hue, or a color and color difference meter which measures saturation, and the like is preferably used.

[0056] As the spectral color difference meter, there is a product number NF 333 made by Nihon Densyoku Kogyo Co. Ltd., and the like. As the color and color-difference meter, there are product numbers CR-400, CR-410 made by Konica Minolta Co., Ltd., and the like.

[0057] A judging device **61** constituted by a computer incorporated in the controller **60** which controls operations of each section of the polishing apparatus **10**, judges the dressing state of the pad from a color value of the surface of the polishing pad **20** which is quantified by the measuring device **51**.

[0058] Note that the polishing apparatus **10** is provided with both the camera **41** and the measuring device **51** which are the observing device, but the polishing apparatus **10** may be provided only with the camera **41** so as to perform visual observation, or may be provided only with the measuring device **51** to quantify the pad surface state.

[0059] Next, a pad dressing evaluation method according to the present invention is explained using a flow chart shown in FIG. **2**. First, while the polishing pad **20** whose

surface or surface layer part is colored with a color different from a color inside the polishing pad **20** is rotated, water is supplied to the surface of the polishing pad **20**, and the pad dressing is performed by the rotating pad dresser **30** for a predetermined time period (step S**1**).

[**0060**] Next, the surface of the polishing pad **20** subjected to the pad dressing is imaged by the camera **41**, so that the dressing state of the polishing pad **20**, particularly, the dressing uniformity in the pad surface is evaluated from color irregularity of the pad surface using the monitor television **42**. At this time, the image may be compared with a sample image obtained beforehand, so as to judge whether the dressing state is acceptable or not (step S**2**).

[**0061**] Further, instead of the camera, the surface of the polishing pad **20** is directly measured by a color difference meter as the measuring device **51**, so as to enable the dressing state to be digitized. Further, the image obtained by the camera **41** may be digitized by the color difference meter. In this case, the digitization is preferably performed by measuring plural points of the polishing pad **20**.

[**0062**] In digitizing the image, the RGB values and the Munsell values which are used for digitizing a general color, may be utilized to perform the digitization. Further, the color change may be set in plural stages, so as to make a numerical value assigned to each of the stages, as a result of which the color change is quantified by an original evaluation method.

[**0063**] In this way, a standard deviation of the numerical values in the pad surface is obtained by performing digitization for respective points in the polishing pad **20**. The uniformity of the dressing state in the pad surface is obtained by dividing the obtained standard deviation by the average value of the numerical values (step S**3**).

[**0064**] Next, whether or not the obtained dressing uniformity in the polishing pad **20** surface is within a range set beforehand is judged by the judging device **61** in the controller **60** (step S**4**). When the in-plane uniformity of the dressing is within the range set beforehand, the process is moved to the polishing process of a product wafer (step S**5**).

[**0065**] When the in-plane uniformity of the dressing is deviated from the range set beforehand in step S**4**, whether or not the pad dressing is further continued is judged by the judging device **61** on the basis of the degree of deviation from the set range (step **86**).

[**0066**] When it is judged that the re-dressing is to be performed in step S**6**, the process is returned to step S**1**. When it is judged that the dressing is not to be continued, an alarm is outputted, and the polishing apparatus **10** is temporarily stopped (step S**7**).

[**0067**] Note that in the flow chart shown in FIG. **2**, the flow is described such that step S**3** is performed after step S**2**, but the order of step S**2** and step S**3** may be reversed, or the dressing state may be evaluated only by one of step S**2** and step S**3**.

EXAMPLE 1

[**0068**] First, the surface of the polishing pad **20** made of foamed polyurethane is colored by uniformly spraying an oil-based color spray on the surface of the polishing pad **20**. The thickness of colored layer is set to about 5 μm. The polishing pad **20** is attached to the polishing surface plate **11** and rotated. In this state, the pad dressing is performed using two kinds of pad dressers (referred to as A dresser and B dresser) for the same time period, respectively. Then, the dressing state (the dressing uniformity in the pad surface) is compared on the basis of color irregularity of the pad surface.

[**0069**] The pad dressing conditions are set such that the rotation speed of the polishing pad **20** is 30 rpm and the rotation speed of the pad dresser is 80 rpm. Under these conditions, the pad dressing is performed while supplying pure water to the surface of the polishing pad **20**.

[**0070**] FIG. **3** shows a result of the pad dressing. As is apparent from FIG. **3**, it can be seen that color irregularity is observed in the pad surface as the result of the pad dressing performed by using the dresser A, and that the dressing is inferior in the in-plane uniformity.

[**0071**] On the other hand, it can be seen that almost no color irregularity is observed in the pad surface as the result of the pad dressing performed by using the dresser B, and that the dressing is excellent in the in-plane uniformity. In this case, the surface roughness of the polishing pad **20** is Ra 0.5 μm, and the surface is roughened uniformly.

EXAMPLE 2

[**0072**] In the example 1, a polishing pad with a relatively small diameter is dressed, and the dressing effect is simply verified by observing the color irregularity. In the present example 2, a polishing pad with a large diameter, which is actually used in the polishing apparatus **10**, is dressed, and the uniformity of the pad dressing is quantified.

[**0073**] In the present example 2, the uniformity of the pad dressing is quantified in the following two cases: a case (referred to as case **1**) where the dressing is performed by using a conventional type pad dresser (referred to as 4-inch disk type dresser) produced by making diamond abrasive grains electrodeposited on a disk with a diameter of 100 mm; and a case (referred to as case **2**) where the dressing is performed by using a new type pad dresser (referred to as 4-inch elastic brush type dresser) produced by making a number of piano wires (linear elastic bodies) planted in a brush shape on a disk with a diameter of 100 mm, on the tip of which piano wires diamond abrasive grains are electrodeposited. The details are explained below.

[**0074**] First, the surface of the polishing pad **20** with a diameter of 760 mm made of foamed polyurethane (IC1400 made by Nitta Haas Incorporated) is colored with Magic Ink (black) made by Teranishi Chemical Industry Co., Ltd. The thickness of the colored layer is set to about 5 μm.

[**0075**] The pad dressing conditions are set such that the rotation speed of the polishing pad **20** is 30 rpm and the rotation speed of the pad dresser is 80 rpm. Under these conditions, the pad dressing is performed, while the pad is made to oscillate in the radial direction, and pure water is supplied to the surface of the polishing pad **20**. The dressing pressure is set to 4 Kgf, and the dressing time periods are set to 15 minutes in the case **1** and 21 minutes in the case **2**, respectively.

[**0076**] The dressing conditions are summarized in FIG. **6** and FIG. **7**. When the pad dresser is made to oscillate in the radial direction of the pad, the area is increased in accor-

dance with the increase of the radius. Thus, the oscillation speed is reduced by the amount corresponding to the increase in the area, thereby making the staying period of the pad dresser on the pad increased. Specifically, as shown in the table of FIG. **7**, the polishing pad **20** is divided into eleven stages, of which the first to tenth stages are set by dividing the polishing pad **20** from the central position with the radius of 75 mm to the periphery in increments of 30 mm, and the eleventh stage is set by the last fraction of 5 mm. In this state, the staying period in the respective stages is changed.

[**0077**] In each of the case **1** and the case **2**, the color of the pad surface is measured and quantified at 81 points in the surface of the polishing pad **20** after dressing. The measuring points in the surface of the polishing pad **20** are shown in FIG. **8**, and coordinate values of each measuring point are shown in a table of FIG. **9**.

[**0078**] The apparatus used for measuring the color is the color and color difference meter CR-400 made by Konica Minolta Co., Ltd., and the color is digitized on the basis of the definition in which numerical values from 0 to 20 are assigned as shown in FIG. **10**. That is, the part which is not colored is assigned to 20 (upper limit), the part which is completely colored is assigned to 0 (lower limit), and continuous numerical values are assigned between the upper and lower limits.

[**0079**] FIG. **11** is a table which shows XY coordinates of respective measuring points, and the measured values corresponding to the respective measuring points in the case **1** and the case **2**. FIG. **12** is a bird's-eye view showing the result of the case **1**, in which the average value of the respective measuring points is 10.46, and the standard deviation in terms of 1σ value is 2.379. When the dressing uniformity is defined as "a value obtained by dividing the standard deviation of all measuring points by the average value thereof", the dressing uniformity is 22.73%.

[**0080**] FIG. **13** is also a bird's-eye view showing the result of the case **2**, in which the average value of the respective measuring points is 10.93, and the standard deviation in terms of 1σ value is 0.65. When the dressing uniformity is defined as "a value obtained by dividing the standard deviation of all measuring points by the average value thereof", the dressing uniformity is 6.03%.

[**0081**] As is apparent from the bird's-eye views shown in FIG. **12** and FIG. **13**, a large amount of color irregularity is observed in the case **1**, and little amount of color irregularity is observed in the case **2**. Further, since the dressing uniformity is defined as described above, the smaller numerical value indicates the more excellent dressing uniformity. In this way, the dressing uniformity can be easily digitized, and thereby, it is possible to perform qualitative and quantitative comparison between the case **1** and the case **2**.

[**0082**] As describe above, according to a polishing pad, a pad dressing evaluation method, and a polishing apparatus of the present invention, the in-plane uniformity of a dressing state of the polishing pad can be simply and accurately evaluated. This makes it possible to prevent excessive grinding in the pad dressing and to thereby make the life of the polishing pad prolonged. In addition, this also makes it possible to effectively perform the pad dressing and to thereby reduce the number of dummy wafers.

What is claimed is:

1. A polishing pad of a polishing apparatus for polishing a workpiece, comprising

a surface or a surface layer part of the polishing pad which is colored with a color different from a color inside the polishing pad.

2. A pad dressing evaluation method for evaluating a dressing state of pad dressing by which the surface of a polishing pad of a polishing apparatus is dressed, comprising the steps of:

performing the pad dressing for a predetermined time period by using the polishing pad whose surface is colored, or whose surface or surface layer part is colored beforehand with a color different from a color inside the polishing pad; and

evaluating the dressing state of the pad dressing on the basis of color irregularity of the polishing pad surface ground by the pad dressing.

3. The pad dressing evaluation method according to claim 2, wherein

the color irregularity of the polishing pad surface is obtained by measuring and quantifying color of the polishing pad surface ground by the pad dressing at plural points.

4. The pad dressing evaluation method according to claim 2, wherein

the evaluation of the dressing state is to evaluate dressing uniformity in the surface of the polishing pad.

5. The pad dressing evaluation method according to claim 3, wherein

the evaluation of the dressing state is to evaluate dressing uniformity in the surface of the polishing pad.

6. A polishing apparatus for polishing a workpiece, comprising:

a polishing pad whose surface or surface layer part is colored with a color different from a color inside the polishing pad;

a pad dresser which performs dressing of the polishing pad; and

an observing device which observes the surface of the polishing pad.

7. A polishing apparatus for polishing a workpiece, comprising:

a polishing pad whose surface or surface layer part is colored with a color different from a color inside the polishing pad;

a pad dresser which performs dressing of the polishing pad; and

a measuring device which measures and quantifies a color of the polishing pad surface.

8. The polishing apparatus according to claim 7, further comprising a judging device which judges whether or not the quantified values are within a range set beforehand, and thereby judges whether or not polishing of the workpiece is performed.

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